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"Are R&D collaborative agreements persistent at the firm level? Empirical evidence for the Spanish case"

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Abstract

We provide evidence on the dynamics in firms' R&D cooperation behaviour. Our main objective is to analyse if R&D collaborative agreements are persistent at the firm level, and in such a case, to study what are the main drivers of this phenomenon. R&D cooperation activities at the firm level can be persistent due to true state dependence, this implying that cooperating in a given period enhances the probability of doing it in the subsequent period and it can also be a consequence of firms' individual heterogeneity, so that certain firms have certain characteristics that make them more likely to carry out technological alliances. A second contribution of the paper deals with the differentiated persistence pattern of collaboration agreements for three different types of partners: customers and/or suppliers, competitors and institutions. We specifically explore the degree of the persistence in R&D collaborative activities when considering them separately as well as the possibility of finding crossed-persistence across these different partner types.

JEL classification: L24; O32; D22; C23
Keywords: R&D cooperation; Persistence; Innovative Spanish firms; Technological partners

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1. Introduction

Nowadays, thanks to the globalization and the rapid diffusion of technological knowledge, firms are forced to accelerate their rhythm of innovation and to expand their technological capabilities. This can be made through different mechanisms, either internal efforts in R&D or accessing external sources of technological knowledge and skills. In particular, collaborative agreements have become a strategy of knowledge sharing and transfer across firms which are increasingly recognised as an important (quasi-market) mechanism to access such external knowledge (Schilling, 2008).

In this sense, empirical contributions on the study of different strategies of R&D cooperation have expanded significantly in the last decades. Some of these studies have shown, among other results, that R&D cooperation with other firms or institutions has a positive and significant effect on firms' performance (Miotti and Sachwald, 2003; Belderbos et al., 2004a; Lööf and Broström, 2008; Aschoff and Schmidt, 2008).[1] Despite this extensive literature on the impact of R&D cooperation, little attention has been paid on the persistence with which these types of agreements are carried out. This paper aims to provide empirical evidence on this issue. Most previous studies have examined the simple occurrence or existence of R&D cooperation, but it is clear that the use of this strategy as a way to undertake innovation activities may be more or less durable in time.

According to Jacob et al. (2013), persistent utilization of cooperation agreements may allow firms to maintain their focus on their core domains through in-house specialisation, while external collaboration may provide them with a window of newly emerging technological opportunities that fall beyond their main areas of expertise. The collaboration will be so much more fruitful if the firm has a partner with resources that complement its own and that are relevant to the innovation being sought (Nieto and Santamaría, 2007). In addition, from a management perspective, cooperating in a persistent way allows firms obtaining know-how knowledge, which involves information about who knows what and who knows what to do, as well as the social ability to co-operate and communicate with different partners (Lundvall, 2004).

[1] According to the theoretical work of D'Aspremont and Jacquemin (1988), cooperation may even have a positive effect on social welfare. Nonetheless, it has also been pointed that welfare could be reduced if firms collude in output and hence, alliance strategies should not be supported if they involve product market collusion (Greenlee and Cassiman, 1999; Goeree and Helland, 2010).

Innovation is the result of a dynamic process, which involves relationships both in the short and long term. Indeed, R&D activities at the firm level have been found to be highly persistent mainly due to true state dependence, this implying that performing R&D in a given period enhances the probability of R&D being performed in the subsequent period. However, it can also be a consequence of firms' individual heterogeneity, so that certain firms have certain characteristics that make them more likely to carry out R&D activities. If these characteristics tend to persist over time, they will inexorably provoke persistence in R&D as well. In any case, it is generally accepted that technological advances cannot take place without systematic involvement in R&D (Mañez-Castillejo et al., 2009) and therefore, those firms for which cooperation is one of the main ways to access knowledge also need to be persistent in their cooperation agreements.

In this paper we aim at providing evidence on the dynamics in firms' R&D cooperation behaviour. The main objective is, therefore, to analyse if R&D collaborative agreements are persistent at the firm level, and in such a case, to study what are the main drivers of this phenomenon. Knowing which determinants of persistence are prevalent has important policy implications. If carrying out R&D collaboration activities is state dependent, collaboration-stimulating policy measures, such as government support programmes, are supposed to have a deeper effect because they do not only affect current collaboration agreements but are also likely to induce a permanent change in favour of cooperation. If, on the contrary, persistence is driven by individual characteristics, temporary shocks to technological collaboration will rapidly dissipate, and support programmes are unlikely to have long-lasting effects and policy should focus more on policies trying to improve the specific factors that drive R&D cooperation. In such a case, understanding the determinants of the persistence of firms when undertaking agreements of collaboration would allow policy makers to focus resources on "survival-winners" and avoid wasting resources on "survival-losers". The present paper contributes to this issue. In particular, we follow a dynamic approach in the analysis of cooperation persistence, taking into account the unobserved individual heterogeneity and handling the initial conditions problem. We use a representative sample of Spanish firms for the period 2002-2010.

In addition, following with the well-documented idea that cooperative experience can be considered as an incremental learning process in terms of the management of collaborative agreements (Powell et al., 1996), we aim at providing evidence on the extent to which having participated in technological collaborations with one type of partner in the past may be a significant dimension when it comes to analysing current collaborative agreements not only with the same but also with other type of partners. The literature on organizational learning (Levitt and March, 1988) discusses how firms recurrently cooperating learn how to manage cooperation agreements by repeatedly engaging in them. This gives us arguments to state that this experience of cooperation activities is not restricted to the fact of cooperating with the same partner or even with the same type of partner (i.e. competitors, clients, suppliers or universities and research centers). Firms with experience of technological cooperation agreements gained through long-standing relationships are likely to join other partners, even if they are of a different nature that the previous ones, just because they have learnt to develop and establish routines, policies and procedures based on their previous experiences (Nieto and Santamaría, 2007). Therefore, a second contribution of the present paper deals with the differentiated persistence pattern of collaboration agreements for three different types of partners: customers and/or suppliers, competitors and institutions. We specifically explore the degree of the persistence in R&D collaborative activities when considering them separately as well as the possibility of finding crossed-persistence across these different partner types.

After this introduction, Section 2 proceeds with the literature review on the topic of the persistence in R&D cooperation activities. Section 3 describes the database used and the methodological issues. In Section 4 we present and discuss the results obtained and finally, the main conclusions of the paper are presented in Section 5.

2. Literature review

In a similar line to that of innovation persistence, the degree of cooperation persistence of a firm could be defined as the positive impact of past collaborations on present cooperation agreements (Flaig and Stadler, 1994). In principle, there are several potential sources for persistent behaviour (Heckman, 1981). Firstly, it might be caused by true state dependence, this meaning that the decision to innovate through cooperation in one period in itself enhances the probability to cooperate in the subsequent period. Secondly, firms may have some specific characteristics which make them mostly prone to cooperate. To the extent that these characteristics persist over time, they will inevitably induce persistence in cooperation agreements as well. Such features can be classified into observable attributes, such as firm size or firm's absorptive capacity, and unobservable ones, like managerial abilities or the stock of tacit knowledge, that are typically not observed. If these unobserved features present correlation over time, and are not properly controlled for in the estimation, past cooperation activities may appear to affect future cooperation simply because it picks up the effect of these persistent unobservable characteristics. It is known in the literature as spurious state dependence. As a consequence, the unobserved individual heterogeneity and the well-known initial conditions problem have to be addressed rigorously.

There are basically three theoretical explanations for real true dependence in the case of cooperation in innovation activities. The first one is based on the hypothesis of “success-breeds-success”. The idea is that successful R&D cooperation projects positively affects the conditions for further cooperation agreements in subsequent years. Firms tend to establish routines that are associated with positive performances, and are, therefore, replicated and perpetuated without drastic changes, leading to path dependency in their behaviour and strategy (Cyert and March, 1963; Nelson and Winter, 1982; Levitt and March, 1988; Belderbos et al., 2012). Thereby, firms gaining positive returns from innovations made in cooperation with other firms or institutions are keener to continue conducting this cooperative strategy than firms without a relative experience in this kind of activities. Furthermore, experience in cooperation may make firms more attractive as partners as they would be better able to generate value from partnerships (Gulati, 1995).

A second reason why some firms are expected to be persistent R&D co-operators lies in the fact that cooperation agreements involve costs that may not be recoverable. Firms need to incur start-up costs for establishing cooperation agreements (for instance, costs related to searching, training and adapting to the partner of cooperation) and sometimes require a relatively large initial investment. This kind of costs can be considered, at least partly, as sunk costs (Sutton, 1991; Cohen and Klepper, 1996) and entail barriers to entry into and exit from cooperation projects. Firms involved in cooperation agreements should better not stop cooperating in order to increase the probability of recovering their initial investments and gain from positive results from such agreements. The presence of important sunk costs represents an essential motive for entering and staying in a specific regime of R&D activity (Le Bas et al., 2011). As pointed by Clausen et al. (2012), technological alliances in which knowledge is jointly developed between firms, interactions between customers and suppliers or cooperation with research institutions may have important sunk costs and may, therefore, be more durable.

A third explanation focuses on firms' knowledge accumulation. Cooperation experience should be considered as an incremental learning process in two ways: in terms of the technical learning of innovation itself, and in terms of the management of collaborative ties (Powell et al., 1996). With respect to the first one, by cooperating firms acquire a set of capabilities and knowledge stocks that allow them to benefit by learning from specific areas of specialization of their partners. This way, having participated in technological collaborations in the past may be a hugely important dimension when it comes to analyzing current innovation capability. This absorptive capacity is dependent on the firm's level of prior-related knowledge which is partly made up thanks to previous experience of collaboration. Secondly, experience in networking will also have an effect on the management of collaborative agreements. The literature on organizational learning shows that firms continuously engaged in alliances learn from previous experience as firms learn how to manage these hybrid organizational forms by repeatedly engaging in them. In addition, the more alliance experience a firm has, the more it becomes structurally embedded in an alliance network, providing it with network-level information on new partnering opportunities (Granovetter, 1985). Similarly, this mechanism brings information with respect to a firm's reputation to potential partners, enhancing their ability to assess the firm's attractiveness. In a similar vein, a greater degree of trust between firms cooperating continuously is reached, which is a basic requisite for a successful partnership (Nooteboom, 2004). As a consequence of the whole process, experience in cooperation allows firms not only to obtain quite specialised competences but also to find the most reliable experts, forming a source of information on potential partners over time. This learning is also related to the concept of "learning by interacting" which points to how interaction in innovation enhances the relationship with external partners (Lundvall, 1988; Lundvall, 2004; Jensen et al., 2007). Since a firm's ability to recognise the value of new external information as well as to assimilate and apply it to commercial ends, is a function of the level of knowledge, learning in one period will allow for a more efficient accumulation of external knowledge in subsequent periods (Cohen and Levinthal, 1990). This cumulative nature of knowledge would induce state dependence in cooperative behaviour.

While most studies on R&D cooperation strategies have examined the determinants of carrying out this strategy and their consequences on the firm's performance in a single point in time, the dynamics of R&D cooperation behaviour has been relatively ignored. In contrast, there has been an important amount of literature on the dynamic character of innovation itself, and in particular, on the persistence of innovation (Cefis, 2003; Mañez-Castillejo et al., 2009; Peters, 2009; Raymond et al., 2010). In general, the method used to examine innovation persistence consists in modelling the probability of a firm to innovate as a function of the lagged dependent variable (i.e. whether or not the firm innovated in a previous period) and other control variables. Innovation persistence occurs when the lagged innovation variable has a positive and significant sign (Clausen et al., 2012). Most studies investigating persistence of innovation have found evidence in favour of state dependence in the decision to innovate using dynamic discrete choice models or survival analyses. Nevertheless, the degree of persistence obtained in these papers depends, among other things, on how the authors measure innovation and if the firm's unobserved heterogeneity has been taken into account. In relation with the measurement issue, Geroski et al. (1997), Cefis and Orsenigo (2001) and Cefis (2003) relying on patent data and/or major innovations obtained a low level of persistence in such activities combined with bimodality, i.e., strong persistence for great innovators and non-innovators; whereas in studies using R&D and innovation survey data, persistence in innovation activities is found to be high (Duguet and Monjon, 2002; Mañez-Castillejo et al., 2009; Peters, 2009). Yet, innovation persistence is found to differ significantly across sectors, firm size and types of innovation (product and process innovation). Raymond et al. (2010) emphasize that persistence may be spurious and its existence can be ascertained only after accounting for individual effects and handling properly the initial conditions problem. Once this is done, these authors find a significant persistence in the occurrence of innovation in high-tech industries, while such evidence is not found in low-tech industries.

Although innovation persistence has become an important topic in applied industrial organization since the publication of the seminal paper by Geroski et al. (1997), from our knowledge, Belderbos et al. (2012) and Jacob et al. (2013) are the only ones to explore the persistent character of alliance strategies although with very specific objectives. Whereas the first one uses a data set on innovative Dutch firms to analyse the persistence of, and interrelation between horizontal and vertical technology alliances, the second one examine to what extent prior engagement in international alliances with partners from developed countries increases the propensity to form technology alliances with partners based in emerging economies and vice versa. In our paper, we study the extent of the phenomenon of persistence in the firms' decisions to engage in cooperation agreements as a way to carry out innovation activities, attempting to control for the presence of unobserved individual heterogeneity and the initial condition problem. In this sense, we consider that the issue of persistence in R&D cooperation activities is relevant and merits further research since it determines how systematically firms access external knowledge and resources to carry out innovation activities, which can be behind the traditional issue of whether or not, and to what extent, innovation is persistent.

3. Empirical issues

3.1 Methodology

Our empirical approach follows the definition of cooperation persistence as "state dependence" presented in the previous section, basically that having engaged in R&D cooperation activities increases the probability to engage in such arrangements currently. So, the study considers a dynamic random effects probit model which allows for state dependence and unobserved individual heterogeneity to analyse the discussed causal relationship. In addition, in order to distinguish whether persistence is due to true state dependence or to the spurious one, this dynamic framework accounts for unobserved individual effects correlated with the initial conditions, as will be discussed next.

The latent equation for this model is specified as follows:

$$y_{it}^{*} = \gamma\, y_{it-1} + x_{it}^{'}\,\beta + \alpha_i + \varepsilon_{it} \qquad i = 1, ..., N; t = 2, ..., T \qquad (1)$$

where y_{it}^{*} is the latent dependent variable which measures the difference between benefits and costs that firm i obtains during the current period t by cooperating in R&D with other firms or institutions; y_{it-1} is an indicator for cooperation during the previous period and captures the previous cooperation experience (true state dependence); γ is the parameter that represents the true state dependence to be estimated; x_{it} is a vector of observable characteristics of the firm that may be associated with the cooperation indicator and β the corresponding vector of parameters to be estimated; α_i are unobserved individual-specific random effects which are assumed to be uncorrelated with the independent variables; and ε_{it} is a time and individual-specific error term that is assumed to be distributed as $N(0,1)$ [2]. If y_{it}^* is larger than zero we observe that firm i engages in cooperation, so the observed binary outcome variable is defined as:

$$y_{it} = \begin{cases} 1 & if \ y_{it}^* > 0 \\ 0 & else \end{cases} \tag{2}$$

Since ε_{it} is normally distributed, the dynamic model of interest is given by

$$P\left[y_{it} = 1 | x_{it}, y_{it-1}, \alpha_i\right] = \Phi\,(\gamma\, y_{it-1} + x_{it}^{'}\,\beta + \alpha_i) \tag{3}$$

where Φ is the cumulative distribution function of a standard normal.

In this context, the relative importance of the unobserved effect is measured as $\rho = \sigma_\alpha^2 / (\sigma_\alpha^2 + 1)$, which shows the percentage of total variance explained by unobserved heterogeneity. Testing the statistically significance of this coefficient leads to an easy test for the presence of the unobserved effect, that is, the relevance of the random effects estimator over the pooled one.

A positive and statistically significant estimate of γ identifies the presence of persistence in the decision to engage in cooperation agreements for innovation. As we mentioned in the literature review section, it may arise due to true state dependence or due to unobserved characteristics of the firms that are correlated over time. As pointed out by Raymond et al. (2010), the existence of true persistence can be ascertained only after accounting for unobserved individual effects and handling properly the initial conditions problem. The simplest assumption is to take the initial conditions to be exogenous, but it is not expected so because the start of the observation period for each firm could be correlated with the unobserved characteristics of the firms. In our context, if the initial conditions are taken to be exogenous, the coefficient of the lagged dependent variable would be overestimated. In other words, it will lead to an overstatement of the true state dependence in R&D cooperation decisions. Since for most firms the cooperation process did not start at the same time of this study's observation timeframe, we assume the initial conditions to correlate with the unobserved effect.

[2] Later in the paper we discuss why the random effects model is preferred over the fixed effects in our case.

We follow the Wooldridge's (2005) procedure which deals with the initial conditions problem in non-linear dynamic random effects models where it is necessary to model the unobservable heterogeneity. Specifically, we assume that the unobserved individual heterogeneity depends on the initial conditions (y_{i0}) and the time-varying exogenous variables, namely:

$$\alpha_i = \delta_0 + \delta_1 y_{i0} + \delta_2 \overline{x}_i + u_i \qquad (4)$$

where $\overline{x}_i$ represents the means of time-variant exogenous variables; u_i is assumed to be distributed $N(0,1)$ and independently of the explanatory variables, the initial conditions (y_{i0}), and the idiosyncratic error term (ε_{it}).[3]

3.2 Dataset and variables

We use the Technological Innovation Panel (PITEC)[4] produced jointly by the Spanish National Statistics Institute (INE), the Spanish Foundation for Science and Technology (FECYT) and the Cotec Foundation. The data come from different successive waves of the Spanish Innovation Survey conducted every year by the INE, which in turn is based on the Community Innovation Survey (CIS). An important advantage of using this database is that it allows us to study different issues related to innovation activities of Spanish manufacturing and service firms over time as it is specifically designed to analyse technological activities. Given the specific aim of this study and because the questions about cooperation are asked in a three-year period, i.e. the survey asks whether or not the firm cooperated in the period between t-2 and t, we consider four waves of the PITEC: 2004 (wave 2002-2004), 2006 (wave 2004-2006), 2008 (wave 2006-2008) and 2010 (wave 2008-2010), covering the period 2002-2010.

[3] Since the regressors exhibit too little time variation (within variation) and given the high correlation between the variables and their within means (see Table 2 and Table A2 in the Appendix), we are not able to identify δ_2 and hence, we followed the strategy adopted by Raymond et al. (2010) assuming that the unobserved individual effects are correlated only with the initial values of y_{it}.

[4] This database is available at http://icono.fecyt.es/PITEC/Paginas/por_que.aspx

A cleaning process has been carried out and only those firms belonging to the industrial and service sectors, with at least ten employees and positive sales have been taken into account. [5] In addition, since we are interested in the persistence of R&D cooperation activities, our analysis is restricted to firms engaging in innovative activities[6] for which technology collaboration is relevant. We distinguish two panel data sets. The first one is an unbalanced panel comprising all firms that are present in at least two consecutive waves[7]; and the second one is a balanced sub-sample, so that only firms which are present in all the waves are included. In Table 1 we show some characteristics of the two data sets.

[Insert Table 1 around here]

In each PITEC survey, for a three-year period, the firm is asked if it had any cooperation agreement with other firms or institutions on its innovation activities. Based on this question, we define the *cooperation* variable as an indicator variable which takes the value 1 if the firm decided to cooperate and zero otherwise,[8] which is our main dependent variable. We follow the standard modelling procedure for analyzing (innovation) persistence in which the lagged dependent variable is an explanatory variable included in the model in order to test the persistence hypothesis. However, we also control for other factors that have been traditionally considered in the literature as influencing the decisions to engage in R&D cooperation activities as outlined below. Not considering them explicitly in the regression analysis would bias the results concerning the true state dependence in the innovative cooperation strategy.

The process of cooperation in innovation activities is complex. Following previous theoretical and empirical papers, among the factors leading firms to engage in collaborative innovative activity, we focus on incoming spillovers, appropriability conditions, the firm's absorptive capacity and the receipt of public funding for innovation. We also control for some firms' characteristics such as firm size, belonging to a group of enterprises and sectoral dummy variables.

[5] Firms that report confidentiality issues, mergers, closures and employment incidents are eliminated.
[6] That is, firms that have introduced innovations in products or processes, or who were undertaking innovation activities during the analysed period or abandoned them.
[7] Using the unbalanced panel allows us to obtain more precise estimates as a higher number of observations and for a greater variety of firms are considered. Additionally, we control partly for survival biases as firms are allowed to enter and exit the sample at any period.
[8] Note that a lag of this variable refers to two to four years, two lags refer to four to six years and so on.

Incoming spillovers refer to the flows of external knowledge that a firm is able to capture, and the information sources for them are usually situated in the public domain (Cassiman and Veugelers, 2002). This way, this variable is measured by the importance that the firm attributed, on a four-point scale, to publicly available information for the innovation process of the firm. The information sources were conferences, trade fairs, exhibitions, scientific journals and trade/technical publications, professional and industry associations. To generate a firm-specific measure of incoming spillovers, we aggregated these answers by summing the scores on each of these questions and then the variable was rescaled from 0 (unimportant) to 1 (crucial). Firms that place a higher value on incoming spillovers and externally generated knowledge in their innovative activity might have a greater scope for learning and gaining from knowledge exchange through cooperative agreements. So these firms are expected to be more likely to be actively engaged in cooperative R&D agreements and to do it more persistently.

Likewise, we account for *appropriability conditions*, which could be an important factor in explaining patterns in cooperation and their persistence as firms can have less incentives to cooperate for anti-competitive reasons or they may have more incentives in order to learn from others while internalizing the knowledge flows shared between partners. In other words, a better appropriability of the results of innovation through protection may have a positive effect on cooperating persistently in R&D, as firms can control outgoing information flows and there are less incentives for others to become a free rider on other firms' investments (Cassiman and Veugelers, 2002). However, excessive legal protection may hinder the internalization of the flows shared by the partners and may thus have a negative effect on R&D cooperation (Hernán et al., 2003; López, 2008). As a proxy for appropriability conditions, we computed the variable *legal protection*, which considers whether the firm used at least one legal method for protecting inventions or innovations (patents, registered an industrial design, trademark or copyright), taking a value of 1 if used, and zero otherwise.

Regarding the *receipt of public funding for innovation*, when firms obtain public R&D subsidies they may be more likely to establish cooperation agreements with other firms or with institutions given that this way they have the resources to do the research (Arranz and Fernandez de Arroyabe, 2008; Busom, Fernández-Ribas, 2008; Abramovsky et al., 2009). Also, many times public support programmes for R&D activities aim to ease cooperative innovation agreements by firms that would otherwise not engage in such activity. In order to distinguish the effect from different sources of public R&D subsidies, we define three binary variables: *local, national and European funding*, taking the value 1 if the firm received public funding from local or regional authorities, central government and European Union, respectively, to carry out its innovation activities, and zero otherwise.

R&D intensity as a proxy for absorptive capacity and *firm size* are expected to influence positively cooperation activities. Firms' R&D intensity (measured as the share of internal R&D expenditures in total sales) represents their R&D efforts (experience and knowledge accumulated) and according to Cohen and Levinthal (1989), greater efforts in R&D increase the firm's capacity to recognize, value, and assimilate external knowledge from cooperation agreements. Absorptive capacity has been identified in many studies as an important feature of the firms since it makes them more likely to be successful innovators, which could make them more attractive cooperation partners for other firms and make them being persistent co-operators (Bayona et al., 2001; Fritsch and Lukas, 2001; Miotti and Sachwald, 2003; Hernán et al., 2003; Belderbos et al., 2004b; Röller et al., 2007; Arranz and Fernandez de Arroyabe, 2008). On the other hand, it is argued that large firms have more resources and certain capabilities to be more able to face commitments required for partnerships and to benefit from cooperation agreements and from economies of scale (Bayona et al., 2001; Fritsch and Lukas, 2001; Tether, 2002; Miotti and Sachwald, 2003; Belderbos et al., 2004b; Belderbos et al., 2012). Firm size is a categorical variable (<50 employees, 50-249, 250-499 and >500) according to the number of employees.

We expect firms *belonging to a group* of enterprises to be more likely to engage in R&D cooperation and to do it in a continuous way. Firms that are part of a group may have access to a substantial pool of resources that make them more attractive as cooperation partners (Ahuja, 2000; Miotti and Sachwald, 2003; Belderbos et al., 2012). We define a binary variable taking the value 1 if the firm belongs to a group of companies, and zero otherwise. See Table A1 in the Appendix for a more detailed explanation of the definitions of the variables. To avoid problems of simultaneity with the decision of engaging in R&D cooperative agreements, all the independent variables are one period-lagged.

Some descriptive statistics of the variables used in our empirical analysis are shown in Table 2. Although all of them can vary across firms and time we can see that in all cases the variation across firms (between variation) is much higher compared to the time variation (within variation).

[Insert Table 2 around here]

PITEC also asks firms which kind of partner they cooperated with in their innovation processes. According to this question, we distinguish between three different types of cooperation agreements in order to analyse to what extent the experience in cooperating with one type of partner influences the probability of cooperating with the same of with other types of partners:[9] Horizontal cooperation (with competitors or other enterprises of the same sector; Vertical cooperation (with suppliers of equipment, materials, components or software or with customers or clients) and Institutional cooperation (with consultants, commercial labs, or private R&D institutes, universities or other higher education institutions, government or public research institutes and technological centres).

4. Main results

Table 3 reports the transition probabilities of engaging in R&D cooperation agreements between periods t-1 and t, t-2 and t and t-3 and t for both the unbalanced and the balanced panels. In the unbalanced panel, nearly 71% of the cooperators in one wave persisted in cooperation in the subsequent wave, that is, after two to four years, while 29% stopped their arrangements. In a similar vein, about 84% of the non-cooperators remained in this status in the following wave and 16% changed it engaging into agreements of cooperation in the subsequent period. The corresponding figures are very similar in the balanced panel. Therefore, it turns out that the probability of cooperating in period t was about 55 percentage points higher for previous co-operators than for previous non-cooperators, showing the considerably high persistence in cooperation activities from period to period. In addition, although the probability of permanence in the same state decreases as the period of observation extends, the last transition matrices (t-3 and t) still show a high level of persistence in the decisions to engage in R&D cooperation: almost 57% of co-operators and 73% of

[9] The survey also offers information on another type of cooperation: cooperation with firms in the same group. However, we do not consider such typology since only firms belonging to a group can cooperate within their group, while all the other types of partners can be chosen by all firms. However, in order to control for the possible different behaviour of such firms, the regression analysis includes a dummy variable for firms belonging to a group.

non-cooperators remain in their initial state after six to eight years, with very similar figures for the balanced panel.

[Insert Table 3 around here]

In any case, the probability of persisting in cooperation agreements in the case of Spanish firms seems not to be as high as the one observed in R&D activities reported in previous studies. Also for a panel of Spanish manufacturing firms observed during the period 1998-2009, Arqué-Castells (2013) report that 89% of R&D performers in one year persisted in R&D the subsequent year, while 11% ceased their R&D activities. Similarly, 95% of non R&D performers maintained their status the next period while only 5% entered into R&D. Thus, compared with innovation, neither persistence is as high in cooperation activities, nor transitions are so infrequent. The firm may decide to carry innovation activities as a strategy to survive, however, there are several ways to develop such innovation, so that according to different objectives, it may not always be necessary to follow cooperative agreements with other firms and/or institutions. Besides, the continuity of a cooperation agreement not only depends on the firm itself, but also on the decision from the other counterpart of continuing with such alliance, which can make these types of activities of a less-continuous nature in themselves.

The results on the regression estimation are given in Table 4. As it is observed, the statistical significance of the panel-level variance component over the total variance (ρ) indicates that the random effects estimator is preferred over the pooled probit estimator, indicating the accuracy of considering the former.[10] In the first column we report the marginal effects from the estimation of the dynamic random effects probit model taking into account the unobserved individual heterogeneity and assuming the initial conditions as being exogenous. As mentioned before, since the persistence of engaging in R&D cooperation may be spurious when the individual effects and the initial conditions are not addressed, these results can be contrasted with the estimates obtained

[10] Additionally, since we are considering a sample of the whole population of Spanish firms, i.e., a random sample from a large population, the random effects model would be more appropriate based on theoretical grounds (Baltagi, 2005). This way, we can make inferences about all the unobservable effects in the population, and not only in the sample, as would be the case with a fixed effects model. Also, following Mundlak (1978) and Hsiao (2003), we prefer the random effects model because it allows for treating omitted factors that affect the dependent variable as random errors instead of constants.

assuming that the initial conditions are correlated with the individual effects, as presented in the second column. The two additional columns report the same regressions as before for the balanced panel. By and large, the results of the two datasets are very similar. Therefore, it can be taken as a robustness check confirming our results about the persistence in R&D cooperation activities.

[Insert Table 4 around here]

The estimates in column (1) that allow individual-specific effects but take initial conditions to be exogenous, give an average marginal effect of the lagged dependent variable of 0.47, positive and highly significant. This result indicates that firms are persistent in carrying out cooperation activities as a strategy to undertake their innovation activities. The Wooldridge estimates that are shown in the second column, after taking into account the assumption of the initial conditions correlated with the unobserved individual effects, yield an average marginal effect of 0.34, that is, firms that performed cooperation agreements at t-1 have a probability of cooperating at t around 34 percentage points higher than do firms that did not cooperate at t-1. Two main conclusions arise. First, there is evidence of the existence of a behavioural effect in the sense that the decision to cooperate in our period enhances the probability of being co-operator in subsequent periods. That is, our results suggest a significant state dependence effect for cooperation activities. Second, in line with previous findings in the literature, the hypothesis of exogenous initial conditions leads to overestimation of the degree of persistence.

While taking into account the dynamic behaviour of cooperation, we also find that the importance attributed to sources of information publicly accessible, the use of protection methods, firm size, and the fact of belonging to a group of enterprises affect positive and significantly the probability to cooperate. Furthermore, it is worth noting that the firm's decision to cooperate in R&D activities depends significantly on public funding (local, national and European). This result is in accordance with many studies analysing the relationship between R&D cooperation and subsidies (Busom and Fernández-Ribas, 2008; Arranz and Fernandez de Arroyabe, 2008; Abramovsky et al., 2009) and evidence that R&D subsidies designed to encourage innovation activities could alleviate barriers to cooperation. Of course this dependence of R&D cooperation on public funding can be a problem for the long-term R&D strategy of the firm, since not receiving public funds because of government budget cuts could force the firm stopping their cooperation agreements.

With the aim of analysing the strength of this persistence found in cooperation activities, the first two columns in Table 5 refer to the same estimations as those given in Table 4, but including an additional variable that takes the value 1 if the firm decided to cooperate two periods before (t-2), irrespectively of what was done in period t-1. As observed, true state dependence is also observed in the case of a longer time span, which in our case corresponds to four to six years, although with a much lower intensity. This result is in line with the evolutionary perspective that sees innovation as a dynamic process that develops over time. In this process, having participated in cooperation activities in the past may allow firms to accumulate technological knowledge which increases their absorptive capability which will allow them to engage in further innovation projects carried out jointly with other partners. That is, it enables firms to strengthen their resource endowment which last over time. However, what happens when a firm that has been cooperating in innovation activities, stops doing it? Can it re-start cooperating with more feasibility than those that not cooperated before? Columns (3) and (4) include an explanatory variable, namely $Coop_{t-2/t-1=0}$, that takes the value 1 if the firm cooperated in t-2, restricted to the fact of not having carried out cooperation activities in t-1. Under the same scenario of non-cooperators in t-1, the value of such variable is 0 if the firm did not cooperate either in t-2. According to the literature on organizational learning (Levitt and March, 1988, Powell et al., 1996), firms repeatedly engaged in an activity such as innovation cooperation learn from experience as learn how to manage these organizational forms by engaging in them repeatedly, as they develop and establish routines, policies and procedures based on their experiences. According to our estimates, firms not engaged in cooperation activities in t-1 but with previous experience in t-2 have a significantly higher probability of engaging in cooperation agreements in t, if compared with those that had not carried out cooperation activities in the past (at least the time periods that fall under control in our sample). This past dependence is much lower than in the case of cooperating continuously, but still points to the fact that once a firm begins to collaborate, it will gain experience and develop a reputation as a partner which keeps in time. This "learning by doing" seems to be maintained in time, at least in short periods of time.

[Insert Table 5 around here]

Persistence pattern of collaboration for different types of partners

We turn now to the analysis of the differentiated persistence pattern of collaboration agreements for three types of partners: customers and/or suppliers, competitors and research institutions. We specifically explore the degree of persistence in R&D collaborative activities when considering them separately as well as the possibility of finding such effect across the different partnerships.

Table 6 shows the transition probabilities of cooperation agreements for the three types of partners. First of all, it turns out that there are hardly any differences between the unbalanced panel and the smaller balanced panel. We also observe that persistence in cooperation at the firm-level is larger in the case of research institutions and universities, with more that 68% of firms that cooperated in one period that persisted in cooperation activities in the subsequent period, followed by co-operators with clients or suppliers, that presented a persistence rate of 63%. In the case of cooperating with competitors, about 52% of them persisted in t+1, l6 percentage points lower that with institutions. Among other reasons, one could point to the fact that cooperating with competitors may follow strategic reasons that can vary substantially over time depending on the market conditions, economic cycle and the situation of the two firms. Also, it could be that as a consequence of their bilateral nature, in which two competitors have to be in accordance to follow the alliance, this type of agreements suffers from relatively important fluctuations. On the contrary, cooperation agreements with institutions may follow structural objectives of the firm cooperating, which tend to be of a long-term nature. In any case, transitions are relatively frequent in all the cases. For instance, nearly 32% of co-operators with institutions in one year ceased such cooperative activities in the following, which is the lowest share (this probability increases in the case of vertical cooperation until 37%, and sums up to nearly 48% in horizontal cooperation). This higher stability for the case of technological cooperation with research institutions and universities, can be due to the fact those firms do not look for merely short-term alliances but for a way to carry out a long-term innovation strategy. Indeed, when the firm values positively the results obtained from collaboration agreements with research institutions, the fact of having participated in technological collaborations with them in the past allow the firm to develop and establish procedures based on such previous experiences which may be a significant dimension when it comes to analysing current collaborative agreements of such type.

[Insert Table 6 around here]

Columns (1) to (3) in Table 7 show the estimates of our specification for the separate cases of the 3 types of partners. In other words, we want to analyse whether it is possible to observed different persistence trends according to type and diversity of partners. Again, after taking into account the assumption of the initial conditions correlated with the unobserved individual effects, we obtain lower parameters for persistence than with the hypothesis of exogenous initial conditions.[11] The Wooldridge estimates yield an average marginal effect of 0.29 for institutions, that is, firms that performed cooperation agreements with research institutions at t-1 have a probability of cooperating at t around 29 percentage points higher than do firms that did not cooperate at t-1 with research centers. The same applies for the case of cooperation with clients or suppliers, with almost the same probability. In the case of cooperating with competitors, this probability is of 11 percentage points, much lower but still significant.

Several conclusions are worth pointing out. First, that irrespective of the type of partner, there exists a behavioural effect in the sense that the decision to cooperate with one type of partner in one period enhances the probability of being the same kind of co-operator in subsequent periods. These results suggest a significant state dependence effect for cooperation activities even once we consider separately the different types of alliances. Second, among the reasons of the highest persistence in the case of collaboration with customers, clients and institutions one may think of the relative limited spillovers risks if compared to the one in agreements with competitors, which may imply a higher persistence of the former alliance strategies. In the case of collaboration with competitors, due to the similar knowledge both firms share, the capacity for absorption of knowledge spillovers and, as a consequence, of creating free-ridership (Nooteboom, 2004) is particularly important. As a consequence, agreements of cooperation with competitors are not only scarcer but also less permanent.

[Insert Table 7 around here]

[11] We do not offer the results without the Wooldridge correction to save space. They can be provided by the authors upon request.

According to the alliance portfolio view, having a diversity of partnership is positive for the firm, since the potential complementarities between different types of partners may bring in different sets of knowledge or complementary capabilities (Vassolo et al., 2004). Indeed, different partner types play different functions in complementing the internal resources and capabilities of a firm, which may have different connotations for a firm's tendency to engage in such agreements. Therefore, the aim now to analyse whether firms with experience in technological cooperation agreements are likely to join partners of a different nature. Columns 4 to 6 in Table 7 provide the results of the regressions in which we include not only the past alliance engagement in the same type of partnership but also variables that consider if the firm reported to be previously engaged in an alliance with each of the other two types of partners. As a consequence, the size and significance of the coefficients on prior engagement in the same type of cooperation partnership indicate persistence, whereas the coefficients on prior involvement in the other two types of alliances show the interrelation among them.

According to our results, once again the magnitude of persistence in alliances is significantly positive and of a similar magnitude than the ones obtained when the interrelations across types of partners were not included. That is, persistence in the case of institutional as well as vertical cooperation is higher than in the case of collaboration agreements with competitors, and in all cases, these persistence effects are stronger than the interrelation effects. In all the cross-partners opportunities we obtain that cooperation agreements with one type increase the likelihood of cooperating in the future with a different type of partner, although with a much lower intensity than in the case of the same partnership group. The highest persistence is observed for firms that performed cooperation agreements with research institutions at t-1, which have a probability of cooperating with clients or suppliers at t around 9 percentage points higher than do firms which did not cooperate at t-1 with such institutions. Among the reasons behind this higher influence of past alliances with institutions, we could think on the idea that relations with research centres or universities may allow the firm to obtain higher insights on future opportunities for innovation and the creation of a next-generation technology. Subsequent to this, the firm may need to start technological collaboration agreements with clients or suppliers so that they adapt their processes to this new technology. As for the other interrelation patterns across partners, they are also significant although of a much lower magnitude. All in all, it seems fair to think that the use of a wide range of co-operators as a source of external knowledge can help the firm to achieve and sustain innovation

(Becker and Dietz, 2004; Laursen and Salter, 2006). This way, the knowledge diversity gained through the collaboration with different types of partners should enhance innovation by enabling firms to make linkages and gain a broader spectrum of experiences with diverse partners (Anand and Khanna, 2000).

5. Conclusions

Our study is an attempt to analyse persistence in R&D cooperation activities and, as a consequence, understand innovation in a globalised environment. Initially, persistence in cooperation agreements is appealing, as it provides firms with a stream of information that becomes available thanks to being embedded in a network. The results show that there is a high persistence in R&D cooperation activities at the firm level. After discounting the impact of observed and unobserved firm characteristics, a firm cooperating in t-1 has a probability of cooperating which is approximately 34 percentage points higher than that of a firm not having cooperated in the previous period. This could be explained by the knowledge accumulation and capabilities that may be gained from past experiences in cooperation projects, the barriers to enter and exit which can arise due to sunk costs, and the success and reliability in past cooperation agreements. In addition, we observe that firms with higher incoming spillovers, higher R&D intensity, large firms and firms that belong to a group of enterprises as well as firms that use protection methods (such as patenting, registered an industrial design, trademark or copyright) are more persistent in their technological collaborative agreements.

When taking into account the different types of partnership, we conclude that the highest persistence is found in the case of collaboration with institutions, followed by customers and clients. One potential explanation may be related to the relative limited spillovers risks in those types of alliances if compared to the one in agreements with competitors, which may imply a higher persistence of the former alliances. Finally, in all the types of partners, we obtain that cooperation agreements with one type increase the likelihood of cooperating in the future with a different type of partner, although with a much lower intensity than in the case of the same partnership group.

From a policy view, the fact of R&D cooperation being state dependent implies that collaboration-stimulating policy measures, such as government support programmes, are supposed to have a deeper effect because they do not only affect current collaboration agreements but are also likely to induce a permanent change in favour of cooperation. In addition, since persistence is also driven by certain individual characteristics of the firms, they could be taken into account when designing policies to stimulate cooperation in a persistent way: firms with high R&D intensity, large firms and firms that belong to a group of enterprises as well as firms that use protection methods. Policy makers could decide to focus resources on "cooperation-survival-winners".

References

Abramovsky, L., Kremp, E., López, A., Schmidt, T., Simpson, H., 2009. Understanding co-operative innovative activity: evidence from four European countries. Economics of Innovation and New Technology 18(3), 243-265.

Anand, B., Khanna, T., 2000. Do firms learn to create value? The case of alliances. Strategic Management Journal 21(3), 295–315.

Arqué-Castells, P., 2013. Persistence in R&D performance and its implications for the granting of subsidies. Review of Industrial Organization, 43, 193-220.

Arranz, N., Fernandez de Arroyabe, J.C., 2008. The choice of partners in R&D cooperation: an empirical analysis of Spanish firms. Technovation 28, 88-100.

Aschhoff, B., Schmidt, T., 2008. Empirical evidence on the success of R&D cooperation -- Happy together?. Review of Industrial Organization 33(1), 41-62.

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

Baltagi, B.H., 2005. Econometric Analysis of Panel Data. Wiley and Sons, Chichester.

Bayona, C., Gracia-Marco, T., Huerta, E., 2001. Firms' motivation for cooperative R&D: an empirical analysis of Spanish firms. Research Policy 30(8), 1289–307.

Becker, W., Dietz, J., 2004. R&D co-operation and innovation activities of firms-evidence for the German manufacturing industry. Research Policy 33, 209–223.

Belderbos, R., Carree, M.A., Lokshin, B., 2004a. Cooperative R&D and firm performance. Research Policy 33(10), 1477-1492.

Belderbos, R., Carree, M.A., Diederen, B., Lokshin, B., Veugelers, R., 2004b. Heterogeneity in R&D co-operation strategies. International Journal of Industrial Organization 22(8-9), 1237–63.

Belderbos, R., Gilsing, V., Lokshin, B., 2012. Persistence of, and Interrelation Between, Horizontal and Vertical Technology Alliances, Journal of Management 38(6), 1812-1834.

Busom, I., Fernández-Ribas, A., 2008. The impact of firm participation in R&D programmes on R&D partnerships. Research Policy 37(2), 240-257.

Cassiman, B., Veugelers, R., 2002. R&D cooperation and spillovers: some empirical evidence from Belgium. The American Economic Review 92(4), 1169-1184.

Cefis, E., 2003. Is there persistence in innovative activities?. International Journal of Industrial Organization 21(4), 489-515.

Cefis, E., Orsenigo, L., 2001. The persistence of innovative activities: a cross-countries and cross-sectors comparative analysis. Research Policy 30, 1139–1158.

Clausen, T., Pohjola, M., Sapprasert, K., Verspagen, B., 2012. Innovation strategies as a source of persistent innovation. Industrial and Corporate Change 21(3), 553–585.

Cohen, W.M., Klepper, S., 1996. A reprise of size and R&D. Economic Journal 106, 925-951.

Cohen, W., Levinthal, D., 1989. Innovation and learning: the two faces of R&D. Economic Journal 99, 569–596.

Cohen, W.M., Levinthal, D.A., 1990. Absorptive capacity: a new perspective of learning and innovation. Administrative Science Quarterly 35(1), 128–152.

Cyert, R.M., March, J.G., 1963. A behavioral theory of the firm. Englewood Cliffs, NJ: Prentice Hall.

Duguet, E., Monjon, S., 2002. Creative destruction and the innovative core: is innovation persistent at the firm level?. UCL discussion paper 02-07.

D'Aspremont, C., Jacquemin, A., 1988. Cooperative and noncooperative R&D in duopoly with spillovers. The American Economic Review 78(5), 1133-7.

Flaig, G., Stadler, M., 1994. Success breeds success. The dynamics of the innovation process. Empirical Economics 19(1), 55–68.

Fritsch, M., Lukas, R., 2001. Who cooperates on R&D?. Research Policy 30, 297-312.

Geroski, P.A., Van Reenen, J., Walters, C.F., 1997. How persistently do firms innovate? Research Policy 26, 33–48.

Goeree, M.S., Helland, E., 2010. Do Research Joint Ventures serve a collusive function? Working Paper No 448, University of Zurich.

Granovetter, M., 1985. Economic action and social structure: the problem of embeddedness. American Journal of Sociology 91, 481-510.

Greenlee, P., Cassiman, B., 1999. Product market objectives and the formation of Research Joint Ventures. Managerial and Decision Economics 20, 115-130.

Gulati, R., 1995. Social structure and alliance formation patterns: a longitudinal analysis. Administrative Science Quarterly 40, 619–652.

Heckman, J.J., 1981. Heterogeneity and state dependence. In S. Rosen (Ed.), Studies in labor markets, 91-140. Chicago: Chicago University Press.

Hernán, R., Marin, P., Siotis, G., 2003. An empirical analysis of the determinants of Research Joint Venture Formation. Journal of Industrial Economics 51, 75-89.

Hsiao, C., 2003. Analysis of Panel Data. Cambridge University Press.

Jacob, J., Belderbos, R., Gilsing, V., 2013. Technology alliances in emerging economies: persistence and interrelation in European firms' alliance formation. R&D Management 43(5), 447-460.

Jensen, M., Johnson, B., Lorenz, E., Lundvall, B.A., 2007. Forms of knowledge and modes of innovation. Research Policy 36, 680–693.

Laursen, K., Salter, A., 2006. Open for innovation: the role of openness in explaining innovation performance among UK manufacturing firms. Strategic Management Journal 27(2), 131–150.

Le Bas, C., Mothe, C., Nguyen-Thi, T.U., 2011. Technological innovation persistence: Literature survey and exploration of the role of organizational innovation, CEPS Instead, Working Paper 2011-54.

Levitt, B., March, J.G., 1988. Organizational learning, Annual Review of Sociology 14, 314-340.

López, A., 2008. Determinants of R&D cooperation: evidence from Spainsh manufacturing firms. International Journal of Industrial Organization 26, 113-136.

Lööf, H., Broström, A., 2008. Does knowledge diffusion between university and industry increase innovativeness? The Journal of Technology Transfer 33(1), 73-90.

Lundvall, B.-Å., 1988. Innovation as an interactive process: from user–producer interaction to the national system of innovation. In: Dosi, G. Freeman, C., Nelson, R., Silverberg, G., Soete, L. (Eds.), Technical Change and Economic Theory. Pinter, London, 349–369.

Lundvall, B.-Å., 2004. The economics of knowledge and learning. In J.L. Christensen and B.-Å. Lundvall (Eds.), Product Innovation, Interactive Learning and Economic Performance (Research on Technological Innovation and Management Policy, vol 8). Emerald Group Publishing Ltd., 21-42.

Mañez-Castillejo, J.A., Rochina-Barrachina, M.E., Sanchis-Llopis, A., Sanchis-Llopis, J.A., 2009. The role of sunk costs in the decision to invest in R&D. Journal of Industrial Economics, 57, 712–735.

Miotti, L., Sachwald, F., 2003. Cooperative R&D: why and with whom? An integrated framework of analysis. Research Policy 32(8), 1481-1499.

Mundlak, Y., 1978. On the pooling of time series and cross section data. Econometrica 46, 69–85.

Nelson, R.R., Winter, S.G., 1982. An evolutionary theory of economic change. Cambridge, MA: Belknap.

Nieto, M.J., Santamaría, L., 2007. The importance of diverse collaborative networks for the novelty of product innovation, Technovation 27, 367-377.

Nooteboom, B., 2004. Inter-firm collaboration, learning and networks: An integrated approach. London: Routledge.

Peters, B., 2009. Persistence of innovation: Stylised facts and panel data evidence, The Journal of Technology Transfer 34, 226-243.

Powell, W., Koput, K., Smith-Doerr, L., 1996. Interorganizational collaboration and the locus of innovation: Networks of learning in biotechnology, Administrative Science Quarterly 41(1), 116-146.

Raymond, W., Mohnen, P.A., Palm, F., Van der Loeff, S.S., 2010. Persistence of innovation in Dutch manufacturing: is it spurious? The Review of Economics and Statistics 92, 495-504.

Röller, L., Siebert, R., Tombak, M., 2007. Why firms form (or do not form) RJVS. The Economic Journal 117(522), 1122-1144.

Schilling, M.A., 2008. Understanding the alliance data, Strategic Management Journal 30(3), 233-260.

Sutton, J., 1991. Sunk costs and market structure (MIT Press, London).

Tether, B.S., 2002. Who co-operates for innovation, and why: an empirical analysis. Research Policy 31(6), 947-967.

Vassolo, R.S., Anand, J., Folta, T.B., 2004. Non-additivity in portfolios of exploration activities: A real optionsbased analysis of equity alliances in biotechnology. Strategic Management Journal 25, 1045-1061.

Wooldridge, J., 2005. Simple Solutions to the Initial Conditions Problem in Dynamic Nonlinear Panel Data Models with Unobserved Heterogeneity. Journal of Applied Econometrics 20, 39–54.

Tables

Table 1. Characteristics of the panel data sets used

	Unbalanced panel	Balanced panel
Number of observations	25,364	16,016
Number of firms	7,566	4,004
Number of consecutive obs. per firm	>=2	4
Average number of consecutive obs.	3.4	4

Table 2. Descriptive statistics of variables in the empirical analysis

	Unbalanced				Balanced			
	mean	std. dev.			mean	std. dev.		
		overall	between	within		overall	between	within
Cooperation_t-1	0.382	0.486	0.414	0.268	0.409	0.492	0.395	0.293
Incoming spillovers	0.363	0.277	0.240	0.151	0.380	0.275	0.223	0.161
Legal protection	0.357	0.479	0.408	0.266	0.377	0.485	0.387	0.291
R&D intensity	0.075	0.245	0.240	0.083	0.071	0.233	0.216	0.086
Firm size	314.244	1430.165	1440.760	280.152	334.356	1305.782	1277.710	269.809
Local funding	0.300	0.458	0.390	0.252	0.321	0.467	0.379	0.273
National funding	0.269	0.444	0.370	0.250	0.296	0.456	0.366	0.273
European funding	0.074	0.261	0.220	0.139	0.083	0.276	0.228	0.155
Belonging to a group	0.416	0.493	0.472	0.147	0.442	0.497	0.470	0.160

Table 3. Transition probabilities matrix

		Cooperation in t			
		Unbalanced panel		Balanced panel	
Cooperation in		Non-cooperation	Cooperation	Non-cooperation	Cooperation
t-1	Non-cooperation	83.70	16.30	82.50	17.50
	Cooperation	29.24	**70.76**	27.39	**72.61**
t-2	Non-cooperation	78.22	21.78	77.63	22.37
	Cooperation	39.01	**60.99**	36.99	**63.01**
t-3	Non-cooperation	73.35	26.65	73.35	26.65
	Cooperation	43.43	**56.57**	42.89	**57.11**

Table 4. Marginal effects from dynamic random effects probit model

	Unbalanced panel		Balanced panel	
	Random effects probit	Wooldridge correction	Random effects probit	Wooldridge correction
Cooperation $_{i,t-1}$ (*persistence*)	0.473***	0.337***	0.470***	0.329***
	(0.008)	(0.018)	(0.011)	(0.020)
Cooperation $_{i,t0}$ (*initial conditions*)		0.188***		0.204***
		(0.021)		(0.024)
Incoming spillovers	0.095***	0.106***	0.090***	0.099***
	(0.016)	(0.018)	(0.020)	(0.024)
Legal protection	0.035***	0.040***	0.036***	0.041***
	(0.009)	(0.010)	(0.011)	(0.013)
R&D intensity	0.088***	0.107***	0.096***	0.123***
	(0.024)	(0.028)	(0.035)	(0.042)
Firm size (base <50 employees)				
50 – 249 emp	0.039***	0.046***	0.038***	0.047***
	(0.010)	(0.012)	(0.013)	(0.016)
250 – 499 emp	0.056***	0.067***	0.056***	0.070***
	(0.016)	(0.020)	(0.020)	(0.025)
500 or more emp	0.102***	0.119***	0.097***	0.115***
	(0.018)	(0.022)	(0.023)	(0.028)
Public funding for innovation				
Local funding	0.096***	0.099***	0.103***	0.103***
	(0.010)	(0.011)	(0.013)	(0.015)
National funding	0.099***	0.104***	0.098***	0.101***
	(0.011)	(0.012)	(0.013)	(0.015)
European funding	0.119***	0.124***	0.133***	0.134***
	(0.019)	(0.022)	(0.023)	(0.027)
Belonging to a group	0.062***	0.071***	0.077***	0.091***
	(0.010)	(0.012)	(0.013)	(0.015)
Industry dummies	Included	Included	Included	Included
Time dummies	Included	Included	Included	Included
Observations	17,568	17,568	12,012	12,012
Number of firms	7,566	7,566	4,004	4,004
Log L	-8418.381	-8370.928	-5852.373	-5809.207
Wald test (χ^2)	5007.341	3605.362	3256.116	2339.050
	Pval = 0.000	Pval = 0.000	Pval = 0.000	Pval = 0.000
Rho (ρ)	0.049	0.288	0.080	0.320
Likelihood test (H_0: $\rho=0$)	4.375	78.444	7.681	77.860
	Pval = 0.018	Pval = 0.000	Pval = 0.003	Pval = 0.000

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 5. Marginal effects from dynamic random effects probit model (unbalanced panel)

	Random effects probit (1)	Wooldridge correction (2)	Random effects probit (3)	Wooldridge correction (4)
Cooperation $_{i,t-1}$	0.483***	0.482***		
	(0.011)	(0.011)		
Cooperation $_{i,t-2}$	0.138***	0.121***		
	(0.014)	(0.020)		
Coop $_{i,t-2/t-1=0}$			0.082***	0.057***
			(0.012)	(0.021)
Cooperation $_{i,t0}$		0.022		0.026
		(0.018)		(0.017)
Incoming spillovers	0.106***	0.106***	0.030*	0.030*
	(0.022)	(0.022)	(0.016)	(0.016)
Legal protection	0.050***	0.050***	0.033***	0.034***
	(0.013)	(0.013)	(0.010)	(0.010)
R&D intensity	0.048	0.047	0.012	0.012
	(0.035)	(0.035)	(0.033)	(0.033)
Firm size (base <50 employees)				
50 – 249 emp	0.041***	0.041***	0.025**	0.025**
	(0.014)	(0.014)	(0.011)	(0.011)
250 – 499 emp	0.065***	0.065***	0.040**	0.041**
	(0.022)	(0.022)	(0.019)	(0.019)
500 or more emp	0.109***	0.109***	0.075***	0.076***
	(0.024)	(0.024)	(0.023)	(0.024)
Public funding for innovation				
Local funding	0.102***	0.101***	0.051***	0.050***
	(0.014)	(0.014)	(0.012)	(0.013)
National funding	0.099***	0.099***	0.066***	0.067***
	(0.015)	(0.015)	(0.014)	(0.014)
European funding	0.079***	0.079***	0.051	0.051
	(0.028)	(0.028)	(0.031)	(0.032)
Belonging to a group	0.042***	0.042***	0.013	0.013
	(0.013)	(0.013)	(0.010)	(0.010)
Industry dummies	Included	Included	Included	Included
Time dummies	Included	Included	Included	Included
Observations	10,002	10,002	6,104	6,104
Number of firms	5,998	5,998	4,133	4,133
Log L	-4441.680	-4440.926	-2369.920	-2368.611
Wald test (χ^2)	2438.253	2438.502	298.691	125.828
	Pval = 0.000	Pval = 0.000	Pval = 0.000	Pval = 0.000
Rho (ρ)	0.066	0.067	0.001	0.080
Likelihood test (H_0: $\rho=0$)	2.995	3.008	0.001	0.173
	Pval = 0.042	Pval = 0.041	Pval = 0.491	Pval = 0.339

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 6. Transition probabilities matrix – Type of cooperation

		Unbalanced panel		Balanced panel	
		Non-cooperation	Cooperation	Non-cooperation	Cooperation
		Vertical cooperation in t			
Vertical cooperation in t-1	Non-cooperation	89.10	10.90	88.19	11.81
	Cooperation	37.24	**62.76**	34.86	**65.14**
		Horizontal cooperation in t			
Horizontal cooperation in t-1	Non-cooperation	95.32	4.68	95.01	4.99
	Cooperation	47.65	**52.35**	45.84	**54.16**
		Institutional cooperation in t			
Institutional cooperation in t-1	Non-cooperation	88.63	11.37	87.68	12.32
	Cooperation	31.59	**68.41**	30.17	**69.83**

Table 7. Marginal effects from dynamic random effects probit model – Type of cooperation (unbalanced panel)

VARIABLES	Vertical cooperation (1)	Horizontal cooperation (2)	Institutional cooperation (3)	Vertical cooperation (4)	Horizontal cooperation (5)	Institutional cooperation (6)
Vertical cooperation $_{i,t-1}$	0.288***			0.251***	0.016***	0.056***
	(0.022)			(0.022)	(0.004)	(0.011)
Horizontal cooperation $_{i,t-1}$		0.115***		0.053***	0.098***	0.033**
		(0.025)		(0.013)	(0.023)	(0.015)
Institutional cooperation $_{i,t-1}$			0.294***	0.092***	0.024***	0.275***
			(0.021)	(0.009)	(0.004)	(0.022)
Vertical cooperation $_{i,t0}$	0.135***			0.120***		
	(0.018)			(0.018)		
Horizontal cooperation $_{i,t0}$		0.057***			0.046***	
		(0.011)			(0.010)	
Institutional cooperation $_{i,t0}$			0.189***			0.179***
			(0.021)			(0.021)
Incoming spillovers	0.068***	0.028***	0.086***	0.049***	0.022***	0.076***
	(0.012)	(0.005)	(0.014)	(0.012)	(0.005)	(0.015)
Legal protection	0.021***	0.003	0.036***	0.016**	0.001	0.034***
	(0.007)	(0.003)	(0.008)	(0.007)	(0.003)	(0.008)
R&D intensity	0.046***	0.009*	0.077***	0.039**	0.007	0.076***
	(0.016)	(0.005)	(0.020)	(0.016)	(0.005)	(0.020)
Firm size (base <50 employees)						
50 – 249 emp	0.036***	0.011***	0.030***	0.036***	0.010***	0.027***
	(0.009)	(0.003)	(0.010)	(0.009)	(0.003)	(0.010)
250 – 499 emp	0.053***	0.017***	0.052***	0.052***	0.015**	0.046***
	(0.015)	(0.006)	(0.017)	(0.014)	(0.006)	(0.017)
500 or more emp	0.104***	0.027***	0.099***	0.098***	0.022***	0.089***
	(0.017)	(0.008)	(0.020)	(0.017)	(0.007)	(0.019)
Public funding for innovation						
Local funding	0.054***	0.015***	0.087***	0.038***	0.011***	0.085***
	(0.008)	(0.003)	(0.009)	(0.008)	(0.003)	(0.009)
National funding	0.062***	0.020***	0.098***	0.050***	0.017***	0.096***
	(0.009)	(0.004)	(0.010)	(0.008)	(0.004)	(0.010)
European funding	0.045***	0.031***	0.106***	0.028**	0.026***	0.097***
	(0.015)	(0.007)	(0.019)	(0.014)	(0.007)	(0.018)
Belonging to a group	0.042***	0.007**	0.020**	0.039***	0.006**	0.019**
	(0.008)	(0.003)	(0.009)	(0.008)	(0.003)	(0.009)
Industry dummies	Included	Included	Included	Included	Included	Included
Time dummies	Included	Included	Included	Included	Included	Included
Observations	17,568	17,568	17,568	17,568	17,568	17,568
Number of firms	7,566	7,566	7,566	7,566	7,566	7,566
Log L	-6892.452	-3648.657	-7008.542	-6815.628	-3592.438	-6988.545
Wald test (χ^2)	2966.723	1659.641	3450.835	3146.194	1775.496	3521.336
	Pval = 0.000	Pval = 0.000	Pval = 0.000	Pval = 0.000	Pval = 0.000	Pval = 0.000
Rho (ρ)	0.249	0.297	0.301	0.223	0.261	0.286
Likelihood test (H_0: $\rho=0$)	47.277	39.453	68.394	38.404	30.518	61.847
	Pval = 0.000	Pval = 0.000	Pval = 0.000	Pval = 0.000	Pval = 0.000	Pval = 0.000

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Appendix

Table A1. Definition of the variables included in the empirical analysis

Variables	Definitions
Dependent	
Cooperation $_t$	= 1 if the firm cooperated in some of its innovation activities with other enterprises or institutions in the period t = 0 otherwise
Type of Cooperation:	
Vertical Cooperation $_t$	= 1 if the firm cooperated in some of its innovation activities with clients or customers; suppliers of equipment, materials, components or software in the period t = 0 otherwise
Horizontal Cooperation $_t$	= 1 if the firm cooperated in some of its innovation activities with competitors or other enterprises of the same sector in the period t = 0 otherwise
Institutional Cooperation $_t$	= 1 if the firm cooperated in some of its innovation activities with consultants, commercial labs or private R&D institutes; universities or other higher education institutions; government or public research institutes; technological centres in the period t = 0 otherwise
Independent	
Cooperation $_{t-1}$	= 1 if the firm cooperated in some of its innovation activities with other enterprises or institutions in the period t-1 = 0 otherwise
Incoming spillovers	= 1 if firm gives high importance to the following information sources for undertaking its innovation activities: conferences, trade fairs, exhibitions; scientific journals and trade/technical publications; professional and industry associations. = 0 otherwise
Legal Protection	= 1 if the firm uses at least one of the following legal methods for protecting inventions or innovations: applied for a patent; registered an industrial design; registered a trademark; claimed copyright = 0 otherwise
R&D Intensity	Ratio between intramural R&D expenditure and turnover
Firm Size	<50 employees =1 if the firm has less than 50 employees; =0 otherwise 50 – 249 employees =1 if the firm has between 50 and 249 employees; =0 otherwise 250 – 499 employees =1 if the firm has between 250 and 499 employees; =0 otherwise 500 or more employees =1 if the firm has 500 or more employees; =0 otherwise
Local funding	= 1 if the firm receives funding from local or regional authorities to carry out its innovation activities = 0 otherwise
National funding	= 1 if the firm receives funding from central government to carry out its innovation activities = 0 otherwise
European funding	= 1 if the firm receives funding from European Union to carry out its innovation activities = 0 otherwise
Belonging to a group	= 1 if the firm belongs to a group of enterprises = 0 otherwise

Table A2. Correlation between the explanatory variables and their corresponding within means

Incoming spillovers	0.839
Legal protection	0.832
R&D intensity	0.941
Firm size	0.981
Local funding	0.836
National funding	0.826
European funding	0.846
Belonging to a group	0.954

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