Abstract

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Surprisingly, although extant research has acknowledged that investments in R&D could potentiate the establishment of collaborative agreements, the literature has no analysed the impact on innovation performance that persistence in these two activities have, both individually and jointly. In this paper, we analyse the effect that persistence in R&D and persistence in collaboration have on innovation performance, and the moderating effect that persistence in R&D has on the relationship between persistence in collaboration and innovation performance. We argue that both activities have a positive impact on innovation performance and that persistence in R&D potentiates the relationship between persistence in collaboration and innovation performance. To test empirically these hypotheses, we will use a large panel of Spanish innovating firms for the period 2005-2013.
UNDERSTANDING THE INNOVATIVE BEHAVIOUR OF FIRMS: THE PERSISTENCE DECISION
Abstract

The study of the dynamic patterns of behaviour has recently attracted the attention of scholars studying the investments in R&D of firms and the establishment of collaborative agreements. Surprisingly, although extant research has acknowledged that investments in R&D could potentiate the establishment of collaborative agreements, the literature has no analysed the impact on innovation performance that persistence in these two activities have, both individually and jointly. In this paper, we analyse the effect that persistence in R&D and persistence in collaboration have on innovation performance, and the moderating effect that persistence in R&D has on the relationship between persistence in collaboration and innovation performance. We argue that both activities have a positive impact on innovation performance and that persistence in R&D potentiates the relationship between persistence in collaboration and innovation performance. To test empirically these hypotheses, we will use a large panel of Spanish innovating firms for the period 2005-2013.

Keywords

Persistence in R&D; Persistence in collaboration; Innovation performance; Product innovation; Process innovation
1. INTRODUCTION

Over the last years, whether firms are able to persist in their innovation activities has been a popular topic for debate in the innovation literature (Cefis and Orsenigo, 2001; Peters, 2009). The persistence of innovation refers to the impact of past innovation activities on present and future ones (Ganter and Hecker, 2013). Although existing empirical studies have offered mixed results that do not provide a consistent picture of the phenomenon (Peters, 2009), most of them have highlighted that understanding these phenomena in innovation activities is increasingly important in terms of the conceptual view of the underlying processes that drive innovation (Peters, 2009; Raymond, Mohnen, Palm and Schim van der Loeff, 2010).

On this basis, this stream of research on innovation has tried to deepen in the analysis of persistence in innovation activities (Ganter and Hecker, 2013; Triguero and Córcoles, 2013), moving into two directions. The first has focused on analysing the drivers of the persistence in innovation activities (Peters, 2009; Triguero and Córcoles, 2013). From this point of view engaging and persisting in innovation activities depends on firm level decisions but results are contingent to the environment in which firms operate (Raymond et al., 2010; Ganter and Hecker, 2013). Particularly, some studies have found empirical evidence of the existence of differences in the persistence in innovative activities for product and process innovation (Roper and Hewitt-Dundas, 2008; Martínez-Ros and Labeaga, 2009), across different countries (Malerba and Orsenigo, 1999; Cefis and Orsenigo, 2001), for different industries (Raymond et al., 2010) or innovation inputs (Peters, 2009; Máñez, Rochina-Barrachina, Sanchis-Llopis and Sanchis-Llopis, 2015) and outputs (Cefis, 2003; Raymond et al., 2010; Roper and Hewitt-Dundas, 2008).

The second research stream on persistence in innovation has dealt with the identification of the several theoretical explanations to the persistence in innovation activities (Raymond et al.,
Specifically, the arguments being generally accepted by the literature to explain the phenomenon of persistence in innovation focus on firm’s investments in R&D (Raymond et al., 2010; Ganter and Hecker, 2013). Therefore, it seems that the literature suggests that persistence in innovation activities could only be explained through R&D activities, a fact that implies that persistence in innovation could be equated to persistence in R&D.

However, this idea could be incomplete given that extant research on innovation has affirmed that though R&D is an important input to innovation, it does not capture all aspects pertinent to innovation (Raymond et al., 2010; Ganter and Hecker, 2013). The literature has specified that, besides, innovation activities depend on the development and integration of new knowledge, especially obtained from external sources (Cassiman and Veugelers, 2002). In fact, scholars have found that, in addition to doing research and development, firms typically tap knowledge of external sources to the firm, for example, through the establishment of collaborative agreements (Arora and Gambardella, 1994; Cockburn and Henderson, 1998). Taking this evidence as starting point, recent investigations have maintained that the combination of both sources leads to an improvement of the results of the innovation process, thanks to the existence of complementarities (Cassiman and Veugelers, 2006; Hess and Rathaermel, 2011). On this basis, analysing persistence in R&D activities without considering persistence in the external innovation activities that organizations develop could allow us to study the phenomenon of persistence in innovation activities only partially.

Based on this lack, in this paper we intend to provide an overview about the effect that persistence in R&D activities and persistence in external innovation activities, as collaborative agreements, exercise on innovation performance. Although the idea that R&D activities and external innovation activities should be combined in the innovation process
seems to be accepted (Cassiman and Veugelers, 2006), there is no framework under which the effect of persistence in these activities on innovation performance is studied. In turn, this has led us to know relatively little about how the persistence in these activities could jointly affect innovation performance. Given that recent research on innovation has recognized the existence of complementarities between R&D activities and external innovation activities (Hess and Rothaermel, 2011), suggesting that investments in R&D allow for a higher degree of knowledge outsourcing, we intend to analyse the effect on innovation performance that persistence in R&D activities and persistence in external innovation activities jointly exercise.

Our contention is that persistent cooperative behaviour and persistence in R&D exercise a positive impact on innovation performance. Also, we argue that persistence in both activities allows firms to outperform rivals, because R&D investments contributes to external innovation activities not only because it builds the base of knowledge that is needed for firms to be able to recognize the value, assimilate and exploit existing new knowledge from the external environment (Cohen and Levinthal, 1990), but also because it creates firm specific knowledge that may not be easily traded, redeployed outside the firm or imitated by competitors (Dierickx and Cool, 1989). The introduction of the simultaneous effect of persistence in R&D activities and persistence in external innovation activities is important, given that it has been argued that these activities cannot be understood separately, but as a continuous (Cassiman and Veugelers, 2006).

The hypotheses raised by this investigation are tested through the Panel of Technological Innovation database (PITEC), which contains information of the innovative activity of Spanish firms. This database is especially useful for the purposes of this work, mainly for two reasons. First, it provides information about the cooperative agreements established by the firms included in the sample and their investment in R&D. With this information, we are able to construct our independent variables. Second, the data provided by PITEC, in contrast to
other innovation surveys, is administered on a yearly basis. Hence, it provides information about innovation variables from 2003 to 2012. That fact makes the data very suitable for the analysis of the persistence in cooperative agreements and persistence in R&D.

Our contribution to the literature is threefold. First, it integrates two literatures, the persistence in R&D literature and the persistence in collaboration literature, which have proceeded separately. Their integration could be necessary and particularly interesting because, as the literature has affirmed, investments in R&D could determine the establishment of cooperative agreements. Therefore, to omit this relationship prevents us to address the discussion about persistence in R&D and in cooperative agreements integrally and may even result in obtaining biased results. In this sense, the simultaneous consideration of these two literatures could help to analyse the phenomenon more precisely. Second, we advance the knowledge about persistence in cooperative agreements, a topic in which the literature has not devoted much attention to the moment, although scholars have pointed out that it matters for innovation performance. Prior studies have often tended to focus on the static analysis of the cooperative agreements, forgetting that is the dynamic analysis what really represents the behaviour of firms. Third, existing research focuses mainly on innovation performance without distinguishing between product or process innovation (Triguero and Corcoles, 2013). However little is known about the differences in persistence patterns between product and process innovation.

2. THEORETICAL FRAMEWORK AND HYPOTHESES

2.1 Persistence in R&D

The concept of persistence in R&D is generally used to describe the influence of past innovation activities on current and future innovation behaviour and success (Peters, 2009). In its simplest economic interpretation and as the literature has started recognizing, the notion of R&D persistence can be related to the Schumpeterian intuition that critical market feedbacks
link R&D investment, technological performance and profitability (Malerba, Orsenigo and Peretto, 1997). This argument is present even in the most recent investigations, adding that persistence in R&D plays an important role in endogenous growth and industry dynamics (Raymond et al., 2010; Ganter and Hecker, 2013).

Based on its relevance, persistence in R&D has attracted the attention of researchers during the last years (Peters, 2009; Raymond et al., 2010). Particularly, the most recent investigations on this stream of research have been devoted to the analysis of the drivers of the R&D persistent behaviour. Environmental factors as market dynamism (Triguero and Corcoles, 2013) and technological intensity (Raymond et al., 2010) have been put forward in the literature highlighting the positive impact that they have on R&D persistence. Firm specific characteristics, as size and outsourcing, have been also taken into consideration, showing its positive effect on R&D persistence (Triguero and Corcoles, 2013). Moreover, scholars have found that the type of innovation (organizational, product and process innovation) determines the persistence in R&D activities (Ganter and Hecker, 2013).

However, the topic in which most investigations on persistence in R&D have focused their attention is the analysis of the several theoretical explanations of R&D persistence (Raymond et al., 2010; Triguero and Córcoles, 2013). Particularly, scholars like Malerba and Orsenigo (1996), Peters (2009), Raymond et al. (2010), among others, have widely disclosed the three conceptually distinct reasons to expect that R&D activities are persistent. The first is based on the “success-breeds-success” assumption (Flaig and Stadler, 1994; Geroski, Van Reenen and Walters, 1997). Actual innovative success positively affects the development of further innovations in subsequent years (Raymond et al., 2010). Another explanation focuses on how firms accumulate technological capabilities to improve the introduction of innovations (Peters, 2009). Scholars like Malerba and Orsenigo (1999) have affirmed that knowledge accumulation ensures that today’s knowledge and innovative activities support tomorrow’s
innovations. Finally, and as Cohen and Klepper (1996) have recognized, it is generally accepted that R&D involves, at least partly, sunk costs. Given that these costs would be irrecoverable if the firm did not obtain any innovations, firms should persistently invest in R&D to increase the probability of recovering their investments.

Taking as a starting point these three arguments, we would think that firms being persistent in R&D could be able to experiment greater success in terms of innovation, for mainly two reasons. First, and according to Mansfield (1968), a firm’s innovation success broadens its technological opportunities, which makes subsequent innovation success more likely. Given the continuous investments of firms being persistent in R&D (Raymond et al., 2010), they will have more technological opportunities and hence, they could have a greater chance of success (Peters, 2009; Ganter and Hecker, 2013). Moreover, and as scholars have affirmed, the learning by doing effect enhances knowledge stocks and, therefore, the probability of future innovations (Peters, 2009; Raymond et al., 2010). Based on the type of behaviour of firms being persistent in R&D, we could think that they are provided with a wide-ranging knowledge and they have accumulated capabilities and a significant technological base (Peters, 2009; Raymond et al., 2010). Consequently, it seems that firms being persistent in R&D are going to be able to launch a greater number of innovations (Peters, 2009). The more numerous and different the innovations resulting from this process, the higher the possibility those firms satisfy the different segments and market needs (Fleming and Sorenson, 2001). That fact could justify that these firms could meet a greater number of needs, and even the demand for different market segments.

Second, the existence of sunk costs that forces organizations to introduce innovations constantly increase the probability of firms being persistent in R&D to be successful (Peters, 2009; Raymond et al., 2010). The justification is that the more numerous the innovations introduced, the higher the possibility to recover their investments. Hence, firms being
persistent in R&D, given they are able to introduce more innovations, are going to get more from their investments.

Consequently, all the reasons stated above suggest that firms being persistent in R&D will have returns above normal. Therefore, a persistent behaviour in R&D could enhance the innovation performance of firms. According to this, we propose our hypothesis as follows:

**HYPOTHESIS 1**: A persistent behaviour in R&D has a positive impact on innovation performance.

### 2.2 Persistence in collaboration

Research on collaboration has defined persistence in collaboration as the degree to which prior involvement in an alliance strategy predicts current alliance strategy engagement (Belderbos, Gilsing and Lokshin, 2012). The literature has recognized that it is the most common pattern of collaboration (Goerzen, 2007; Belderbos et al., 2012), although scholars have not devoted their attention to its analysis until recent years (Lokshin, Hagedoorn and Letterie, 2011; Belderbos, Carree, Lokshin and Sastre, 2015).

To the moment, extant literature suggests that the establishment of collaborative agreements with a particular type of partner could enable organizations to be more persistent (Belderbos et al., 2012). Particularly, customer alliance strategies are more persistent than supplier alliance strategies and competitor alliance strategies (Belderbos et al., 2012). The arguments that have led the literature to reach these conclusions evolve fundamentally around the role of habitual forces and path dependence (Belderbos et al., 2015). Organizations tend to establish routines that are associated with satisfactory performance, which are then replicated and perpetuated, leading to path dependency in their behaviour and strategy (Cyert and March, 1963; Nelson and Winter, 1982). On this basis, persistent cooperative behaviour could have its origin in a firm’s reliance on routine action that favours repetition of past action (Li and Rowley, 2002). The result of this repetitive behaviour could be that firms that persist in
cooperation are more likely to refine their organizational routines for collaboration and to gain experience in managing that type of inter-firm relationships (Das and Teng, 2000). Given that the ability to find and interpret information on potential partners, and to carefully discriminate among them, is enhanced by the amount of collaborative experience (Gulati, 1999), we could think that organizations being persistent in cooperation will be able to get more out of the collaborative agreements.

In addition, firms with more experience in the establishment of collaborative agreements could be more desirable as partners, because their repeated collaboration allows firms to build up of trust (Gulati 1995). Hence, firms being persistent in cooperation are not only competent partners that disposes over valuable and scarce expertise but also reliable and trustworthy (Belderbos et al., 2015). This could reduce risks of partner opportunism and negative referrals or lock out from future collaborative opportunities (Nooteboom 2004). On this basis, these firms could be able to exchange tacit and even fine-grained information and knowledge (Gilsing and Nooteboom 2006) and to collaborate with more competent partners, being able to generate more value from partnerships and hence, from collaboration.

Consequently, it may suggest that organizations being persistent in collaboration could increase the efficiency of their partnering strategies (Nieto and Santamaría 2007), being particularly well placed to boost the innovation performance effects of their R&D ties. For all the arguments stated above, the following hypothesis is stated as:

**HYPOTHESIS 2**: A persistent collaborative behaviour has a positive impact on innovation performance.

**2.3 Persistence in innovation activities**

Today, when developing their innovations, even the largest organizations cannot rely solely on their investments in R&D, given that they do not ensure that innovation occurs (Peters, 2009; Raymond et al., 2010). Firms also require the development and integration of new
knowledge, generally obtained from external sources (Rigby and Zook, 2002). The necessity to combine both types of activities has led firms to typically use external sources, as collaborative agreements, in addition to doing research and development (Cassiman and Veugelers, 2006). Thus, these firms could benefit from the existence of complementarities, given that the investments in R&D lead organizations to increase their degree in collaboration (Schmiedeberg, 2008).

Particularly, firms establishing collaborative agreements aim to finding resources and knowledge that allows them to develop innovations. Technological resources are not allocated efficiently in the market (Galende, 2006), so the establishment of collaborative agreements could be a solution to allow partners of which obtain resources and to exploit complementarities (Das and Teng, 2000; Belderbos, Carree and Lokshin, 2004). However, organizations that persist in their collaborative agreements could be stricter with regard to the resources they seek because they are cooperating continuously and hence, they could have agreed to some of the resources they need and now they could be more specific in their search. Consequently, not all resources are equally useful for these firms, who shall identify those they need. However, not all firms have the same ability to identify the resources and the knowledge they seek (Raymond et al., 2010). This is because the notion of ‘absorptive capacity’, introduced by Cohen and Levinthal (1989), which stress the importance of a stock of prior knowledge to effectively scan, screen and absorb the external know-how that firms obtain through their collaborative agreements (Raymond et al., 2010). Firm’s knowledge base acts as guidance to more easily identify the resources that best complement the existing (Peters, 2009), a fact that justifies that firms not having accumulated knowledge have no orientation in capturing external resources, taking the risk of absorbing those that are useless to them. Hence, the higher the firm’s knowledge base, the higher the possibility those firms obtain and integrate the resources that they need.
Therefore, it seems that the development of activities that enables organizations to build a knowledge base could be especially appropriate if they are persistent in their collaborative agreements. This is precisely the nature of organizations persisting in R&D, whose starting point is the continuous growth of their R&D base (Peters, 2009; Raymond et al., 2010). Based on this type of behaviour, firms persisting in R&D could be more likely to recognize the value, assimilate and exploit the resources that best complement the existing, being able to further capitalize on the benefits obtained from cooperation (Raymond et al., 2010). Accordingly, they will be able to increase the marginal return to their persistent cooperative behaviour (Todorova and Durisin, 2007).

In addition, organizations that persist in their cooperative agreements could obtain a lot of external knowledge but the disadvantage is that it is generally available (Jaffe, 1986), that means that it is unlikely to become a source of competitive advantage for firms (Cassiman and Veugelers, 2006). The only way in which this knowledge could lead organizations being persistent in collaboration to competitive advantage is the integration with their internal base (Cassiman and Veugelers, 2006), creating exclusive knowledge and specific organizational capabilities that competitors cannot obtain. In other words, the effective use of the large external knowledge obtained through persistent cooperative agreements is only visible when it is integrated with the one internally generated (Gupta, Smith and Shalley, 2006). Therefore, it seems that firms that have an important knowledge base could create firm specific knowledge that may not be easily traded, redeployed outside the firm or imitated by competitors (Dierickx and Cool, 1989), because the external knowledge will become more valuable co-evolving with their R&D resources (DeSarbo, Benedetto, Song and Sinha, 2005), which behave like isolation mechanisms. Hence, being persistent in R&D could allow firms being persistent in collaboration to leverage the investments that they have made.
Based on the arguments above, we could expect that firms being persistent in collaboration are going to be able to get more out of the knowledge and resources that they have obtained if they persist in R&D. On this basis, firms being persistent in collaboration are going to have returns above normal. Therefore, persistence in R&D could enhance the effect that persistence in cooperation exercise on innovation performance. Accordingly, the following hypothesis is formulated as follows:

**HYPOTHESIS 3**: A persistent behaviour in R&D positively moderates the relationship between persistent collaborative behaviour and innovation performance.

3. METHODS

3.1 Sample

To test our hypotheses, we use the Technological Innovation Panel database (PITEC). The PITEC is a statistical instrument for studying the innovation activities of a large sample of manufacturing and service Spanish firms from 2003 to 2013. The database is developed by the National Institute of Statistics (INE), with the support of the Spanish Foundation for Science and Technology (FECYT) and the Spanish Foundation for Technological Innovation (COTEC). PITEC is based on Community Innovation Survey (CIS) framework, which is a valid tool in studying innovation that follows guidelines in the Oslo Manual (OCDE, 2005) and is one of the most used datasets for studying innovation. Finally, it is important to highlight that these data have been previously used for several purposes (see for instance Vega Jurado, Gutierrez Gracia and Fernandez de Lucio, 2009; DeMarchi, 2012; Barge-Gil and López, 2014).

PITEC is particularly appropriated for the purposes of this work. First, it provides information about the cooperative agreements established by the firms included in the sample

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1The dataset, the questionnaire and the description of each variable is available at the website: [http://icono.fecyt.es/PITEC/Paginas/por_que.aspx](http://icono.fecyt.es/PITEC/Paginas/por_que.aspx). In order to avoid firms can be identified some variables are “anonymized”. López (2011) shows that the expected biases due to this anonymization are small through the comparison of regressions that use original and harmonized data alternatively.
and their investment in R&D. With this information in mind, and following the logic of previous papers (see, for example Raymond et al., 2010 and Belderbos et al., 2015), we are able to construct our independent variables. Second, the data provided by PITEC, in contrast to other innovation surveys, is administered on a yearly basis. Hence, the dataset has a longitudinal dimension, providing information about innovation variables from 2003 to 2013. That fact makes the data very suitable for the analysis of the persistence in cooperative agreements and persistence in R&D.

From these data we used information for the period 2005 to 2013. We selected our sample by following three steps. First, since we are analysing the impact on the innovation performance of the persistence in R&D and persistence in collaboration, our analysis is restricted to firms engaging in innovative activities (He and Wong, 2004; Laursen and Salter, 2006). Second, and after excluding non-innovation firms, we restricted our sample to manufacturing and service firms. Third, we dropped those firms with no information on the main variables, those that have suffered problems associated to mergers and acquisitions and those that are public or newly created. This means that we were left 39,904 observations.

Table 1 presents a first approximation to the data by showing the distribution of the number of firms depending on size. About 40% of companies have between 10 and 49 employees (small enterprises), closely followed by medium enterprises (around 32% of the sample fits in this category).

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Insert Table 1 Here
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2 Innovators are those firms that have developed product or process innovation.
3 Classification made according to the criteria established by the European Commission Regulation (CE) N° 800/2008 of 6 August 2008 (DOUE L214/3 of 9 of August, 2008), which defines the requirements for three categories of companies: microenterprise, comprising those which employ fewer than 10 workers, small business which includes those which occupies 10 to 49 employees and medium enterprises, formed by the occupying between 50 and 249 workers.
Similarly, Table 2 shows the distribution of the number of firms taking into account if they are manufacturing or service firms.

3.2 Variables

Dependent variable

We have measured innovation performance taking into account whether firms introduce product innovations, process innovations or both. We distinguish between these types of innovations because previous papers (Kraft, 1990; Martínez-Ros, 1999) have pointed out that innovation can be directed towards product or process innovation, but no necessarily towards both. In addition, we believe that the report of product or process innovations is a more complete indicator of innovation performance than the use of the number of patents, the indicator that investigations of this topic usually use, since there are many innovations that are introduced without being patented (Reichstein and Salter, 2006; Damanpour and Gopalakrishnan, 2001). On this basis, we have used a dependent variable distinguishing between product and process innovations. Specifically, and in line with Martínez-Ros (1999), we have created two dummy variables of whether a firm engages in product and/or process innovation.

Independent variables

Persistence in R&D and persistence in cooperation are the independent variables in this paper. Regarding persistence in R&D and in line with Lööf, Andersson, Johansson and Karlsson (2012), we distinguish between two types of firms. Firms in which R&D activities are ongoing, that is, those that have invested in R&D in three consecutive yearly surveys in \(t\), \(t – 1\) and \(t – 2\), are awarded “1” for this variable and “0” otherwise.
To construct persistence in cooperation variable, we consider that firms having a persistent cooperative behaviour are those that have collaborated in three consecutive yearly surveys in t, t – 1 and t – 2. Those firms receive a “1” and “0” otherwise. In this sense, it is important to note that our persistence in cooperation variable will incorporate information of five years. The justification is that PITEC questionnaire asks firms about their cooperative agreements in the last three years. Consequently, t includes information about t, t-1 and t-2; t-1 includes information about t-1, t-2 and t-3 and t-2 includes information about t-2, t-3 and t-4).

Control variables

When assessing the effect of persistence in R&D and persistence in cooperation on innovative performance it is critical to control for other variables that may impact on innovation performance. First, we take into account the size of firms. Several papers have pointed out that innovation performance might benefit from economies of scale and scope (Henderson and Cockburn, 1994). Thus, firm size may be directly related to the continuity in the firm’s R&D and cooperative activities (Malerba et al., 1997). Following Raymond et al. (2010), we use the number of employees as a measure of firm’s size. Previous research has pointed out that firms that are part of a group, defined in the Oslo manual (OECD, 2005) as an association of enterprises bound together by legal or financial links, are expected to be more innovative because they benefit from knowledge spillovers, internal access to finance, and synergies in marketing (Veugelers and Cassiman, 2004). We use a binary variable indicating whether an enterprise belongs to a group. We also control for operating in international contexts, because it could make firms being more innovative (Cassiman and Veugelers, 2006). We use de propensity to export, that is, the ratio between exports and sales to proxy this variable (Nieto and Santamaría, 2007).

Innovative activity of organizations is, in turn, affected by factors related to the technological intensity of the sector to which the firm belongs (Miotti and Sachwald, 2003;
Auh and Menguc, 2005). To measure this effect, this work has made a sectorial classification based on the technological intensity of the sector following the classification of high-tech indicators established by the Spanish National Statistics Institute (INE). We have considered two technological intensity levels, high and low, of the two sectors under analysis. As a result, we have approached the technological intensity of the sector through four dummies (high manufacturing, high service, low manufacturing, low service), taking the value 1 if the firm belongs to this sector and 0 otherwise. In addition, we also account for time effects by introducing appropriate dummies in each equation.

3.3 Descriptive Statistics

Table 3 shows the descriptive statistics of the sample as well as the correlation matrix. Our sample consists of a total of 39,904 observations that are used in the model. The means of the dependent variables are 68.7% and 68.8%, indicating that this is, on average, the probability of introducing product and process innovation, respectively. With respect to the independent variables, Table 3 shows that the average of firms being persistent in R&D (62.4%) is higher than the average of firms being persistent in cooperation (24.4%). This result is in line with the literature on innovation (Peters, 2009), affirming that firms, being aware that R&D is the most important input to innovation, focus on this type of activities. Hence, external innovation activities are less common (Raymond et al., 2010).

Finally, the correlation matrix shows that, generally, the variables have low correlations between them. However, variance inflation factors (VIFs) were computed to assess the severity of multicollinearity. The average VIF value is 1.06, with the maximum VIF value of 1.09, which are well below the cut-off point of 10 (Chatterjee, Hadi, and Price, 2000), a fact that means that we do not have problems of multicollinearity if we include these variables in the same regression.
3.4 Analysis

The hypotheses are going to be tested with Probit regression analysis because the dependent variables, product and process innovations, are dichotomous. Probit regression analysis provides, for each variable in the equation, a nonstandardized coefficient (\( \beta \)) that ranges from positive to negative infinity and is distributed as a \( z \) score (Greene, 2004). The coefficients represent the effect of each independent variable on the probability that a particular event will occur, in our case the probability that persistence in R&D and persistence in collaboration enhance the introduction of product and process innovations.

It should be noted that the literature has conceptualized product and process innovations as heterogeneous activities that could respond differently to the explanatory variables (Kraft, 1990; Martínez-Ros, 1999). The point is that, in general, process innovation will be cost reduction driven, while product innovation is more likely to be oriented towards product differentiation (Reichstein and Salter, 2006). That fact gives place to scholars to distinguish both product and process innovations expecting different effects according to the two types of innovation (Zmud, 1984). Moreover, previous papers on this topic have pointed out that technological research and innovation can be directed towards product and process innovations, but not necessarily towards both. This, however, has been ignored most of the time in empirical work, where innovation has been considered as a homogeneous activity (Reichstein and Salter, 2006). Based on the arguments presented above, we could think that product and process innovations do not have to show the same dynamics, a fact that could indicate that analysing them together could lead us to ignore the different effect that persistence in R&D and in collaboration could produce on product and process innovations.
To avoid this problem, we estimate separated Probit models attending to the two types of innovation.

Another important issue is whether there may be some interdependencies between product and process innovations, in the sense that when firms introduce a new product in the market, there will also be a need to improve the production process. The empirical model will allow for such possible interdependencies since we estimate Bivariate Probit models that serve as a generalization of the Probit model. Our Bivariate Probit model consists of a system of two (Probit) equations, one for each innovation type estimated: product and process innovations. The Bivariate Probit could be expressed as follows:

\[ y_{im}^* = \sum \beta_{im} X_{im} + \varepsilon_{im} \]
\[ y_{im} = \begin{cases} 
1, & \text{if } y_{im}^* > 0 \\
0, & \text{otherwise} 
\end{cases} \]

Here, \( y_{im}^* \) are latent variables with \( m = 1, 2 \) indicating if the firm in developing product or process innovations; \( \varepsilon_{im} \) are error terms following a bivariate normal distribution with zero mean and correlation matrix.

\[ \Sigma = \begin{pmatrix} 1 & p_{12} \\
p_{21} & 1 \end{pmatrix} \]

In order to estimate the model parameters, we apply Roodman’s (2011) Stata command `cmp`, implementing the Geweke, Hajivassiliou and Keane (GHK) algorithm.

4. RESULTS

Table 4 reports Bivariate Probit estimates for the relationships between persistence in R&D and persistence in cooperation and product and process innovations.\(^5\) It should be noted

\(^4\)StataCorp. 2013. Stata Statistical Software: Release 13. StataCorp LP, College Station, TX.

\(^5\)It should be noted
that, following previous literature (Martínez-Ros, 1999), the independent variables have been lagged one period. We have run three nested models. The first model is the based model only including the effect of the control variables on product and process innovations. The second model is the extended model, which introduces the direct effects of persistence in R&D and persistence in cooperation on product and process innovations. Finally, the interaction model is the full model, including the moderating effect of persistence in R&D on the relationship between persistence in cooperation and product and process innovations, respectively. It is important to note that the chi-square statistic shown at the end of the table indicates strong significance (p<0.001) for each model. The explanatory power of the models can be assessed through the log likelihood and the AIC test. Both indicate that the complete models are preferred.

As shown in the interaction model, firm size has a positive and significant influence on product and process innovations. This is consistent with previous findings that maintain that innovation strategies can be affected by size through economies of scale and scope (Nieto and Santamaría, 2007). Belonging of a group has a positive and significant effect on product and process innovations. Similarly, the development of international activities has a positive and significant effect on the introduction of product and process innovation. This is in line with Cassiman and Veugelers (2006). The dummy variables capturing time-specific influences and the effect of the industry are globally significant.

Regarding the main independent variables of our study, the results indicate that the effect of persistence in R&D on product innovation is positive and significant (β = 0.499, p<0.01)

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5 PITEC questionnaire contains information for each variable for a 3-year period, so part of the persistence in our variables could be due to a one-year overlap. On this basis, we have repeated the analysis but using a sample without any overlap in the period (i.e. we have considered three waves: 2007 (2005-2007), 2010 (2008-2010) and 2013 (2011-2013)), and the results do not vary. However, we have not chosen this sample because this would imply losing observations and for the case of persistence in innovation, Raymond et al. (2010) found that the effect of the overlapping year is not important.

6 This explains why our number of observations declines from the 39,904 showed in the descriptive statistics to 31,925.

7 Our estimates has taken the variable that represents low services as base category, a fact that explains its coefficient is not in Table 4.
and negative and significant on process innovation ($\beta = -0.090, p<0.01$). Therefore, our hypothesis 1 is only partially confirmed, highlighting the differences, in terms of the output of innovation, which involves carrying out continuous investments in R&D. Particularly, it means that firms being persistent in R&D could only be able to potentiate the development of product innovations, but not of process innovations, whose introduction will even be reduced.

Moreover, the effect of persistence in collaboration on product and process innovations is positive and significant ($\beta = 0.215, p <0.01; \beta = 0.106, p <0.05$, respectively). This result is consistent with hypothesis 2. It seems that the continuous establishment of collaborative agreements provides firms with sufficient resources and information to develop product and process innovations. This finding demonstrates the importance of establishing collaborative agreements, regardless of the type of innovation that is going to be developed.

Once we have analysed the effects of persistence in R&D and persistence in collaboration on innovation performance, what is remarkable is their different dynamic, which will be fully addressed in the conclusions and discussion section.

Our data also reveals that persistence in R&D positively moderates the relationship between persistence in cooperation and product innovation ($\beta = 0.076; p <0.10$) and the relationship between persistence in cooperation and process innovation ($\beta = 0.142; p <0.01$). Therefore, our hypothesis 3 is supported. This means that firms being persistent in collaboration could be able to use their continuous investments in R&D for obtain the resources that they need to introduce both product and process innovations.

Insert Table 4 Here

5. CONCLUSIONS AND DISCUSSION

This study was motivated by the desire to better understand how dynamic patterns of innovative behaviour, as persistence in R&D and persistence in collaboration, affects the
introduction of product and process innovations. Prior research has analysed the antecedents of these type of behaviour, but we still do not know the effect that persistence in R&D and persistence in collaboration, individually and jointly, exercises on innovation performance. This is somewhat surprising given that innovation literature has understood that investments in R&D could potentiate the establishment of collaborative agreements (Cassiman and Veugelers, 2006). Our paper has covered this gap by analysing the effect that persistence in R&D and persistence in collaboration have on product and process innovations, also studying the moderating effect that persistence in R&D has on the relationship between persistence in collaboration and product and process innovations.

Our results reveal that being persistent in R&D allows firms to introduce product innovations but has a negative effect on the introduction of process innovations. This asymmetric result could suggest that the sources that drive product and process innovations are different. This idea is in line with previous literature that has acknowledged that while the development of product innovations is normally associated with R&D investments, the majority of companies that develop process innovations do not invest in R&D (Arundel, Bordoy and Kanerva, 2007). In order to develop this type of innovations, firms tend to focus on activities such as the acquisition of innovations from external sources or the combination of knowledge they already possess. Taking this idea as starting point and based on the results we have obtained, it seems that it could be interesting to analyse which are the sources that drive product and process innovations. This analysis could also serve to reinforce the necessity of analysing them separately, as they clearly have different nature.

We also find that firms being persistent in their collaborative agreements could be able to increase the development of product and process innovations. The point here could be that the continuous establishment of collaborative agreements allows firms to obtain resources and information with a high degree of novelty through the establishment of relationships based on
trust between partners that allows them to introduce product innovations. Moreover, being persistent in collaboration could also allow firms to access to knowledge with a low degree of novelty through the point contact with certain partners, being able to introduce process innovations.

Previous findings highlight the different effect that persistence in R&D and persistence in collaboration exercises on innovation performance. While persistence in R&D does not always act in the same direction in terms of innovation performance -its effect is positive on product innovation but negative on process innovations-, to be persistent in collaboration always generate a positive impact. Again, it seems that the introduction of process innovations is driven by different sources than the development of product innovations. As it has been indicated before, to develop process innovations firms do not use to invest in R&D. They tend to focus on activities such as the acquisition of innovations from external sources. That fact could explain the different effect that persistence in R&D and persistence in collaboration exercises on process innovations, once again clearly strengthening the necessity of identify its determinants.

Finally, for a better understanding of its impact on innovation performance, we have offered an insight into the effect that persistence in R&D and persistence in collaboration jointly exercise. Specifically, we have demonstrated that to be persistent in R&D could increase the impact that persistence in collaboration exercises on product and process innovations. In line with this affirmation, it seems that although persistence in R&D does not exert the same effect on product and process innovations, as we have discussed before, its impact is positive in both cases when the firm is also persistent in cooperation. This result highlights the relevance of having a high absorptive capacity, derived from persistence in R&D, to develop both product and process innovations. The evidence suggests that a high absorptive capacity could act as a guidance to more easily identify the resources from
collaboration that best complement the existing (Raymond et al., 2010), allowing firms to introduce product and process innovations. This result is in line with previous literature that has pointed out that external resources will be more valuable when they coevolve with internal resources, a fact that justifies why persistence in R&D exercises a positive effect on product and process innovations.

Our paper also aims to contribute to the innovation literature (Peters, 2009; Ganter and Hecker, 2013) in three ways. First, it integrates two streams of research, persistence in R&D literature and persistence in collaboration literature, which have proceeded separately. This integration could be especially important given that, as the literature has affirmed, investments in R&D could determine the establishment of cooperative agreements (Hess and Rothaermel, 2011). In this sense, our paper not only shows that persistence in R&D exercises a positive effect on the relationship between persistence in collaboration and product and process innovations. In turn, it demonstrates that persistence in R&D turns positive for the development of process innovation when firms persist in collaboration. This finding reinforces the importance of persisting in collaboration, as it allows firms to create stable relationships with partners reducing the risk of free riding on each other’s knowledge, a fact that makes persistent investments in R&D more profitable. Second, our paper demonstrates that persistence in R&D and persistence in collaboration have not the same dynamic, a fact that reinforces the idea of taking into account persistence in collaboration when analyzing persistence in innovation activities. In this way, we offer a much more nuanced picture of the phenomenon of persistence in innovation activities, analysing it from a more rigorous point of view. Third, our findings offer an insight about the different effect of persistence in R&D on product and process innovations, a result that highlights the differences between these types of innovations and suggests the necessity of distinguishing them in future research.
In spite of the contribution of our research to integrating two literatures, several issues will require additional attention. One is that our paper has focused on analyzing whether firms persist in their R&D activities, but does not distinguish between different levels of investment. A different research approach establishing differences between levels would allow us to have a much more nuanced picture of how persistence in R&D is related to innovation performance. Another important limitation is that our paper has not identified partners by type. Thus, as a future research line, we propose identifying partner types because it could allow us to study how persistence in collaboration across partner types impacts innovation performance. Another one is that given that our database provides information about Spanish firms, our results are only representative of the behaviour of the organizations operating in this country, a fact that prevents us from generalising our findings. Thus, as a future research line, we propose the extension of this analysis to other countries. Checking whether this phenomenon occurs in different scenarios could give a greater consistency to our findings.
REFERENCES


Jaffe, A. B. 1986, Technological opportunity and spillovers of R&D: evidence from firms’ patents, profits and market value.


Mansfield, E. 1968, "Industrial research and technological innovation; an econometric analysis.


## Tables

### Table 1. Firms by size

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>%</th>
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</thead>
<tbody>
<tr>
<td>Micro-enterprises</td>
<td>3,912</td>
<td>9.80</td>
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<tr>
<td>Small enterprises</td>
<td>15,782</td>
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<tr>
<td>Medium enterprises</td>
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<td>32.30</td>
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<td>Large enterprises</td>
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<td>18.35</td>
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<td><strong>Total</strong></td>
<td><strong>39,904</strong></td>
<td><strong>100.00</strong></td>
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### Table 2. Firms by activity

<table>
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<tr>
<td>Manufacturing</td>
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<tr>
<td>Services</td>
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<tr>
<td><strong>Total</strong></td>
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<td><strong>100.00</strong></td>
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Table 3. Descriptive statistics and correlation matrix

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<th>Std. Dev</th>
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<th>Max</th>
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<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
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<tr>
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<td>0.463</td>
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<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Process innovation</td>
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<td>0.462</td>
<td>0</td>
<td>1</td>
<td>0.013</td>
<td>1</td>
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<td>Persistence in R&amp;D</td>
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<td>0.484</td>
<td>0</td>
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<td>0.238</td>
<td>-0.014</td>
<td>1</td>
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<tr>
<td>Persistence in cooperation</td>
<td>39.904</td>
<td>0.244</td>
<td>0.429</td>
<td>0</td>
<td>1</td>
<td>0.138</td>
<td>0.083</td>
<td>0.246</td>
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<td>Size (000)</td>
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<td>0.001</td>
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<td>0.150</td>
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<td>International context</td>
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<td>0.240</td>
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<td>1</td>
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<td>0.073</td>
<td>-0.024</td>
<td>0.137</td>
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Table 4. Bivariate Probit models for the probability of introduction of product and process innovations

<table>
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<tr>
<th>Dependent Variable</th>
<th>Based Model</th>
<th>Extended Model</th>
<th>Interaction Model</th>
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<tr>
<td>R&amp;D persistence</td>
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</tr>
<tr>
<td></td>
<td>0.510***</td>
<td>-0.071***</td>
<td>0.499***</td>
</tr>
<tr>
<td></td>
<td>(30.92)</td>
<td>(-4.25)</td>
<td>(28.12)</td>
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<tr>
<td>Persistence in cooperation</td>
<td>0.274***</td>
<td>0.223***</td>
<td>0.215***</td>
</tr>
<tr>
<td>R&amp;D persistence * persistence in cooperation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(14.37)</td>
<td>(12.17)</td>
</tr>
<tr>
<td>Size (000)</td>
<td>0.027***</td>
<td>0.126***</td>
<td>0.023***</td>
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<tr>
<td></td>
<td>(4.91)</td>
<td>(11.71)</td>
<td>(4.02)</td>
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<tr>
<td>Group</td>
<td>0.097***</td>
<td>0.199***</td>
<td>0.050***</td>
</tr>
<tr>
<td></td>
<td>(6.28)</td>
<td>(12.67)</td>
<td>(3.18)</td>
</tr>
<tr>
<td>International context</td>
<td>0.178***</td>
<td>0.123***</td>
<td>0.074***</td>
</tr>
<tr>
<td></td>
<td>(6.78)</td>
<td>(4.73)</td>
<td>(2.76)</td>
</tr>
<tr>
<td>High manufacturing</td>
<td>0.576***</td>
<td>-0.117***</td>
<td>0.473***</td>
</tr>
<tr>
<td></td>
<td>(26.71)</td>
<td>(-5.52)</td>
<td>(21.25)</td>
</tr>
<tr>
<td>High services</td>
<td>0.502***</td>
<td>-0.277***</td>
<td>0.394***</td>
</tr>
<tr>
<td></td>
<td>(18.39)</td>
<td>(-10.55)</td>
<td>(14.13)</td>
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<tr>
<td>Low manufacturing</td>
<td>0.234***</td>
<td>0.171***</td>
<td>0.204***</td>
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<tr>
<td></td>
<td>(11.81)</td>
<td>(8.28)</td>
<td>(10.12)</td>
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<tr>
<td>Constant</td>
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<td>-0.093***</td>
</tr>
<tr>
<td></td>
<td>(9.27)</td>
<td>(19.63)</td>
<td>(-3.88)</td>
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<tr>
<td>Temporal dummies</td>
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<td>Yes ***</td>
<td>Yes ***</td>
</tr>
<tr>
<td>N</td>
<td>31.925</td>
<td>31.925</td>
<td>31.925</td>
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<tr>
<td>Rho</td>
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<td>0.038***</td>
<td>0.038***</td>
</tr>
<tr>
<td>Chi-square</td>
<td>3170.61***</td>
<td>4756.32***</td>
<td>4767.95***</td>
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<td>AIC</td>
<td>76,052.97</td>
<td>74,475.27</td>
<td>74,467.64</td>
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</tbody>
</table>

*p < 0.10, **p < 0.05, ***p < 0.01