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"Technological cooperation in Spanish firms"

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Abstract

This paper aims to study to what extent participating in technological cooperation agreements can be a useful mechanism for improving the innovative capacity of Spanish firms, specially in the context of the economic recession. We analyze if there are differences in the returns obtained from cooperation alliances according to the firm's size as well as different geographical scopes of such alliances. In addition, we want to study to what extent innovation cooperation may have a different effect on incremental innovations than on radical/breakthrough innovations. We use the Spanish Technological Innovation Panel from 2004 to 2012 to provide evidence on the above issues.

JEL classification: L25; O31; O33; R1

Keywords: Innovation cooperation; Technological partners; Performance; Spanish firms.

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1. Introduction

Recent studies have emphasized that the development of new products and processes in firms largely depends on the firm's ability to build networks and partnerships as a way to incorporate external knowledge for innovation (Lundvall, 1988, 2007; Tether, 2002; Powell and Grodal, 2005; Vega-Jurado et al., 2009; Trigo and Vence, 2011). In particular, collaborative agreements have become a strategy of knowledge sharing and transfer across firms which are largely recognised as an important (quasi-market) mechanism to access such external knowledge (Schilling, 2008). Accordingly, it is becoming increasingly important for firms to cooperate with other organizations to carry out their R&D activities. Given the ultimate interest of stimulating innovation, the study of R&D cooperation has attracted the attention of both academics and policy-makers and remains an open field of research.

Indeed, policy-makers increasingly promote the development of R&D networks as part of their technological policies. Most EU and national public funding for R&D is directed at stimulating cooperation between firms, and between firms and public institutions (López, 2008). In the 'smart specialisation' strategy, where a new innovation policy concept is aimed to promote the efficient and effective use of public investment in research, the European Commission emphasized that it needs to be based on a strong partnership between businesses, public entities and knowledge institutions, since such partnerships are recognised as essential for success (European Commission, 2012). Having this in mind, the results obtained from research on cooperation strategies should have important implications for public policy.

In this context, this research focuses on the study of firms' cooperative agreements with other actors in the innovation system (firms, universities, public or private research institutions) with the objective of performing innovation activities. Specifically, we provide evidence on the impact of R&D cooperation strategies on firms' innovative performance.

Specifically, we focus our empirical research on the impact of innovative cooperation on product innovation and how this has an effect on the firm's sales, which is a real measure for innovation performance. Indeed, obtaining a new product does not imply that the sales are increased consequently, or at least not all new products would imply equal increase of the sales. Therefore, we understand that a measure such as of the share of sales the firm states are due to new products developed by the firm should be a better proxy for the innovative performance of firms. Thus, in a first step, we want to provide evidence on whether the acquisition of knowledge from cooperation agreements is positively associated with innovation performance in terms of the share of sales the firm says are due to new products developed by the firm.

Additionally, we plan to analyse if there are differences in the returns obtained from such cooperation according to the firm's size, the context of the great recession as well as the geographical scope of the cooperation networks. In addition, we want to study to what extent innovation cooperation may have a different effect on incremental innovations than on radical/breakthrough innovations. We use the Spanish Technological Innovation Panel from 2004 to 2012 to provide evidence on the above issues.

The outline of the paper is as follows. The second section sketches the empirical model whereas the data are presented in section 3. Some descriptives are provided in section 4 and the main results are given in section 5. We finally conclude in section 6.

2. Empirical model

We aim to estimate the impact of research collaboration on innovative performance. Since innovative performance can only be observed for firms that report at least one innovation, we follow a two-stage approach to address the potential selection bias on the estimation of the innovation performance equation. The first stage of our analysis consists of a binary selection model using all available observations and considering as dependent variable whether or not the firm was innovative (d). In the second stage, we estimate the innovation performance equation taking account of the selection process. In this second stage model, the dependent variable that proxies for innovative performance (y) is a measure of the shares of sales due to new or significantly improved products.

The model has the following specification:

$$d_{it} = 1[z_{it}\gamma + \eta_i + u_{it} > 0], \quad (1)$$

$$y_{it} = \begin{cases} x_{it}\beta + \alpha_i + \varepsilon_{it} & \text{if} \quad d_{it} = 1 \\ 0 & \text{if} \quad d_{it} = 0, \end{cases} \quad (2)$$

where i = 1, …, N, t = 1, …, T, and 1[.] is an indicator function that takes on the value 1 if the expression between square brackets is true and 0 otherwise. In addition, γ and β are unknown parameter vectors to be estimated; z_{it} and x_{it} are vectors of explanatory variables with possibly common elements. In equation (2) we assume that there are valid exclusion restrictions. η_i and α_i are unobserved individual specific effects which may be correlated with z_{it} and x_{it}, respectively; and u_{it} and ε_{it} the idiosyncratic errors. The innovation performance variable (y_{it}) is only observable if the firm innovated ($d_{it} = 1$) and the parameter vector of interest to estimate is β.

We estimate the model using Wooldridge's (1995) consistent estimator for panel data with sample selection. This method consistently estimates β by first estimating a probit of d_i on z_i for each *t* and then saving the inverse Mills ratio, $\hat{\lambda}_{it}$. Next, we estimate by pooled OLS the equation of interest augmented by the inverse Mills ratio using the selected sample. The resulting equation is (Wooldridge, 2010):

$$y_{it} = x_{it}\beta + x_i\psi + \sum_{t=1}^{T}\rho_t D_t \hat{\lambda}_{it} + e_{it} \qquad \text{for all } d_{it} = 1 \quad (3)$$

where D_t is a time indicator variable and x_i represents a vector of means of the time-variant regressors.[1]

[1] We assume that the conditional mean of the individual effects are a linear projection on the within individual means of the time-variant regressors (Mundlak, 1978; Nijman and Verbeek, 1992; Zabel, 1992; Wooldridge, 1995).

3. Data.

3.1 Database

The data used in this paper are draw from the Spanish Technological Innovation Panel (PITEC). This panel data results from the combined effort of the Spanish National Statistics Institute (INE), the Spanish Foundation for Science and Technology (FECYT), and the Foundation for Technical Innovation (COTEC) with the intention of having a database available which would make it possible to analyse the innovation behaviour of Spanish firms and how it evolves. Firms participation in PITEC survey is mandatory by law which ensures a large and consistent sample size and a high response rate. The panel survey follows the Oslo Manual methodology applied in the Community Innovation Survey with respect to the selection of variables and indicators (OECD, 2005).

According to the information available in PITEC, we define cooperation as the active participation with other enterprises or non-commercial institutions on innovation activities. Both partners do not necessarily need to gain a commercial benefit. This definition excludes pure contracting out of work where there is no active co-operation. Considering the type of partner with whom agreements are formed, we can identify three types of cooperation: horizontal (with competitors or other enterprises of the same sector), vertical (with suppliers of equipment, materials, components or software or with customers or clients) and institutional (with consultants, commercial labs, or private R&D institutes, universities or other higher education institutions, government or public research institutes, or technological centres).

PITEC[2] is a survey carried out yearly and the questions about cooperation are asked in a 3-year period. The advantage of using this database is that it allows partial control over potential endogeneity problems inherent in this kind of analysis by introducing lags in the explanatory variables.

Our sample contains information on manufacturing and services firms with at least ten employees and positive sales. The time period covered ranges from 2004 to 2012. We use an unbalanced panel

[2] This database is available to the public at http://sise.fecyt.es/

with 90,047 observations which represent about 11,791 firms for the whole period. In order to minimise potential endogeneity problems, all the explanatory variables are lagged. This results in a dataset covering 11,194 firms and 89,137 observations.

3.2 Dependent Variables

The dependent variable in the first stage is binary, indicating whether the firm has been engaged in any innovation activity during the period t-2 and t. In the second stage, the measure of innovation performance, observed at period t, is defined as the share of sales due to new or significantly improved products. In the PITEC survey the firm is asked if it has developed product innovations in the current year or in the previous two years, being they either products only new to the firm or new to the market. The firm is also asked on the economic impact of these innovations with respect to the firm's sales.[3] This is, therefore, a quantitative measure of innovation performance often used in the literature and its logarithmic transformation benefits from being closer to a normal distribution and being symmetric (Raymond et al., 2010; Robin and Schubert, 2013; Barge-Gil, 2013).

However, we also want to account for the fact that the innovation made by a firm can be of different levels of novelty. Some innovations only imply little improvements or even a product which is only new for the firm but not for the market. Whereas those innovations that are more radical, also known as breakthrough innovations, imply a novelty not only for the firm but for the market. These breakthrough innovations are really important for the growth strategy of firms and may be the line that separates the difference between being a follower or a leader in the market. Accessing external knowledge through cooperation agreements may have an important and decisive role on such type of innovations, since the firm can take advantage from different technologies and business models leading the competitors having greater difficulty in the response to such breakthrough innovations.

[3] To our knowledge, this measure reflects better the innovation performance of the enterprise than others used in previous literature. Using a dummy variable only reveals if the firm is engaged into the innovative strategy; but a deeper information is to what extend this strategy is important for the firm's success. Another possibility would be to use the information on the number of innovations patented, but as pointed out by some authors this measure captures codified knowledge and not tacit knowledge embedded on organizational/management processes and also in some cases the patented technological innovation is not developed (Phene et al. 2006).

In order to analyse if there is a differential impact of cooperation on incremental versus radical innovation we construct two new dependent variables. We proxy for incremental innovation through the share of sales due to products only new for the firm; and the proxy for radical or breakthrough innovations considers the share of sales that are due to products new to the market.

3.3 Explanatory variables

Based on previous literature, we explain the probability of being an innovator as a function of the firm size and its squared term (in order to take nonlinearities into account), market share, belonging to a group and industry dummies (Veugelers and Cassiman, 1999; Vega-Jurado et al., 2009; Raymond et al., 2010). We also allow for factors perceived as barriers to innovation activities using four Likert-type constraint variables: cost obstacles, knowledge obstacles, market obstacles, and other obstacles (see Table A1 in Appendix for a detailed description of these variables). These variables are available for both innovative and non-innovative firms. Since the innovation indicator refers to the period between t-2 and t, we defined these explanatory variables in t-2. The variables market share, belonging to a group, and the four variables related to the obstacles to innovation presented above are considered as exclusion restrictions for the second stage. They are considered in the selection model as a likely influence on the decision to carry out innovation activities, but not as determinants of innovation performance.

In the second stage, to evaluate the impact of research alliances on innovation performance, we constructed a dummy variable indicating whether the firm collaborated or not with a partner in order to develop innovation activities.

As control variables we use the proportion of internal R&D expenditures over total sales as a proxy for a firm's absorptive capacity. This measure accounts for the effort of a firm to build a stock of knowledge. Firm size is measured by the logarithm of the number of firm employees and its squared term is also included in order to consider the existence of non-linearities in this relationship. The sign for the impact of firm size is not clear a priori. According to the Schumpeterian hypothesis (Schumpeter, 1942) the size of the firm positively influences its innovative output. Large firms are more likely to have the necessary resources (infrastructure, financial resources, and production and marketing capabilities) to face the risks associated with innovation processes and hence, they are more likely than smaller firms to engage in innovative activities. While some empirical studies have supported the Schumpeterian hypothesis (Tsai, 2009; Raymond et al., 2010), this is not always the case. A number of studies have found that small firms are more innovation-intensive than larger firms. Among other reasons, this is due to a lower degree of rigidity when faced with innovations (Acs and Audretsch, 1988; Lööf, 2009; Arvanitis and Bolli, 2013).

A firm is considered a foreign-owned multinational if it has at least 50% of foreign capital and is headquartered outside Spain. Although the empirical evidence is not conclusive, previous studies suggest that the subsidiary of a foreign parent company may perform better in bringing new products to the market than a host company (Tsai, 2009). The idea is that foreign-owned firms have the advantage of accessing specific knowledge and resources of a group of firms and therefore can transfer technology at lower cost, which enables them to create new products and services in their host country more easily and enjoy a higher turnover from these innovations than a domestically owned firm (Reis, 2001; Dachs et al., 2008; Díaz-Díaz, 2008). In order to control for the experience and knowledge accumulated from past R&D, we also include a binary variable indicating whether the firm conducted internal R&D activities continuously (Permanent R&D), which is argued to have a positive influence on innovation output through learning effects (Aschhoff and Schmidt, 2008; Raymond et al., 2010; Van Beers and Zand, 2014). It is assumed that a firm that conducts R&D regularly has greater potential for detecting ideas for new products.

Further, recent literature considers that firms can better achieve and sustain innovation by adopting a diverse set of sources of information that are available and thus can be a proxy for unintentional externalities or spillovers. According to Duysters and Lokshin (2011) a greater access to external search channels allows firms to broaden the pool of technological opportunities and to draw on ideas from multiple external sources which can lead to a higher innovation performance. To measure the openness degree of a firm to these sources of information we follow a method similar to that of Laursen and Salter (2006) and Robin and Schubert (2013). We use the eight main sources of information available in the survey, each coded as a binary variable which is equal to 1 if the source was used and 0 otherwise. We exclude internal sources within the firm and university or public research institutes sources because, as in Laursen and Salter (2006) and Robin and Schubert (2013), most firms report no usage of these sources. These eight indicators are summed to construct a measure of openness which varies from 0 (no external sources used) and 8 (all external sources used); a higher value indicates a greater openness of a firm to external sources of information for innovation. However, this does not necessarily imply any formal cooperation, which in our case is measured through another set of variables. Finally, we include a demand-pull variable in the model. Following Raymond et al. (2010), we proxy it with a dummy variable that takes value 1 if at least one of the following objectives of innovation is scored as very important in the survey (where 1 is not used/not relevant and 4 is very important on a Likert scale), and 0 otherwise: extend product range, increase market or market share, and improve quality in goods and services. Most empirical studies find that firms that devote more effort to increasing demand for their products, and therefore to market expansion get higher sales of innovative products (Belderbos et al., 2004; Lööf and Broström, 2008; Raymond et al., 2010).

As control variables in the second stage we also include a set of 2-digit industry dummies. Table A1 in the Appendix provides more details on the definitions of the variables that are used in this study.

4. An overview of cooperation in innovation activities in Spain

According to Figure 1, we observe that an average of 74% of Spanish firms declare to make some innovation with a decreasing trend, more accentuated in the crisis. This share is higher in the case of firms with less than 200 employees, for which the average amounts to 78%, with 64% of large firms innovating. However, the crisis from 2009 seems to affect small firms more importantly, with the share of small firms that innovate decreasing considerable from 2010.

[Insert Figure 1 around here]

In Figure 2 we observe that around 36% of innovative firms in Spain cooperate in innovation activities, as an average of the period under consideration (2004-2012). However, this share is higher in the case of firms with more than 200 employees than in the case of SMES (less than 200 employees): 34% versus 44%, respectively. This share maintains quite stable along the expansion period under consideration (2004-2008), whereas is seems to increase in the crisis period (2009-2012). This time profile in the proportion of cooperative firms is reproduced both for small and large firms.

[Insert Figure 2 around here]

It seems, therefore, that large firms tend to innovate less than small firms (considering the share of innovative firms over total number of firms), but when they do it, they tend to cooperate more than small firms. This could be related to the fact that for small firms would find it more difficult to engage in technological alliances with other partners, be them other firms or research institutions. As for the trend in time, it seems that large firms have been able to hold innovation activities during the crisis, whereas this has not been the case of small firms. As for cooperation, the time profile, equal for small and large firms, indicate that whereas the crisis has affected the innovation rates, Spanish firms have relied in cooperation activities as a mechanism to innovate even in the crisis, with an increasing trend after 2009.

Figure 3 displays the distribution of the types of alliance by geographical areas and their temporal pattern, revealing interesting results. As commented above, about one-third of innovative firms maintained some type of research alliances, which although not negligible, implies that only a minority of firms engage in collaborative agreements as part of their innovative process. Concerning the geographical scope of such collaborative agreements, research alliances with national partners are much higher than with foreign partners. On average, more than 60% of collaborative firms maintain research alliances exclusively with national partners with a decreasing pattern from 2005. The national nature of the majority of technological partnerships is not exclusive to the Spanish case. Previous studies with similar figures include Miotti and Sachwald (2003) and Monjon and Waelbroeck (2003) for the French case, and Van Beers and Zand (2014) for Dutch firms. The second most common type of alliance is that including both national and international partners which appears to be increasing over time, ranging from 27 to above 37 percent between 2005 and 2011.

[Insert Figure 3 around here]

Going into the detail of the innovative results obtained by Spanish firms, in Figure 4 we observe the share of sales due to innovative products, which is our endogenous variable in the regressions. The average share in the period under consideration is much higher in the case of cooperative firms (31%) than in the case of non-cooperative firms (25%), a profile which is maintained along time. A test of differences in the mean between cooperative and non-cooperative firms is rejected in all years.

[Insert Figure 4 around here]

When disaggregating by firm's size, Figures 5 and 6 display that in general, small firms present higher innovative results than large firms, this being the case no matter if the firm cooperates or not. A test of differences in the mean between small and large firms is rejected, so that the differences observed between both sizes are statistically significant.

[Insert Figures 5 and 6 around here]

5. Cooperation in innovation activities in Spain in relation to the rest of European countries

The Community Innovation Survey allows to compare innovation and competiveness of firms, industries, and countries across Europe. It includes EU member states and Iceland, Norway, Croatia, Serbia and Turkey (with some exceptions across the seven waves). In here, we consider the last five waves (i.e. 2004-2012) for a most comprehensive picture, since in 2004 new member states were included in the survey.[4]

[4] We consider the following core innovative sectors for 2004-2006: Mining and Quarrying; Manufacturing; Electricity, gas, water supply; Transport, storage and communication; Financial Intermediation; Wholesale trade and commission trade, except of motor vehicles and motorcycles; Computer and related activities; Architectural and engineering activities and related technical consultancy; Technical testing and analysis. For 2008-2012: Mining and Quarrying; Manufacturing; Electricity, gas, steam and air conditioning supply; Water supply, sewerage, waste management and remediation activities; Wholesale trade, except of motor vehicles and motorcycles; Transportation and storage;

In the period considered, more than 700,000 companies participated in the survey each year; of these, about one-third declared to have undertook innovation activities[5]. Countries differ significantly in terms of the innovation behaviour of their firms. Figure 7 shows the share of innovative enterprises on total enterprises by country and wave, ordered by the average shares over the four waves. The average share of innovative firms ranges from the highest one of Germany (64%) to the lowest one of Romania (16%). Spain occupies the second half of the ranking, with an average share of innovative firms of 30%. Such variety is pervasive also in terms of the trend across the years. In particular, Spain shows a decreasing pattern; in 2004, the share of innovative firms is 35%, while in the last wave drops to 23%. Similar declining trends are shown by Poland and Estonia, while Malta is the only country with increasing shares; the remaining countries exhibit more fluctuating trends over the years.

[Insert Figure 7 around here]

R&D cooperation among EU countries concerns about one-quarter of innovative firms (average on the four waves). Figure 8 shows the shares of cooperative innovative firms by country and wave. The country ranking lowest is Italy (13%), while Cyprus is the country with the highest share (54%). In the last two waves, the percentage of cooperative innovative firms of EU members increase from 25% in 2010 to 31% in 2012. Spain collocates among the bottom rows with an average share of 21%. Spain is among the countries which significantly increase the share of cooperative innovative firms in the latest years, from 22% in 2010 to 29% in 2012; similarly, Belgium increases its share from 42% in 2010 to 52% in 2012, while other countries experience a decline instead, such as for example Luxembourg (from 32% in 2010 to 20% in 2012). However, likewise the statistics on the share of innovative firms discussed above, the shares of cooperative innovative firms for each country tend to fluctuate over time. In the case of Spain, the combination of a decrease in the share of innovative firms as discussed above and an increase of the share of cooperative innovative firms signal a possible reinforcement of the links between technological

Publishing activities, Telecommunications, Computer programming, consultancy and related activities, Information service activities; Financial and insurance activities; Architectural and engineering activities; technical testing and analysis.

[5] Innovative firms are those which have product or/and process innovation, regardless of organisational or marketing innovation, including enterprises with abandoned/suspended or on-going innovation activities.

cooperation and innovativeness, meaning that the firms which manage to be innovative are also cooperating to a significant extent.

[Insert Figure 8 around here]

Firms rely on both internal and external sources of knowledge to sustain their competitive advantage. With respect to R&D expenditures, the Community Innovation Survey provides data for in-house R&D and external R&D (i.e. R&D contracted out to other enterprises or research organisations). Figure 9 shows the shares of innovative firms with internal and external R&D by country, averaged on the period 2004-2012. Firms from EU-28 countries which are engaged in internal R&D constitute 39% of innovative firms, while only 18% of innovative firms carry out external R&D. For internal R&D, Bulgaria has the lowest share (11%), while Finland ranks at the top (77%). In terms of external R&D, the lowest share belongs to Malta (6%), while Finland has the highest one (32%). Spain stays in the bottom-half of the ranking, both in terms of internal R&D (35%) and external R&D (19%), although the latter is slightly higher than EU-28 average.

[Insert Figure 9 about here]

By looking at the trends over the period 2004-2012, the shares of innovative firms with internal R&D in Spain vary across time as shown in Figure 10, with the highest figure registered in 2012 (41%), about two percentage-points above EU-28 countries in the same year. About the trends of external R&D showed in Fig. 5, Spain experiences a lower point in 2004, and then a steady increase until 2012, where the percentage of innovative firms with external R&D reaches the same level as in 2004. The increase of both internal and external R&D in the latest years suggests an intensification of the linkage between R&D expenditures and innovation for Spanish firms; if we consider the decreasing trend of the share of innovative firms in the period considered, this suggests that for the firms which manage to stay (or start to be) innovative, R&D remains an important source of knowledge.

[Insert Figures 10 and 11 around here]

6. Results

6.1 Cooperation and Innovation performance

The first step in our empirical model is to estimate the selection equation (the propensity to innovate) for each year. From the estimation of these probit models we obtain the correction terms (the inverse Mill's ratio) which are included in the second stage, focused on the study of the impact of technological cooperation on the firms' innovative performance. Here the correction terms are included to account for the selection bias caused by the fact that we only observe the sales share of innovative products for firm that innovate. Through all the results presented below we perform two Wald tests: one on the joint significance of the six selection effects involved $(H_0 : \rho_{2006} = 0, ..., \rho_{2011} = 0)$ which can be interpreted as a test of selection bias; and the other for the joint significance of the coefficients on the within-individual means to check for the existence of correlated individual effects $(\mathrm{H}_0 : \psi = 0)$. The values for these test statistics are significantly different from zero which points to the necessity of correcting for sample selection bias and suggesting the presence of correlated effects.

Table 1 shows the results for different specifications of our main model of innovation performance. Column 1 contains the control variables plus the cooperation variable. As can be seen, technological collaborations are found to be positive and statistically significant, pointing to a positive benefit from cooperation with firms or institutions. Our results conclude that firms maintaining research collaborations with partners have a higher share of innovative sales if compared with those not carrying out cooperation agreements.

[Insert Table 1 around here]

As for the control variables, we observe that R&D expenses exert a significant and positive impact on innovation performance, a finding in line with the absorptive capacity literature, where it is argued that R&D expenditures stimulate firm's innovation output. Also, our results indicate a negative and non-linear relationship between firm size and innovation performance. This finding is in consonance with other studies where the intensity of innovation is negatively related to size; probably once the firm has decided to innovate, small firms tend to benefit more from their innovations and experience greater impact on their sales. This can also be explained because innovative sales increase with the firm's size, that is, with additional employees, but less than the total sales of the firm (Lööf, 2009; Vega-Jurado et al., 2009; Arvanitis et al., 2013). Also, the variable capturing the experience and knowledge accumulated from past R&D (Permanent R&D) has the expected positive sign. Thus, firms that undertook R&D continuously reach a larger share of innovative sales through learning mechanisms. In line with previous studies, the degree of openness of the firm and the demand pull indicator are positively associated with the intensity of product innovation (Belderbos et al., 2004; Duysters and Lokshin, 2011). In addition, we find that the variable capturing the foreign multinational nature of the firm is not significant, leading to the conclusion that foreign-owned firms are not necessarily different from their domestic counterparts when it comes to innovation output (in line with the results in Tsai, 2009 and Arvanitis and Bolli, 2013).

As stated in the introductory section, one main concern in this research is to disentangle until which degree the acquisition of technologically external knowledge through cooperation in innovation activities can affect the degree of novelty of the innovation made by the firm. Indeed, the new products obtained by a firm thanks to its innovation strategy can be associated with existing products/services that have been improved, but also products that are completely new to the market. The latter can be understood as a novel and unique technological advance in a product category that significantly alters the consumption patterns in a market (Zheng and Bingxin, 2012). This completely new product can generate a new platform or business domain which could imply new benefits and the expansion into new markets (O'Connor et al. 2008).

With this objective in mind, in columns 2 and 3 of Table 1 we consider two different endogenous variables: that proxying for incremental and radical innovations, respectively. As it can be observed, cooperation agreements have a significant and positive impact on radical innovations, whereas the parameter is not significant in the case of incremental innovations.

Among the reasons behind these results, we may think that cooperation in innovation can be understood as a way of accessing to knowledge sources external to the firm and even from abroad. As the enterprises moved geographically outside the national boundaries of the firm for the acquisition of new technologies (cooperation agreements with national and international partners simultaneously increased considerably from 2004 to 2012 as observed in Figure 3), it is feasible to take advantages of different national innovation systems which can be associated with differences in culture, market regulations, organizational managements or preferences that could lead not just to an improvement in the adaption of existing products but also to the creation of new ones. It is clear that going further in the internationalization of the acquisition of knowledge has an incorporated cost, since wider differences in organizational and internal capabilities lead to a more difficult understanding of the foreign knowledge. However, the acquisition of a foreign and different knowledge in conjunction with the internal R&D capabilities can lead to increase the likelihood of discovering a new idea in a highly technological field leading to radical innovations. The idea is that when the firm associates with foreign enterprises that belong to a different national innovation system, the knowledge that can be acquired may have a stronger novelty degree, so that the likelihood that it ends up in the development of a product completely new can be higher. As a consequence, the impact of acquiring knowledge from external sources through cooperation alliances would be higher for radical innovations than for incremental innovations.

6.2 Variability in the impact of cooperation according to firms' size and the crisis

The variability of the impact of cooperation agreements on innovation performance can also be studied from the viewpoint of the firm's size. Going a step further, we now want to disentangle if the impact of cooperation is different for small and large firms. As observed in Table 2, the impact of cooperation is much clearer in the case of large firms, where technological alliances have a significant effect on the generation of both incremental and radical, although the latter is higher. For small firms, cooperation in innovative activities only presents a significant impact on radical innovations.

[Insert Table 2 around here]

Finally, another interesting research point is to disentangle how the economic crisis of 2008 is affecting the innovation performance taking into account the impact of R&D cooperation. In the Spanish case this is very relevant due to the strong impact of the crisis and the difficulty in obtaining funding for innovation. Indeed, according to the INE (National Institute of Statistics in Spain) the rate of success of the enterprises obtaining funding for their innovation projects was 80% in 2007 and 50% in 2010, while the perception on the evolution of the relative access to funding between 2007 and 2010, only 1.1% answered it was better whereas 33.6% said it was worse.

It is a fact that the crisis has affected many firms that had to exit the market. However, as far as we know, nothing has been done about the effect of R&D cooperation on innovation performance in the crisis period, neither for Spain nor for other international contexts. As offered in the descriptive part, the crisis has not implied a decrease in the amount of innovative cooperation done is Spain as a consequence of the reduction in funding for innovation projects, but on the contrary, cooperation activities have experienced an increase in the crisis. Therefore, we now plan to provide evidence on whether the impact of the strategy of acquiring foreign R&D had a lower or a greater impact on the innovation performance during the crisis period.

Initially, one would expect that in a crisis period, with lower funding levels, firms would be more cautious with the resources they spend in new innovation projects and try to choose those with higher chances of success. In such a case, the return obtained from cooperation strategies would be higher. As observed in Table 3, the impact of cooperation does not seem to differ before and during the crisis, being significantly positive in both cases, although of a slightly higher value in the crisis period, which could be related to the argument raised before. More specifically, the general pattern of cooperation in innovation activities having a clear positive impact on radical innovations and not on incremental innovations is maintained in both periods.

[Insert Table 3 around here]

Table 4 presents the results when the collaboration variable is differentiated between collaboration with partners located in the firm's home country compared with partners abroad. As can be seen, collaborations exclusively with national partners and those exclusively with international partners are found to be positive and statistically significant, pointing to a positive benefit from cooperation with external firms or institutions. Moreover, our results conclude that firms maintaining research collaborations with partners abroad increase the share of innovative sales more than those that collaborate only with partners located in the same geographical area. This can be explained by the fact that collaboration with partners abroad can improve access to new or complementary technologies and resources that provide less redundant pieces of knowledge, which would allow enhancing innovation. This is also consistent with two theoretical expectations: first, partners abroad are embedded in different national innovation systems than partners in the local market and therefore such international collaboration would allow firms to have access to complementary knowledge that is in short supply in their home region (Miotti and Sachwald, 2003); second, a firm maintaining collaborations with partners in remote countries is probably exposed to the needs of characteristic foreign markets and may therefore extend the scope of its accessible knowledge base (Lavie and Miller, 2008). With respect to the impact on incremental and radical innovation, it must be said that the same pattern observed in the tables above is reproduced. The impact is clearly significant in the case of breakthrough innovations, but not for incremental.

[Insert Table 4 around here]

7. Conclusions

Cooperation in innovation activities may enable innovating firms to acquire information from a variety of sources which could lead to more synergies and intake of complementary knowledge, thus promoting innovation performance (Belderbos et al., 2006; Laursen and Salter, 2006; Nieto and Santamaría, 2007; Van Beers and Zand, 2014). The present piece of research contributes to this literature. In particular, we focus on the Spanish case and try to disentangle to what extent the impact of technological cooperation may differ according to the firm’s size, the context of the great recession as well as the geographical scope of the cooperation networks. In addition, we also study to what extent innovation cooperation may have a different effect on incremental innovations than on radical/breakthrough innovations.

The results point to a significant and positive impact of cooperative alliances in the Spanish case, with a return that is very similar in expansion and recession periods. With respect to the size of the firms, it seems that large firms obtain a clearer impact from cooperation agreements. This is so specifically because large firms do not only benefit from technological cooperation in order to develop new products both for the firm and also for the market. Whereas innovative cooperation only benefit small firms in terms of obtaining new product for the market (radical innovation) but not when they are only incremental innovation (only new for the firm). Finally, it seems that cooperating with partners abroad allow for a higher impact than when the partners are within the borders of the country where the firm is installed.

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Table 1. Effect of innovation cooperation on innovative performance

	(1)	(2)	(3)
	Innovation	Incremental innovation	Radical Innovation
Cooperation	0.192***	-0.001	0.449***
	(0.060)	(0.058)	(0.047)
RD	1.094***	0.022	0.899***
	(0.151)	(0.110)	(0.139)
Size	-0.226**	0.434***	-0.556***
	(0.096)	(0.078)	(0.090)
Size^2	0.015	-0.042***	0.056***
	(0.010)	(0.008)	(0.009)
Permanent R&D	0.345***	0.123	0.315***
	(0.114)	(0.105)	(0.088)
Foreign Multinational	0.139	-0.001	0.072
	(0.234)	(0.224)	(0.190)
Openness	0.076***	0.108***	0.072***
	(0.016)	(0.013)	(0.011)
Demand pull	0.493***	0.209**	0.279***
	(0.095)	(0.091)	(0.074)
Constant	-4.703***	-6.876***	-8.025***
	(0.318)	(0.260)	(0.261)
Industry dummies	Yes	Yes	Yes
Inverse Mills ratios	Yes	Yes	Yes
Means-fixed effects	Yes	Yes	Yes
Observations	34,572	34,572	34,572
R-squared	0.071	0.037	0.094

Bootstrapped standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 2. Effect of cooperation. Small and large firms

	SMALL FIRMS			LARGE FIRMS		
	Innovation	Incremental innovation	Radical Innovation	Innovation	Incremental innovation	Radical Innovation
Cooperation	0.084	-0.103*	0.461***	0.442***	0.255**	0.359***
	(0.076)	(0.062)	(0.061)	(0.128)	(0.118)	(0.104)
RD	1.114***	0.055	0.866***	1.196*	0.156	1.051
	(0.145)	(0.125)	(0.125)	(0.639)	(0.501)	(0.674)
Size	0.170	0.755***	-0.282*	-1.084*	0.284	-1.052**
	(0.187)	(0.141)	(0.151)	(0.612)	(0.560)	(0.485)
Size^2	-0.039	-0.085***	0.013	0.081*	-0.027	0.096***
	(0.027)	(0.021)	(0.021)	(0.044)	(0.040)	(0.034)
Permanent R&D	0.336***	0.097	0.329***	0.353	0.218	0.245
	(0.130)	(0.106)	(0.111)	(0.280)	(0.254)	(0.198)
Foreign Multinational	0.066	-0.130	0.020	0.241	0.113	0.176
	(0.327)	(0.295)	(0.299)	(0.314)	(0.305)	(0.252)
Openness	0.081***	0.106***	0.070***	0.066**	0.116***	0.077***
	(0.017)	(0.015)	(0.014)	(0.029)	(0.027)	(0.021)
Demand pull	0.535***	0.137	0.345***	0.307	0.435**	0.045
	(0.122)	(0.109)	(0.100)	(0.195)	(0.182)	(0.162)
Constant	-5.399***	-7.442***	-8.547***	-1.848	-6.508***	-6.031***
	(0.392)	(0.287)	(0.327)	(2.126)	(1.962)	(1.674)
Observations	26,571	26,571	26,571	8,001	8,001	8,001
R-squared	0.065	0.035	0.090	0.112	0.075	0.130

Bootstrapped standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Industry dummies, Inverse Mills ratios and mean-fixed effects included.

Table 3. Effect of cooperation. Pre-crisis and crisis periods.

	PRE-CRISIS			CRISIS		
	Innovation	Incremental innovation	Radical Innovation	Innovation	Incremental innovation	Radical Innovation
Cooperation	0.185*	0.003	0.421***	0.206**	-0.006	0.484***
	(0.101)	(0.092)	(0.078)	(0.087)	(0.076)	(0.079)
RD	1.100***	0.130	0.726***	1.089***	-0.075	1.057***
	(0.206)	(0.162)	(0.188)	(0.191)	(0.168)	(0.173)
Size	-0.317**	0.364***	-0.570***	-0.102	0.562***	-0.559***
	(0.132)	(0.101)	(0.110)	(0.135)	(0.100)	(0.112)
Size^2	0.021	-0.041***	0.059***	0.007	-0.048***	0.056***
	(0.014)	(0.011)	(0.012)	(0.013)	(0.010)	(0.011)
Permanent R&D	0.426**	0.069	0.363***	0.243	0.161	0.255*
	(0.169)	(0.159)	(0.138)	(0.175)	(0.162)	(0.137)
Foreign Multinational	-0.648**	-0.713**	-0.143	0.790**	0.603*	0.230
	(0.322)	(0.335)	(0.269)	(0.349)	(0.318)	(0.268)
Openness	0.075***	0.113***	0.063***	0.081***	0.108***	0.080***
	(0.022)	(0.019)	(0.016)	(0.021)	(0.020)	(0.017)
Demand pull	0.543***	0.210	0.424***	0.443***	0.203	0.138
	(0.153)	(0.133)	(0.127)	(0.150)	(0.147)	(0.122)
Constant	-4.531***	-6.543***	-8.122***	-5.097***	-7.467***	-7.894***
	(0.392)	(0.357)	(0.309)	(0.475)	(0.379)	(0.397)
Observations	16,492	16,492	16,492	18,080	18,080	18,080
R-squared	0.074	0.036	0.095	0.072	0.043	0.097

Bootstrapped standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Industry dummies, Inverse Mills ratios and mean-fixed effects included.

Table 4. Effect of cooperation for different geographical scopes

	(1) Innovation	(2) Incremental innovation	(3) Radical innovation
National collaboration	0.224***	-0.021	0.387***
	(0.071)	(0.068)	(0.059)
International collaboration	1.199***	0.214	1.107***
	(0.222)	(0.199)	(0.183)
Multiple collaboration	0.544***	0.272***	1.010***
	(0.104)	(0.085)	(0.079)
RD	1.047***	-0.013	0.827***
	(0.152)	(0.113)	(0.134)
Size	-0.231**	0.425***	-0.576***
	(0.096)	(0.076)	(0.090)
Size^2	0.014	-0.042***	0.055***
	(0.010)	(0.008)	(0.009)
Permanent R&D	0.346***	0.122	0.321***
	(0.115)	(0.109)	(0.088)
Foreign Multinational	0.150	-0.009	0.066
	(0.238)	(0.231)	(0.173)
Openness	0.071***	0.104***	0.065***
	(0.017)	(0.014)	(0.011)
Demand pull	0.500***	0.206**	0.300***
	(0.097)	(0.094)	(0.074)
Constant	-4.667***	-6.817***	-7.895***
	(0.328)	(0.266)	(0.254)
Industry dummies	Yes	Yes	Yes
Inverse Mills ratios	Yes	Yes	Yes
Means-fixed effects	Yes	Yes	Yes
Observations	34,572	34,572	34,572
R-squared	0.072	0.038	0.097

Bootstrapped standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Figure 1. Share of innovative firms over total firms in the sample

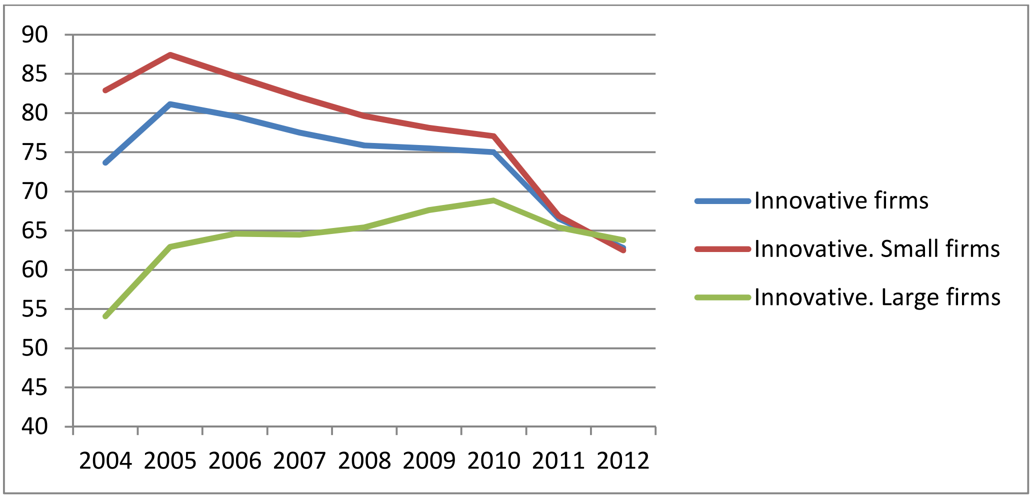


Figure 2. Share of cooperative firms over innovative firms in the sample

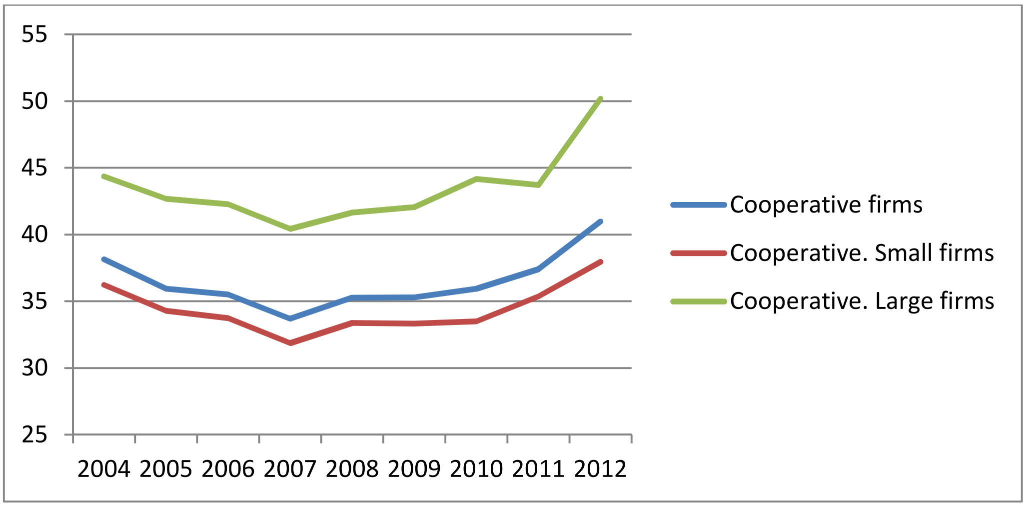


Figure 3. Share of cooperative firms by type of geographical scope of the alliance

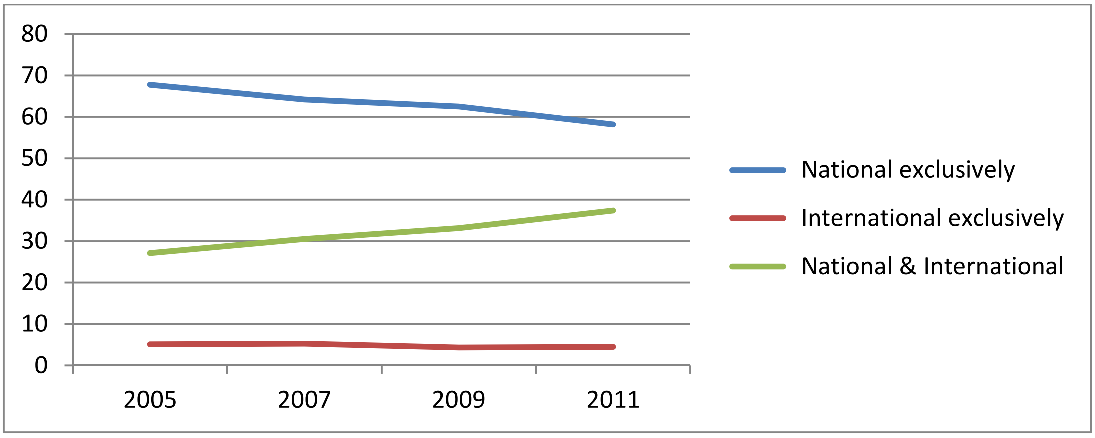


Figure 4. Share of sales due to innovative products

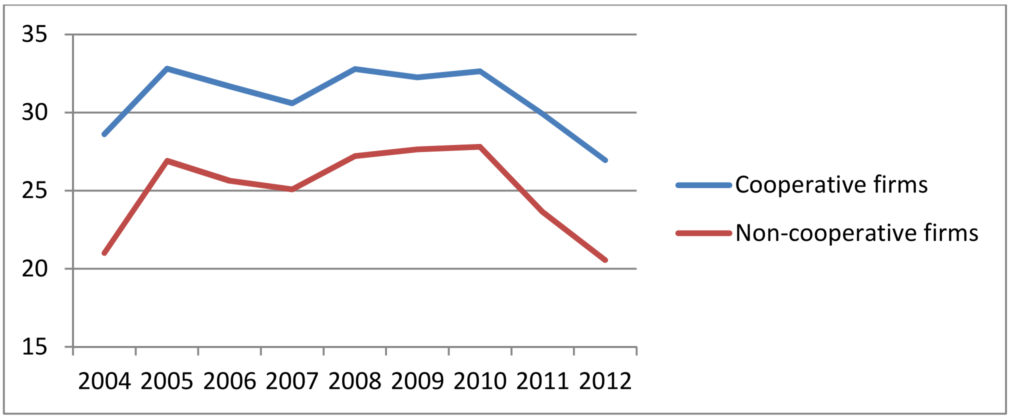


Figure 5. Share of sales due to innovative products. Cooperative firms by firm's size

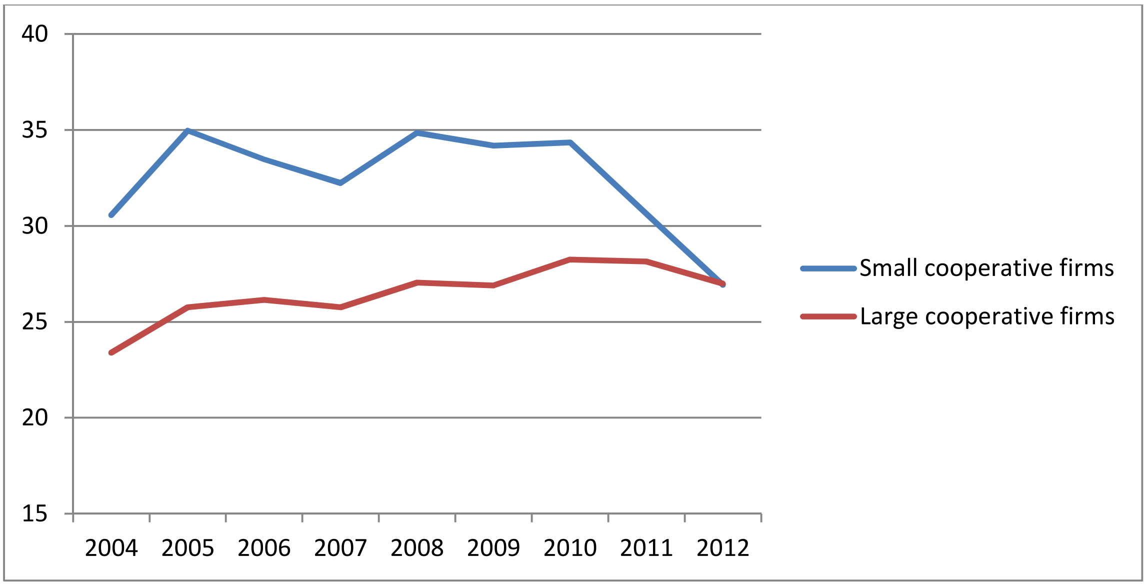


Figure 6. Share of sales due to innovative products. Non-cooperative firms by firm's size

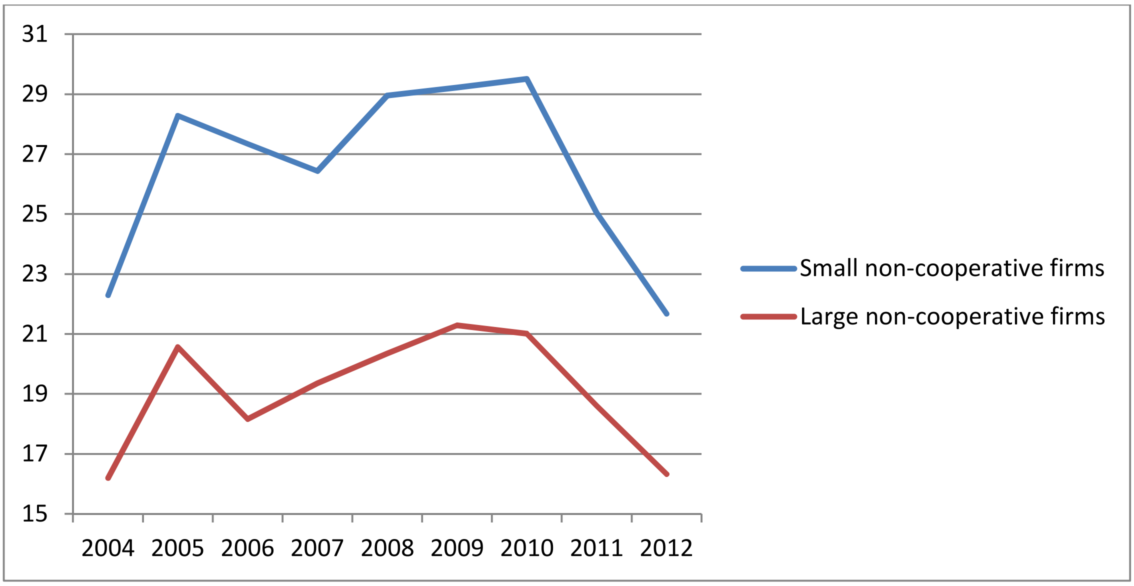
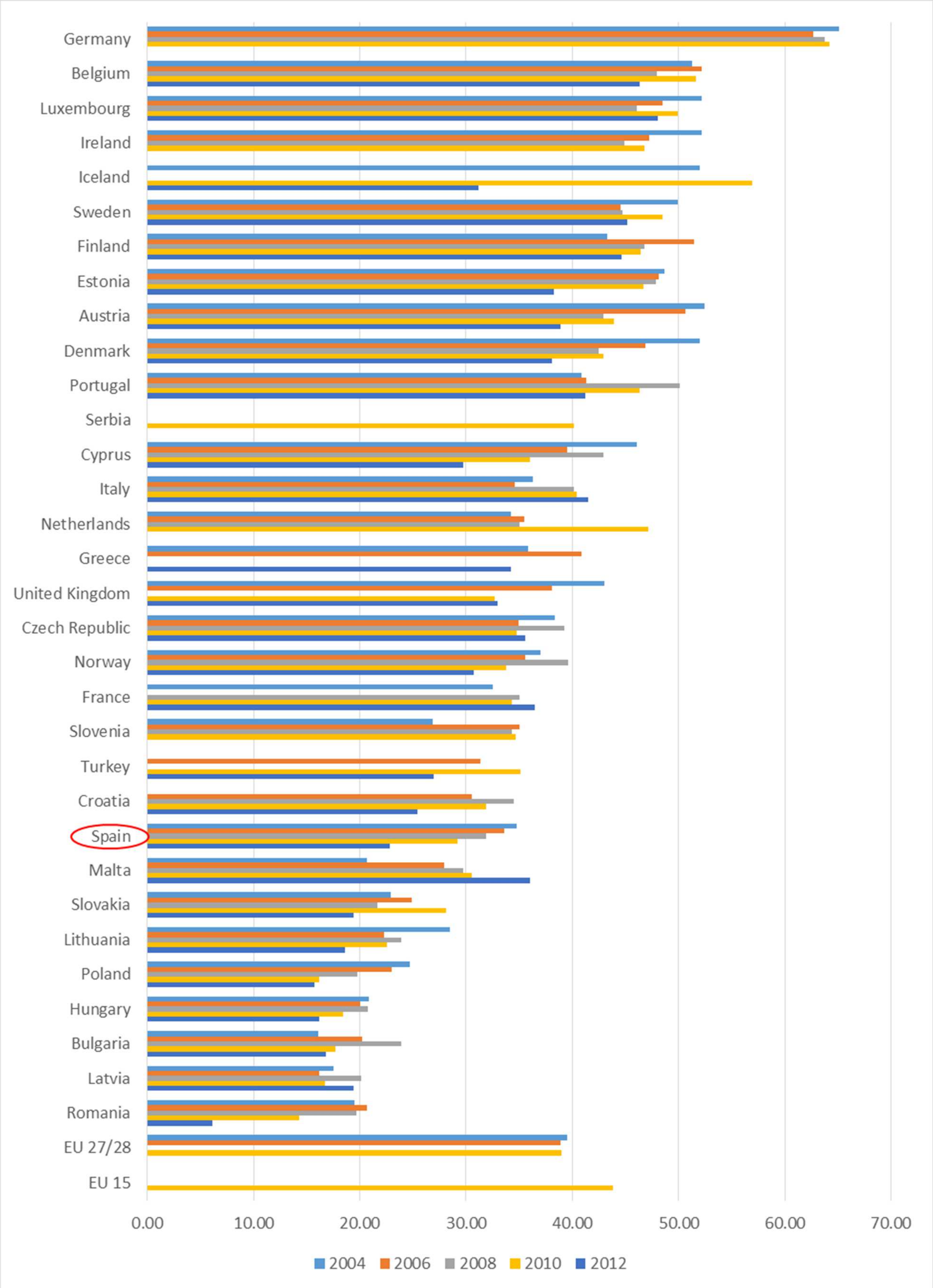
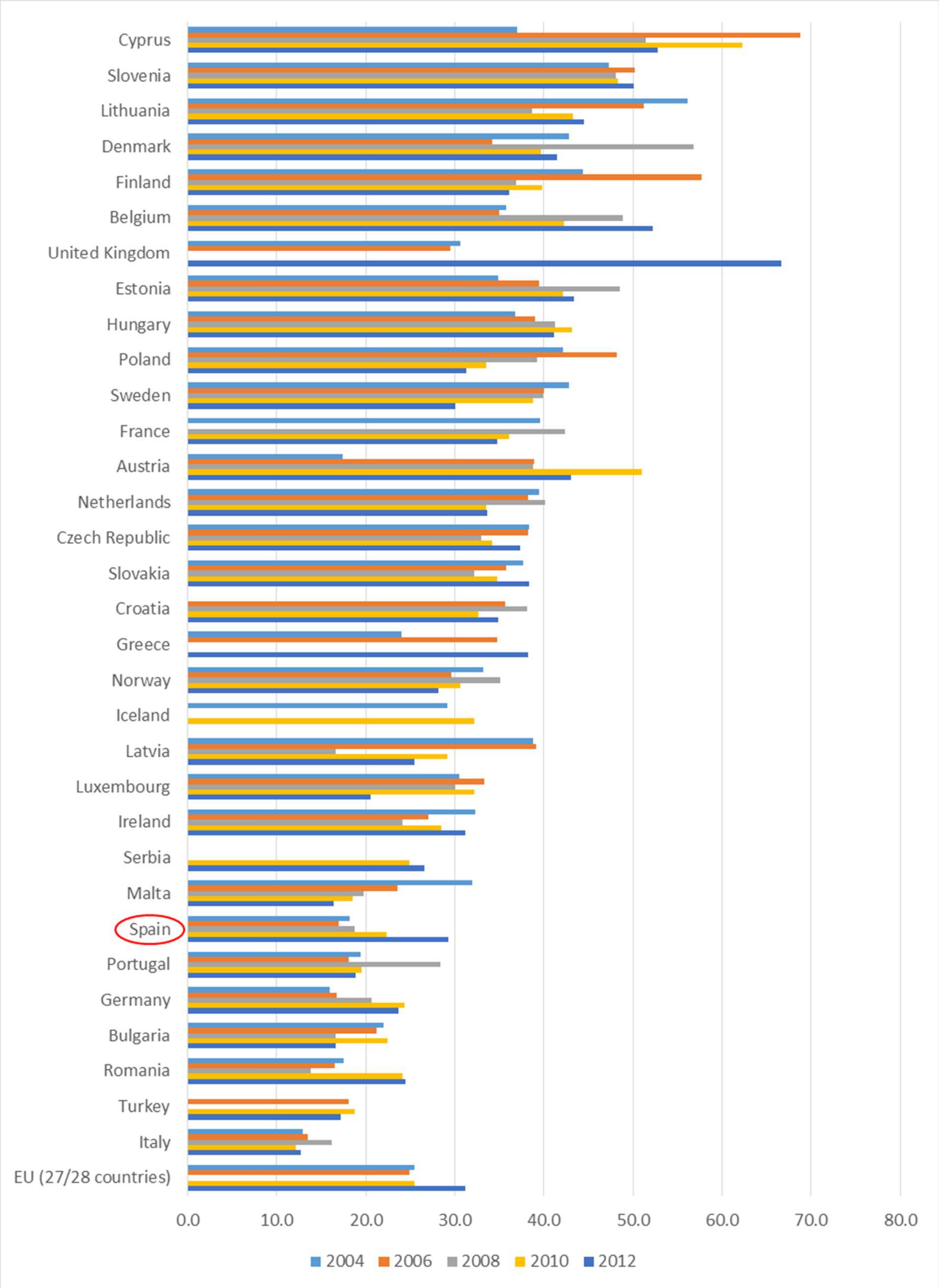


Figure 7. Share of innovative firms on total firms



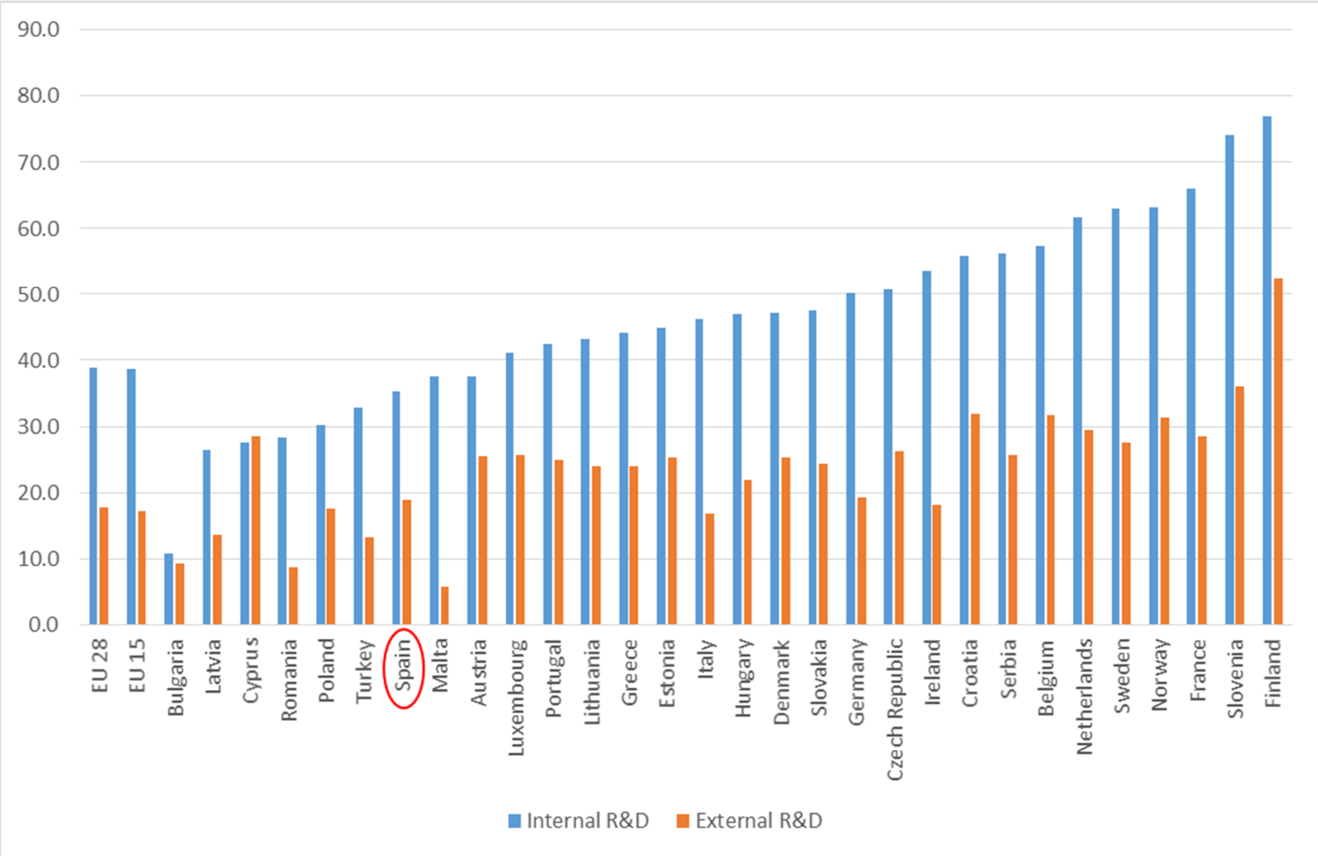
Source: EUROSTAT, Community Innovation Survey

Figure 8. Share of innovative firms with any type of cooperation



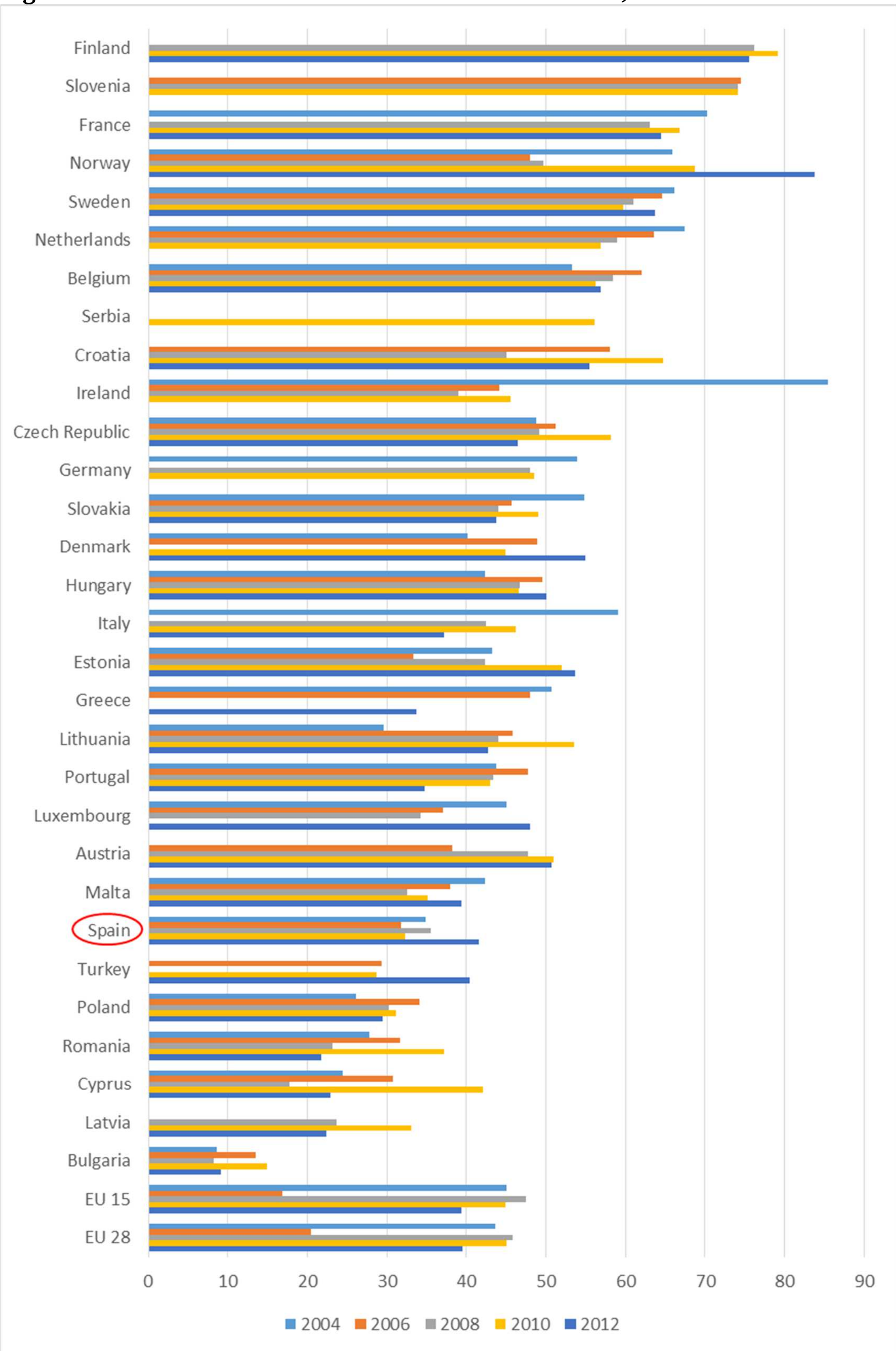
Source: EUROSTAT, Community Innovation Survey

Figure 9. Average shares of innovative firms with internal and external R&D, 2004-2012



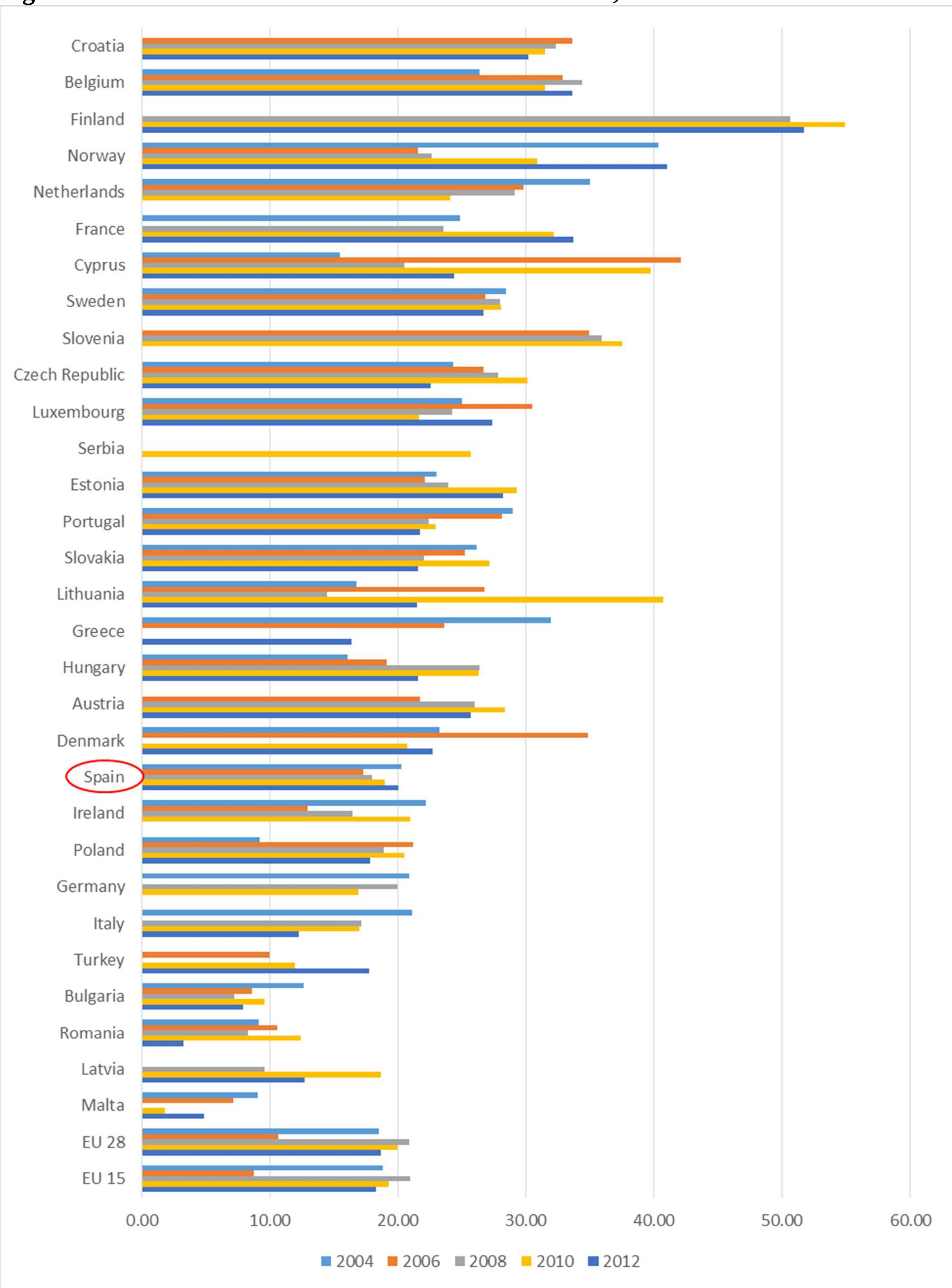
Source: EUROSTAT, Community Innovation Survey

Figure 10. Share of innovative firms with internal R&D, 2004-2012



Source: EUROSTAT, Community Innovation Survey

Figure 11. Share of innovative firms with external R&D, 2004-2012



Source: EUROSTAT, Community Innovation Survey

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

Variables	Definitions
Dependent	
Innovation	1 if the firm develop or introduced new or improved products or processes into the market; 0 otherwise
Innovation sales	Sales share of new or significantly improved products (log[new sales/(1-new sales)])
Independent	
RD	Ratio between intramural R&D expenditure and turnover
Size	Logarithm of number of employees (and its squared term)
Permanent R&D	1 if the firm reported that it performed internal R&D continuously; 0 otherwise
Foreign multinational	1 if the headquarter of the firm is outside Spain and it has at least a 50% of foreign capital; 0 otherwise
Openness	Number of information sources for innovations that a firm reported it had used (from within the firm or group, suppliers, clients, competitors, private R&D institutions, conferences, scientific reviews or professional associations)
Demand pull	1 if at least one of the following demand-enhancing objectives for the firm's innovations is given the highest score [number between 1 (not important) and 4 (very important)]; 0 otherwise: extend product range; increase market or market share; improve quality in goods and services
National	1 if the firm reported engagement in collaborative agreements exclusively with partners located in Spain; 0 otherwise
International	1 if the firm reported engagement in collaborative agreements exclusively with partners located outside Spain; 0 otherwise
Multiple areas	1 if the firm reported engagement in collaborative agreements with partners located in more than one area; 0 otherwise
Cost obstacles	Sum of the scores of importance that the firm attributed [number between 1 (not important) and 4 (very important)] to the following factors that hampered its innovation activities: lack of funds within the enterprise or enterprise group; lack of finance from sources outside the enterprise; innovation costs too high. Rescaled from 0 (unimportant) to 1 (crucial)
Knowledge obstacles	Sum of the scores of importance that the firm attributed [number between 1 (not important) and 4 (very important)] to the following factors that hampered its innovation activities: lack of qualified personnel; lack of information on technology; lack of information on markets; difficulty in finding cooperation partners for innovation. Rescaled from 0 (unimportant) to 1 (crucial)
Market obstacles	Sum of the scores of importance that the firm attributed [number between 1 (not important) and 4 (very important)] to the following factors that hampered its innovation activities: markets dominated by established enterprises; uncertain demand for innovative goods or services. Rescaled from 0 (unimportant) to 1 (crucial)
Other obstacles	Sum of the scores of importance that the firm attributed [number between 1 (not important) and 4 (very important)] to the following factors that hampered its innovation activities: not necessary due to previous innovations; not necessary due to the absence of demand. Rescaled from 0 (unimportant) to 1 (crucial)
Market share	Ratio of the sales of a firm over the total sales of the two-digit industry it belongs to
Belonging to a group	1 if the firm belongs to a group of enterprises; 0 otherwise

Table A2. Estimates of the first stage: selection equations

	(2006)	(2007)	(2008)	(2009)	(2010)	(2011)	(2012)
VARIABLES	ginnova	ginnova	ginnova	ginnova	ginnova	ginnova	ginnova
Size	-0.019	0.101***	0.191***	0.314***	0.334***	0.312***	0.394***
Size	(0.042)	(0.037)	(0.036)	(0.037)	(0.037)	(0.036)	(0.036)
	0.008*	-0.007*	-0.012***	-0.021***	-0.022***	-0.017***	-0.026***
Size^2	(0.005)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
	0.130**	0.310***	0.315***	0.325***	0.241***	0.155***	0.193***
Cost obstacles	(0.062)	(0.055)	(0.055)	(0.057)	(0.057)	(0.057)	(0.058)
	0.422***	0.303***	0.226***	0.279***	0.331***	0.357***	0.385***
Market obstacles	(0.064)	(0.056)	(0.056)	(0.059)	(0.059)	(0.059)	(0.061)
	0.370***	0.314***	0.459***	0.524***	0.384***	0.508***	0.454***
Knowledge obstacles	(0.083)	(0.073)	(0.073)	(0.074)	(0.075)	(0.075)	(0.077)
	-1.136***	-1.050***	-1.070***	-1.090***	-1.249***	-1.198***	-1.157***
Other obstacles	(0.057)	(0.052)	(0.052)	(0.053)	(0.054)	(0.055)	(0.057)
	0.383	3.120***	6.282***	6.631***	5.577***	3.606***	4.843***
Market share	(0.864)	(0.999)	(1.127)	(1.138)	(1.125)	(0.918)	(1.009)
	0.106***	0.129***	0.144***	0.062*	0.107***	0.129***	0.140***
Belonging to a group	(0.036)	(0.034)	(0.033)	(0.033)	(0.034)	(0.034)	(0.035)
	0.189*	-0.039	-0.430***	-0.968***	-0.996***	-1.093***	-1.424***
Constant	(0.111)	(0.097)	(0.097)	(0.099)	(0.101)	(0.099)	(0.100)
Pseudo R-squared	0.205	0.171	0.169	0.176	0.187	0.180	0.192
Log likelihood	-4537.64	-5545.90	-5665.69	-5408.38	-5249.43	-5110.79	-4847.01
Observations	8,653	10,258	10,171	9,669	9,397	9,015	8,662

Bootstrapped standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

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