The regional environment and firms' commitment to innovation: Empirical evidence from Spain*

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Abstract:

Using panel data for Spanish firms, this paper examines the role of firms' regional knowledge environment for commitment to innovation of innovation active firms. The empirical results show that a stronger regional knowledge environment increases the likelihood that an innovator engages continuously in R&D as opposed to occasionally. This positive relationship with the regional knowledge environment is robust and significant in manufacturing and specifically for small firms and for technology intensive firms.

Keywords: Innovation, commitment, continuous innovation, regions.
JEL: O31, R1, D22

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1. Introduction

It is widely recognized that innovation has become the key to competitiveness and future growth. The literature has shown that companies that innovate tend to be more productive, to grow faster and to be more competitive in the long-run (Geroski et al. 1993; Hall and Bagchi-Sen 2002; Mohnen and Hall 2013; Morris 2018). Yet the commitment of firms to innovation can vary; while some carry out innovation activities on an occasional basis, others show continuous commitment to innovation. There is also some evidence that consistent innovators are contributing the bigger share to total patents (Malerba and Orsenigo 1999), have the higher productivity growth rates (Cefis and Ciccarelli 2005; Johansson and Lööf 2010), and have also been more resilient during the 2008 economic crisis (Cruz-Castro et al. 2018).

At the same time, innovation is also highly unevenly distributed across regions. There are many studies that have documented the concentration of innovation in specific regions (for reviews of this literature, see, for example, Audretsch and Feldmann 2004; Carlino and Kerr 2015) and how the regional environment affects the probability to innovate (see, for example, Sternberg and Arndt, 2001; Beugelsdijk 2007; Johansson and Lööf 2008; Antonelli and Colombelli 2015; López-Bazo and Motellón 2018). However, to date there exists still relatively little knowledge on how the firms' external environment affects commitment to innovation, i.e. whether firms engage only occasionally or continuously in innovation. From a regional economic perspective innovation commitment is a key issue for both policy makers and researchers, as the presence of continuous innovators can also be regarded as essential for the long-run competitiveness of regions. An important question for a better understanding of the spatial dynamics of innovation is therefore how the characteristics of the local environment influence the firms' commitment to innovation.

In this paper I use firm level data from the Spanish Technological Innovation Panel (PITEC) for the years 2004-2014. This data set provides information on the commitment to innovation of innovation active firms by distinguishing them into occasional and continuous innovators, where continuous refers to having permanent R&D staff while occasional refers to non-permanent R&D activities carried out as needed in a given year.

Since commitment to innovation is of great relevance, there is also a closely related literature that has analyzed the determinants of persistence in innovation, looking both at persistence in innovation inputs and innovation outputs (see, for example, Geroski et al. 1997; Cefis and Orsenigo 2001; Peters 2009; Martínez-Ros and Labeaga 2009; Raymond et al. 2010; Antonelli et al. 2012; Le Bas and Scellato 2014, amongst others). This literature on innovation persistence has provided valuable insights on how innovation activities in one period influence the probability of innovating in the subsequent period. Other studies have focused on the factors related to the duration of innovation spells (Geroski et al. 1997; Triguero et al. 2014; Máñez et al. 2015).

The present paper differs from this literature in two main respects: first, it focuses on innovation active firms and explores their self-declared degree of commitment to innovation as reported by occasional and persistent R&D effort. This differs from most studies in the innovation persistence literature. Studies that have investigated persistence in innovation have generally identified innovating firms as those having any amount of non-zero innovation- or R&D expenditure in a given year. These studies focus on the probability of being innovative and the differences between innovation performers versus non-performers. They generally have not considered the amount or relevance of the innovation activities carried out by the performer group. In contrast, here I focus on this latter group. Innovating firms that have only sporadically carried out innovation activities in a given year are distinguished from those that engaged in innovation in a continuous way in a given year. Thus, this paper is about the innovation strategies of innovation active firms.

Secondly, the paper focuses on the role of the regional environment for commitment to innovation; a factor that has hardly been addressed in the related literature. The regional innovation environment is proxied by the regional share of business expenditure in R&D (BERD) as percentage of GDP. BERD intensity is a widely used indicator to compare regional R&D performance. Strong regional innovation systems are characterized with a strong business sector. The business sector R&D engagement can provide an important external knowledge source for firms.

The greater possibility and greater ease to access external R&D services in strong and dynamic innovation environments could particularly benefit occasional innovators as it facilitates using external services when needed instead of having to incur in the fixed costs of running an internal R&D department.[1] On the other hand, greater commitment to innovation leads to a stronger internal knowledge base which is an important facilitator for

[1] I would like to thank on of the anonymous referees for drawing attention to this point.

accessing and assimilating new external knowledge and technology. It generates greater absorptive capacity which means a greater ability to learn from the environment (Cohen and Levinthal 1990). This suggests complementarity between external and internal R&D activities (Cassiman and Veugelers 2006). In this context, Lööf and Johansson (2014) show for Swedish firms that the greater the firm's commitment to R&D, the greater indeed the extent to which a firm can exploit the benefits from its locational environment as reflected by a higher productivity premium.

Identification of the true influence of the regional environment crucially hinges on controls for observed and unobserved firm-specific heterogeneity that could be behind regional differences. Exploiting the longitudinal dimension of the data set allows estimating a correlated random effects probit model and thus allows controlling not only for a range of firm-specific observable characteristics but also for unobserved firm heterogeneity. This helps to mitigate problems of spatial sorting. The paper also contributes by analyzing heterogeneity of the relationship between the local knowledge environment and commitment to innovation between firms of different size and in different economic sectors according to their technology level.

The results show that occasional and continuous innovators are not equally distributed spatially. The likelihood of being a continuous innovator as opposed to being an occasional innovator is significantly higher in innovation leading regions even after controlling for a number of observed firm level characteristics as well as unobserved firm level heterogeneity. The regional knowledge environment shows a significant positive relationship with continuous innovation commitment of manufacturing firms and specifically of small firms and in technology intensive sectors. This type of firms appears to be more dependent on their regional environment for knowledge sourcing. The results in this paper highlight that differences in commitment to innovation are a factor related to regional dynamics in innovation.

The rest of this paper is structured as follows: Section 2 presents a brief literature review to set out the theoretical background for the analysis. Section 3 describes the data, provides some descriptives and presents the empirical model. Section 4 shows the estimation results. Section 5 concludes.

2. Literature review

The literature has studied how past innovation relates to current innovation. Three main factors have been put forward as drivers of persistence in innovation defined as true state dependence where the decision to innovate in one year causes a higher probability to innovate the following year (for a review, see for example Peters, 2009; Antonelli et al. 2012; Le Bas and Scellato 2014): Sunk cost - innovation requires investment in R&D facilities (Máñez et al. 2009), "success breeds success" – previous innovation success provides firms with resources that make further success more likely (Flaig and Stadler 1994), and knowledge accumulation that also facilitates new innovations (Arrow, 1962). The same drivers that influence persistence from one year to the next, can also influence the degree of commitment of innovation active firms, e.g. whether the engage in innovation in a continuous way or only occasionally in a given period. For example, occasional innovators lack a formal R&D apparatus and thus face lower sunk costs compared to continuous innovation engagement. In contrast, continuous innovation results in higher knowledge accumulation and higher innovation performance that consequently positively affects subsequent innovations.

Another strand of literature has studied the duration of innovation spells (Geroski et al. 1997; Triguero et al. 2014; Máñez et al. 2015). Both types of studies usually use a non-zero approach, i.e. persistent innovators are distinguished from non-persistent innovators irrespective of their degree of engagement in innovation in a given year.

At the same time, the literature on innovation persistence has mainly focused on firm internal factors as drivers of persistence. External factors can nevertheless also influence a firm's innovation strategy (Antonelli 1994; Sternberg and Arndt 2001; Antonelli and Colombelli 2015)). Different approaches have stressed the region as important factor in the understanding of the process of innovation such as, for example, the regional innovation system approach (Cooke 1992; Tödtling and Kaufmann 1999), the concept of localized learning (Malmberg and Maskell 2006), or the industrial cluster approach (Breschi and Malerba 2005). The key role of the region stems from the localized nature of many knowledge flows and the importance of proximity in the sharing and exchanging of knowledge.

Since knowledge is not ubiquitously available, innovation tends to concentrate in places with a greater local knowledge base in order to take advantages of local knowledge spillovers and information and knowledge sharing. In increasingly globalized and fast-changing markets, knowledge production has become an increasingly complex process. It requires the combination of tacit and explicit forms of knowledge and the combination of firm-internal knowledge with firm-external knowledge. Antonelli and Colombelli (2015) show that external knowledge is indeed an important complementary input for the generation of new knowledge.

External knowledge can stem from the local environment but also from more distant knowledge sources. In this regard, Bathelt et al. (2004) developed the concept of "local buzz" and "global pipelines" to recognize the importance of both local knowledge and access to more distant sources of knowledge in the innovation process. Places that offer both – a strong local knowledge base with technological infrastructure (Hall and Bagchi-Sen 2002) as well as good access to distant knowledge sources - are the most attractive ones for innovative activities. These are overwhelmingly the larger urban and metropolitan areas that are well connected by efficient long-distance transportation networks and intra- and inter-firm networks (Simmie 2003). Miguelez and Moreno (2018) furthermore show that external knowledge flows have a higher impact on regional innovation if they are related to the extant local knowledge base.

Sternberg and Arndt (2001) analyzed firms' innovation behavior in 11 European regions. They found that region-specific characteristics are significant but concluded that firm internal factors are nevertheless more important. This is also in line with Beugelsdijk (2007) who studied innovation output of Dutch companies. Johansson and Lööf (2008) observe for Sweden that while there is regional variation in the number of innovative firms, the region is not significantly related to R&D intensity. Antonelli and Colombelli (2015) study a sample of European listed companies and find evidence that the number of patents registered in the same region positively influence firms' probability to patent. López-Bazo and Motellón (2018) study the role of regional factors in innovation performance of Spanish manufacturing firms. They find that the region accounts for about 4% of the total variability in product innovation. They argue that the regional R&D environment influences firms' innovation output via firms' absorptive capacity. The regional effect on product innovation is found to be stronger with higher firms' own R&D expenditure, but the opposite effect is found for process innovation.

Antonelli et al. (2013) argue that the local knowledge base can also influence innovation persistence through facilitating knowledge sourcing and exchange. They find for Italian manufacturing firms that total factor productivity firm level growth is significantly influenced by firms' external environment, which they interpret as evidence for innovation persistence being path-dependent. [2]

Tavassoli and Karlsson (2018) analyze innovation persistence for Swedish firms. They find that lagged innovation status has a stronger influence on current innovation status for firms in regions of larger economic size, with a higher share of knowledge intensive service sectors, and a greater extent of related variety of sectors as those regions provide better opportunities for knowledge spillovers. Holl et al. (2020) find for German firms that the local patenting activity positively moderates innovation persistence. These papers provide evidence on the influence of firms' external environment on the relationship between lagged and current innovation status. This includes both innovation as well as non-innovation status. Different from these previous studies, I specifically focus on the innovation active firms and ask if the regional knowledge environment influences their degree of commitment to innovation as reflected by occasional versus continuous dedication to innovation in a given year. With the increasing complexity of innovation and the increasing importance of external knowledge in the innovation process, a stronger regional knowledge base can facilitate accessing knowledge and resources that are lacking internally but that are required for the continuous engagement in innovation. By looking at occasional and continuous innovators, a complementary picture on different innovation strategies across space can be gained.

3. Methodology

3.1. Data and descriptives

The firm level data used in this paper comes from the Spanish Technological Innovation Panel (PITEC) prepared by the Spanish National Statistics Institute (INE). PITEC is a

[2] Other studies on innovation persistence have also included some type of regional controls (for Spain, see, for example, Máñez et al. 2009; Lopez-Garcia and Montero 2012; Triguero and Córcoles 2013) to test for regional spillovers. However, in these studies the regional variables relate to the likelihood of having introduced an innovation or having any positive amount of R&D and not specifically to persistence or the degree of commitment to innovation.

representative sample of all sectors. The survey is carried out annually and each firm has a unique identifier which allows creating a true enterprise panel.[3]

Similar to some other CIS surveys, firms that declare to carry out internal R&D activities in a given year are furthermore asked whether they have been carrying out R&D on an occasional basis or continuously in that year. Continuously refers to companies that have permanent R&D staff in-house. In contrast, occasionally refers to R&D activities carried out only as needed. This question regarding the commitment to innovation in PITEC is on an annual base, while other CIS surveys tend to include such questions in reference to a 3-year period. Having annual information is important in a panel data approach, since otherwise results could be biased due to overlapping and double counting (Peters 2009).

There are 55.231 observations for 9386 firms that report internal R&D activities over the period 2004-2014 with firms being observed on average for 6 years.[4] Of these firms with internal R&D in the PITEC sample, on average 21 percent reported to be only occasionally engaged in innovation while the remaining 79 percent reported to be engaged in innovation in a continuous way. Firms with 200 and more employees are more frequently continuously engaged in innovation. Among them only 15 percent report to carry out R&D only on an occasional basis. In contrast, among innovation active SME's with less than 200 employees, about 23 percent carry out innovation activities on an occasional basis.

Over the period from 2004-2014, the share of occasional innovators constantly decreased to 17.5 percent while the share of continuous innovators increased to 82.5 percent. Together with a dramatic drop of over 60 percent in innovation active firms over this period from approximately 51.000 to about 18.500, this suggests that with the economic crisis many

[3] PITEC has different representative sub-samples: a) companies with 200 or more employees, b) companies with less than 200 employees which perform internal R&D, c) companies with less than 200 employees that undertake external R&D but not internal R&D, and d) companies with less than 200 employees and no expenditure on innovation. In 2014, the composition of the sample changed with an important drop of small firms. With the aim to reduce the data collecting burden a sample rotation has been introduced keeping some firms "dormant" and not surveyed in certain years. For the year 2014 this means that about 40% of small firms that responded in 2013 were not included anymore in the 2014 survey, while nearly all medium sized firms and all large firms continued to be surveyed. In robustness check, all models have been re-estimated without the year 2014. Main results remain qualitatively the same and are available upon request.

[4] Firms with extraordinary events such as mergers or acquisitions have been excluded.

firms have given up completely on innovation and particularly so those that had only engaged occasionally in innovation (Busom and Vélez 2016; Cruz-Castro et al. 2018). Figure 1 shows that this trend of a fall of occasional innovators happened among large, medium sized and small firms as well. Over this period, innovation has hence become more concentrated in continuous innovators.

[Figure 1 near here]

Unfortunately, PITEC does not provide the firms' location. However, PITEC reports the regional distribution of firms' internal R&D expenditures.[5] Based on this information, firms are assigned to the 17 Autonomous Community regions following the approach in Holl and Rama (2016) and Cruz-Castro et al. (2018). The big majority of firms (about 93 percent) report internal R&D expenditure only in one region. In the case of the remaining firms, the firm is assigned to the region where it has at least 50% of its internal R&D expenditure. With this procedure 99% of firms are assigned to a region. For a very small number of firms the information on the regional distribution of their internal R&D is missing and for an even smaller number there was no single region where the firm had its majority of internal R&D expenditure. These firms (less than 1% of the sample of firms with internal R&D) are excluded from the analysis because it is not possible to ascribe them to a single region.[6]

Figure 2 shows the share of innovative firms across Spanish regions and the shares of continuous and occasional innovators among the PITEC sample firms. The share of innovation active firms that engages only occasionally in innovation ranges from 34 percent in Extremadura to 18 percent in Madrid and Catalonia. In the 2017 Regional Innovation Scoreboard (European Commission 2017), Extremadura is in fact the only Spanish mainland region that falls in the lowest category of moderate minus.

[5] Firms are also asked about the regional distribution of their R&D employees. Results are qualitatively the same if this information is used instead.

[6] The final sample has information for 9364 firms. The number of observation for each Autonomous Community ranges from more than 14.000 in the case of Catalonia to slightly over 200 for Balearic Islands. The average number of observations per Autonomous Community and year is nearly 300, but for smaller regions, such as the islands and Cantabria, and Extremadura which suffers from a low business population, the number of observations per year is generally below 50. This should be taken into account in the interpretation of results, as signs and significance of the coefficients will be driven by those regions with greater numbers of observations.

[Figure 2 near here]

A key indicator of the regional innovation systems is the amount of business expenditures on research and development (BERD). BERD has been found to be a stronger determinant of growth than non-business R&D (OECD, 2003). Cruz-Castro et al. (2018) show that a greater share of BERD in the regional gross R&D expenditure increased the resilience of firms to the economic crisis and that the effectiveness of regional government R&D support depends on a strong regional R&D business sector in the region. BERD intensity in Spain has, however, been traditionally low and below the EU average and has even worsened in the post-crisis years. In 2016, BERD amounted to just 0.64% of GDP, compared to the 1.33% for the EU-28 (Figure 3).

[Figure 3 near here]

As shown in Figure 4, there are also strong regional variations in BERD intensity. Indeed there is a positive correlation between the regional share of continuous innovators and the regional R&D business expenditure. The differences in the shares of continuous innovators reflect the territorial distribution of R&D and innovation activities in Spain in general, which is very heterogeneous and with a strong concentration in a small number of regions. Madrid, Catalonia, and the Basque Country account for one third of population but for two thirds of patents and for more than two thirds of total innovation expenditure in Spain.

[Figure 4 near here]

The descriptives point to differences in the regional distribution of continuous and occasional innovators with a higher presence of continuous innovators in innovation leading regions. However, the patterns could be driven by differences in firm specific characteristics. As argued in Beugelsdijk (2007) in order to estimate a true effect of the role of the regional environment on firm innovation behavior, it is crucial to control for firm specific heterogeneity. Occasional and continuous innovators differ along a range of characteristics (Johansson and Lööf 2010; Deschryvere 2014) and such differences could also be driving observed regional differences. For example, continuous innovators tend to be larger companies and they come more frequently from high-tech sectors. If larger companies and high-tech firms have a greater probability of locating in innovation leading regions, this could be driving the observed regional differences in continuous and occasional innovators. Thus as a next step, the probability that an innovative firm is a continuous innovator versus an occasionally innovators is estimated conditional on firm specific observable as well as unobservable factors.

3. 2. Model specification

The purpose of this paper is to study the decision of an innovation active firm to engage in innovation either in a continuous or occasional manner. Let continuous innovation y_{it} of firm $i = 1, 2, ..., N$ in periods $t = 1, 2, ... T$ be captured by a binary choice model

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

where the latent variable y_{it}^* representing firm i's underlying propensity to engage continuously in innovation in period t is a linear function of a vector of observables x_{it}.[7]

$$y_{it}^* = \beta x_{it} + v_{it} \tag{2}$$

The vector x_{it} comprises firm specific characteristics c_{it} and a region specific characteristic a_{rt} that captures the regional innovation environment: $x_{it} = (c_{it}, a_{rt})$. v_{it} is assumed to be i.i.d. normal.

In the pooled cross section probit model unobserved firm level heterogeneity is not accounted for. However, innovation commitment is most likely affected by a number of unobserved factors. Product type and quality, managerial strategies or ability could be directly related to firms' commitment to innovation.

To control for firm specific unobservable characteristics v_{it} can be decomposed as

$$v_{it} = u_i + \varepsilon_{it} \tag{3}$$

[7] The dependent variable is based on the PITEC question regarding internal R&D and takes on the value of 1 if the firm has reported carrying out R&D continuously in the survey year and 0 if the firm has reported carrying out R&D occasionally.

where u_i denotes the firm-specific unobservable effect and ε_{it} is the usual random error. Unobservable factors could also influence the firm's location decision as well as its decision towards commitment to innovation. Firms that plan to engage continuously in innovation could have taken this already into account when they decided where to locate in the first place and thus decided to locate in a region with better innovation opportunities. This would lead to sorting on unobservables. This problem of spatial sorting can be reduced by estimating a version of Chamberlain's correlated random effects probit model (CRE) (Chamberlain 1984). Following this approach u_i is assumed to be related to the time averages $\overline{x}_i$ of time varying variables x_{it} and that it follows a conditional normal distribution,

$$u_i | x_{i1}, \ldots, x_{iT} \sim N\left(\varphi + \overline{x}_i \xi, \sigma_\eta^2\right) \qquad (4)$$

where σ_η^2 is the variance of η_i in the regression $u_i = \varphi + \overline{x}_i \xi + \eta_i$ and constitutes the conditional variance of u_i and $\operatorname{cov}(\eta_i, \varepsilon_{it}) = 0$.

Given this specification the model can be written as

$$P\left(y_{it} = 1 | x_{i1}, \ldots, x_{iT}, u_i\right) = \Phi\left(\theta\left(x_{it}\beta + \varphi + \overline{x}_i \xi\right)\right) \qquad (5)$$

where $\theta = \left(1 + \sigma_\eta^2\right)^{-1/2}$.

Innovation is a dynamic process and given the findings in the innovation persistence literature, one can also assume that the probability of being a continuous innovator with a dedicated R&D apparatus will depend positively on the dedication to innovation in the past. Thus to account for the influence of past innovation dedication on current commitment to innovation the one year lagged innovation status y_{it_1} is furthermore included. However, in dynamic non-linear models this leads to the so-called initial conditions problem (Wooldridge 2005). This is addressed by specifying the distribution of u_i conditional on y_{i0} and the exogenous variables (for more details of this approach, see, for example Peters 2009; similar models have been estimated in Lopez-Garcia and Montero 2012; Triguero and Córcoles 2013; Antonelli et al. 2013; Tavassoli and Karlsson 2018, Holl et al. 2020, among others).

3.3. Independent variables

As shown by the literature, firms' innovation behavior is influenced by their regional innovation environment. Here I test if the regional knowledge environment also influences the likelihood that a firm engages in a continuous manner in R&D. Thus, the main variable of interest refers to the regional knowledge environment which is proxied by the three year lagged regional business expenditure in R&D (BERD) as percentage of the regional GDP (BERD/GDP). Greater business sector R&D engagement generates a stronger and more dynamic innovation environment with greater opportunities for knowledge sourcing and knowledge spillovers.

Furthermore, I control for size differences of regions by including the regional population (POP) and for regional industrial structure by including the share of manufacturing in total regional GDP (MANUF) to account for other types of regional influences.

Firm-level controls

Firm size has been extensively analyzed in innovation studies. There is empirical evidence that has shown that SME's have a lower propensity to conduct R&D (Acs and Audretsch 1998). Investing in R&D requires generally high entry costs and SME's often have not the necessary resources in this regard. In contrast, large firms have an advantage in setting up costly R&D labs and thus to engage in innovation activities in a continuous way. R&D is also risky in so far that returns are uncertain and large firms can be in a better position to accommodate such risks as well as to find the necessary external financing. Cefis and Orsenigo (2001) showed that persistence increases with firm size. Johansson and Lööf (2010) also found for Swedish manufacturing and service sector firms that persistent R&D firms are larger in terms of their number of employees. In contrast, SME's tend to carry out R&D more on an occasional basis when there is a specific need in, for example, production or marketing (Rammer et al. 2009). The variable *size* is measured as the log of firms' total number of employees.

Multinational company status could further be related to the innovation commitment of firms. On the one hand, there exists a broad literature that has studied the effect of branch plant status on innovation behavior. FDI plants may invest less in R&D compared with domestic firms, especially when R&D within the multinational group is located at the parent firm (Ortega-Argilés and Moreno 2009; Yang and Huang 2018). In this case, one would expect to see a lower propensity of being a continuous innovator among foreign subsidiaries. On the other hand, regarding persistence in innovation, Johansson and Lööf (2010) found that persistent innovators tend to belong to a multinational company. In their results, the share of firms persistently engaged in R&D is higher among both domestic as well as foreign multinationals compared to firms that are not engaged in R&D or only occasionally. The variable *domgroup* is is a dummy variable that takes on value 1 if the firm belongs to a domestic multinational, whereas *foreign* is a dummy variable that takes on value 1 if the firm reports at least 50% foreign ownership and zero otherwise.

Firm age can reflect accumulated knowledge as well as financial and organizational resources that facilitate establishing permanent R&D activities. However, firm age can also be associated with different market and technological opportunities and thus different innovation strategies (Gkypali et al. 2015). Continuous engagement in innovation activities in early years can raise the possibilities of survival (Audretsch 1991). During the crisis years, newly created firm have been observed to show higher persistence of innovation activities (Archibugi et al. 2013; Holl and Rama 2016; Cruz-Castro et al. 2018). PITEC asks for the year of creation of the companies only since 2009. However firms are also asked whether or not their company was newly created during the survey year or the two previous years of the survey. This information is available for all years and based on this information, I have created the variable *new* as a dummy that takes on value 1 if the firm has answered yes to this question in a given year.

Higher productivity can generate the necessary resources for establishing permanent R&D activities. Cruz-Castro et al. (2018) found for Spanish firms that higher productivity reduced indeed a firm's probability of abandoning innovation activities during the crisis years. Johansson and Lööf (2010) report for Swedish firms that continuous innovators have higher value added per employee. The variable *prod* is the firm's total turnover divided by total number of employees.

Exporters have advantages in accessing distant knowledge sources which can facilitate innovation and exporting firms also face more competitive environments which may require a more continuous engagement in innovation (Cassiman and Veugelers 2006). Empirical evidence shows that continuous innovators are indeed more export orientated (Johansson and Lööf 2010). *Export* is a dummy variable taking the value of 1 if a company reports sales in international markets and zero otherwise.

Furthermore, some firm-specific characteristics reflecting the firms' innovation strategy are included. Firms engaged in R&D cooperation may show a greater commitment to innovation (Becker and Dietz, 2004; Cruz-Castro et. al. 2018) as such collaborations may imply sunk costs (Clausen et al. 2011). The variable *coop* is a dummy variable taking 1 if the company reports cooperation with partners outside the own business group. The literature has also documented that public funding increases the likelihood of innovating (Peters, 2009) and reduces the probability of abandoning innovation activities (Paunov 2012; Cruz-Castro et al. 2018). Thus, public funding may be positively associated with continuous innovation engagement. *Fonpubli* is the percentage of internal R&D expenditure financed via public funds. A summary of the explanatory variables with descriptive statistics is provided in Appendix Table 1.

All firm level control variables are lagged one year to reduce endogeneity concerns. Finally, there are strong sectoral differences in the degree of innovativeness of firms (Huergo and Jaumandreu 2004) and there is also evidence for sectoral differences in persistence (Malerba et al. 1997; Cefis and Orsenigo 2001; Raymond et al. 2010). Sector dummies are included based on the sector aggregation provided in PITEC, which is an aggregation of the CNAE (the Spanish acronym for Spain's National Classification of Economic Activities) classification of 44 sectors. These detailed sector dummies account for specific industry-specific dynamics that affect firms' innovation behavior and thus also their commitment to innovation.

4. Results

As a starting point and benchmark, Table 1 shows the estimation results from pooled cross-section probit models. The coefficients reported are the marginal effects of the probability of continuous engagement in innovation as opposed to occasional engagement of innovation active firms. Column (1) reports results for a parsimonious specification. In addition to the main variable of interest, the regional BERD intensity, I only include firm size, domestic group status, FDI status, and the firm newness variable. In column (2) productivity and export status are added. Column (3) and (4) add R&D cooperation and public R&D funding respectively.

[Table 1 near here]

Starting with the firm specific characteristics, the coefficients are generally in line with prior studies on innovation behavior and also with specific evidence for Spain (see, for example, Ortega-Argilés and Moreno 2009; López-Bazo and Motellón 2018). Larger firms are more likely to be continuous innovators. This is consistent with the arguments in the literature regarding resources and that they are often engaged in more complex innovation strategies (Johansson and Lööf 2010; Le Bas and Poussing 2014; Rammer and Schubert 2018). Firms belonging to a domestic group have also a greater propensity to be continuous innovators. However, belonging to a foreign multinational is not significantly related to continuous innovation engagement. Newly created innovation active firms show a higher probability of engaging in a continuous manner in innovation. Yet studies on innovation persistence have found young firms to be less persistent innovators (García-Quevedo et al. 2014; Máñez et al. 2015). This suggests that while young firms may have a lower probability of engaging in R&D and a tendency for shorter innovation spells, if they dedicate resources to internal R&D in a given year they do so with greater commitment.

Conditional on these controls, higher productivity is not statistically related to a more continuous commitment to innovation, but export status shows a statistically significant positive relation with continuous innovation status as does cooperation for innovation. Firms that receive public funding also show a stronger engagement with innovation. Yet the inclusion of the squared term indicates decreasing benefits from public R&D funding.[8]

Turning to the main variable of interest in this paper, the regional knowledge environment, proxied by the regional BERD as percentage of the regional GDP, shows that firms in regions with higher business R&D expenditure have indeed a higher propensity to be a continuous innovator. The regional variable is significant even when other firm characteristics are controlled for (column 1-4). It is reassuring that the estimated coefficients are stable across the different specifications. Thus potential endogeneity concerns, that could arise with some of the firm level control variables, do not seem to lead to a bias in the estimate of the regional variable. The results confirm that the regional environment matters

[8] A note of caution must be raised in the interpretation of these results as reverse causality cannot be ruled out. Greater innovation engagement could lead to higher productivity or better exporting possibilities (Cassiman and Golovko 2011). Firms with greater innovation engagement are also likely to apply more for public funding. Moreover, the information on public R&D funding is not available for 2004 and for 2006, which thus reduces the estimation sample size in column 4.

for innovation engagement. Nevertheless, as the regional BERD intensity itself could be correlated with other regional factors, I include further regional controls. In Column 5 and 6, the log of the regional population is included to control for the differences in the size of regions and the log of the manufacturing share in total regional GDP is included to control for the regional industrial structure. Column 5 is without the control for public R&D funding and column 6 includes this variable and its squared term. The regional BERD intensity continues to show a positive and significant relationship with continuous innovation commitment even when further regional characteristics are controlled for. The population size of the region also matters while the manufacturing share shows no significant relationship with innovation commitment.

The results from the dynamic correlated random effects probit estimation that controls for unobserved heterogeneity, lagged innovation status and the initial condition are shown in Table 2.[9] Coefficients shown are again the corresponding marginal effects. Past innovation status (*C_Inno_1*) and the initial condition (*C_Inno_0*) are both significant, showing that there is also persistence in the intensity of R&D engagement of innovation active firms.

[Table 2 near here]

Column 1 shows the results for all firms. Turning again to the main variable of interest in this paper, the coefficient for the regional BERD as percentage of the regional GDP is again significant at the 1 percent level and is of similar magnitude as in column 5 of Table 1. The coefficients for the other two regional control variables are not significant. Even after accounting for firm-specific observed and unobserved heterogeneity, there is a significant relation between the regional knowledge environment and firms' commitment to innovation. A doubling of the regional business expenditure on R&D as percentage of GDP is associated with a 1.2 percentage point increase in the probability that an innovation active firm engages in a continuous way in R&D.

However, not all firms may be affected to the same degree by their regional environment. Firm size is an important determinant of firms' commitment to innovation, but at the same time, firms of different size may also be reliant to different degrees on their regional

[9] Note, domgroup and foreign have virtually no time variation and are therefore treated as time-invariant. The variable fonpubli is not included here as the information is missing for 2004 and 2006. However, in unreported estimations with fonpubli included, main results are qualitatively the same. These results are available upon request.

environment for knowledge sourcing (Naz et al. 2015). In column 2 to 4 of Table 2, results for the sample of small, medium-sized, and large firms, respectively are shown.[10] Higher regional business innovation expenditure increases the likelihood of small firms being a continuous innovator. The coefficient is double the magnitude compared to the pooled sample of all firms, indicating that it is especially the group of small firms that is most dependent on their regional environment in their innovation activities. In contrast, the regional BERD intensity is not significant for medium-sized and large firms. The result for the small firms is consistent with the findings in Holl and Rama (2016) for the Basque Country. In this study, the regional effect on the likelihood of abandoning innovation activities during the economic crisis has been significant for small firms, but no significant regional effect was found for large firms. This is also in line with López-Bazo and Motellón's (2018) study on innovation performance in Spain that finds only a significant regional impact for small and medium-sized enterprises and not for large firms. The finding that the regional knowledge environment is more important for small firms than for larger firms is furthermore consistent with the findings in Naz et al. (2015) on innovation rates in Germany. This suggests that small firms are more dependent on their regional environment than large companies as they are likely to depend more on localized knowledge and cooperation networks. Large companies may have the necessary resources and competencies to engage in knowledge exchange and knowledge sourcing over greater distances and to take greater advantage of what Bathelt et al. (2004) has termed "global pipelines".

The literature has also documented higher innovation persistence in firms that are closer to the technological frontier (Raymond et al. 2010; Máñez et al. 2015). To check furthermore for heterogeneity of commitment to innovation across sectors of different technological intensity Table 3 provides further results. Here the sample is split in to 5 sectors. Manufacturing companies are classified following OECD classification into Low Technology Intensity, Medium Low Technology Intensity, and Medium High and High technology Intensity. Service sector firms are classified according to the EUROSTAT classification into High-Tech Services and Low tech Services.

[Table 3 near here]

[10] Small firms are defined as those with fewer than 50 employees, medium-sized firms are those with 50 to 200 employees, and large firms are defined as those with 200 and more employees.

For low-tech manufacturing (column 1) the regional BERD as percentage of the regional GDP is not significant. In contrast, the coefficient for medium-low tech (column 2) and medium high-tech to high tech manufacturing (column 3) is statistically significant at the 5% level for the former and at the 1% level for the latter and suggests that firms in more technology intensive sectors are more strongly influenced in their commitment to innovation by their regional environment. This is also consistent with López-Bazo and Motellón's (2018) study that found that the influence of the regional R&D environment on product innovation in manufacturing is stronger for firms with greater R&D expenditure. The results in column 4 and 5 for low tech and high tech services respectively show no significant statistical relationship of the regional R&D environment with continuous innovation commitment of innovation active firms.

Robustness checks

To test for the robustness of the main result regarding the influence of the regional BERD intensity on firms' commitment to innovation, a number of additional checks are performed. First, there could be firms that are engaging in a continuous manner in R&D external sourcing as a way to acquire new technological knowledge (Holl and Rama 2012). In alternative regressions I have therefore included in the sample of continuous innovators firms that had continuous external R&D expenditure where I test for different definitions of continuous external R&D engagement: a) more than 2 consecutive years of external R&D expenditure, b) more than 3 consecutive years and c) more than 4 consecutive years. Correlated random effects probit results for the samples that include the different definitions of continuous external R&D engagement are shown in Appendix Table 2 in column 1 to 3. The results confirm the role of the regional knowledge environment for continuous engagement in innovation. When continuous external R&D engagers are included, the results remain nearly identical. Next, I also test for alternative lag structures of the regional variables using 2 and 4 year lags instead of the 3 year lag. Results are shown in column 4 and 5 of Appendix Table 2 and the coefficient are again virtually the same as those of the corresponding estimates in Table 2 column 1.

I have furthermore tested the robustness of the results to the inclusion of additional regional controls. In Appendix Table 3, I add first regional fixed effects at the NUTS 1 level to account for unobservable time-invariant differences across regions. Column 1 shows the results when manufacturing and services are pooled and column 2 and 3 show the estimation results for manufacturing and services separately. The BERD intensity continues to show a significant relation with continuous R&D engagement. For the pooled sample of manufacturing and service sector firms, the coefficient is even slightly larger but somewhat less precisely estimated; however qualitatively similar to the results in Table 2. The other regional controls again show no significant relation with continuous R&D engagement. The breakdown between manufacturing and services confirms the previous results of Table 3 that the BERD intensity is statistically significant in manufacturing but for services, none of the regional variables has a significant coefficient.

Second, in column 4 and 5 of Appendix Table 3, I further add additional regional controls to the specification for manufacturing firms. Column 4 includes the regional GDP per capita as additional control. The results show that the commitment to innovation of firms is more strongly related to BERD intensity than to GDP per capita, which is not significant. Column 5, furthermore adds the regional land area. Conditional on land area, POP now reflects density rather than the size of regions. The negative coefficient of POP now reflects that population density does not favor continuous R&D engagement. However, the BERD intensity continues to show a positive and significant relation with continuous R&D engagement. Overall, the additional robustness checks confirm that the regional BERD intensity is positively related to firms' commitment to innovation.

5. Conclusions

The findings in this paper show that a stronger regional knowledge environment increases the likelihood that an innovator engages continuously in R&D as opposed to occasionally. This suggests that there are relevant knowledge spillovers. However, the relationship is strongly heterogeneous across firm size and the technology level of sectors. While small firms are generally less likely to engage in innovation activities in a continuous way, their intensity of commitment to innovation is significantly influenced by their regional knowledge environment. Thus, the regional knowledge environment plays a relevant factor in the propensity that an SME occasional innovator becomes a continuous innovator. This has important policy implications, especially in a country like Spain where the vast majority of firms is of small size and where they constitute an important contribution to the economy. In contrast, the results show no significant relation of the regional knowledge environment with the propensity of large firms to engage continuously in innovation. This suggests that innovative SMEs rely indeed more heavily on local external knowledge. As argued in Rammer et al. (2009) in-house R&D in SMEs is most effective when combined with external knowledge sources. However, SME's have fewer resources to access more distant knowledge sources and therefore seem to rely more on their local and regional environment.

The influence of the regional knowledge environment on firms' commitment to innovation varies not only by firm size but also sector and specifically the technological level, with manufacturing firms in more technological sectors being more strongly influenced by their regional environment.

The evidence for Spain suggests that innovation activity is becoming increasingly concentrated in innovation leading regions as continuous commitment to innovation is stimulated in those regions. In contrast, innovation lagging regions are in danger of falling even further behind when they are left increasingly with occasional innovators. The findings presented are relevant for a better understanding of changes in the dynamics and in the geography of innovation. They also highlight the importance of a strong business sector in the regional innovation system. However, R&D expenditure in the business sector is usually one of the weak factors in moderate innovator countries, and Spain is no exception in this regard. Still regional differences matter. A weak business innovation sector constitutes a barrier to growth in lagging regions and improving its capacity is one of the corner stones of smart specialization strategies. This will be instrumental for reducing regional disparities and achieving a more inclusive growth.

Results should nevertheless be interpreted with caution. Although a wide range of firm-specific control variables have been included together with further regional controls and unobserved time-invariant heterogeneity has also been controlled for, some remaining endogeneity issues related to potential reverse causality cannot be fully ruled out.

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Table 1: Probit models of determinants for being a continuous innovator

	(1)	(2)	(3)	(4)	(5)	(6)
Regional BERD/GDP (log)	0.020***	0.018***	0.019***	0.021***	0.014**	0.017***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.007)
SIZE (log)	0.033***	0.030***	0.028***	0.028***	0.027***	0.027***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
DOMGROUP	0.034***	0.031***	0.026***	0.026***	0.027***	0.027***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
FOREIGN	0.019	0.013	0.008	0.015	0.009	0.016
	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)
NEW	0.060***	0.074***	0.066***	0.052**	0.066***	0.052**
	(0.019)	(0.019)	(0.019)	(0.024)	(0.019)	(0.024)
PROD(log)		0.004	0.004	0.005	0.004	0.004
		(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
EXPORT		0.053***	0.051***	0.047***	0.049***	0.046***
		(0.007)	(0.007)	(0.008)	(0.007)	(0.008)
COOP			0.069***	0.063***	0.070***	0.063***
			(0.006)	(0.006)	(0.006)	(0.006)
FONPUBLI				0.002***		0.003***
				(0.0003)		(0.0004)
FONPUBLI squared				-0.00003***		-0.00003***
				(4.03e-06)		(4.03e-06)
Regional POP (log)					0.012**	0.012**
					(0.005)	(0.005)
Regional MANUF (log)					0.008	0.006
					(0.011)	(0.011)
Number of observations	42513	42492	42492	32736	42492	32736
Log likelihood	-18792.2	-18719.4	-18555.2	-13984.8	-18545.6	-13977.3

Notes: (1) The coefficients reported are the marginal effects computed at mean values. Clustered standard errors are presented in parentheses; ***, **, * = statistically significant at the 99, 95 and 90% levels. (2) All estimations include a constant, industry fixed effects based on 43 unreported sector dummies, and year dummies.

Table 2: Correlated random effects probit estimations for being a continuous innovator:

	(1) All firms	(2) Small firms	(3) Medium sized firms	(4) Large firms
Regional BERD/GDP (log)	0.012***	0.024***	0.006	0.001
	(0.004)	(0.007)	(0.008)	(0.007)
Regional POP (log)	0.004	-0.002	0.014**	0.005
	(0.004)	(0.005)	(0.006)	(0.006)
Regional MANUF (log)	0.003	-0.018	0.018	0.014
	(0.007)	(0.011)	(0.014)	(0.010)
SIZE (log)	0.024***	0.005	0.068***	0.026*
	(0.007)	(0.010)	(0.015)	(0.014)
DOMGROUP	0.012**	0.017*	0.025***	-0.013
	(0.005)	(0.009)	(0.008)	(0.009)
FOREIGN	-0.001	-0.014	-0.021*	-0.010
	(0.008)	(0.020)	(0.012)	(0.011)
NEW	0.026	0.033	-0.065	-0.044
	(0.018)	(0.021)	(0.056)	(0.088)
PROD(log)	0.006	0.001	0.031***	0.010
	(0.004)	(0.005)	(0.010)	(0.010)
EXPORT	-0.007	-0.009	-0.004	0.004
	(0.008)	(0.011)	(0.018)	(0.015)
COOP	0.006	0.002	0.001	0.018**
	(0.005)	(0.008)	(0.009)	(0.008)
C_Inno_1	0.219***	0.248***	0.219***	0.171***
	(0.006)	(0.088)	(0.010)	(0.010)
C_Inno_0	0.073***	0.068***	0.078***	0.046***
	(0.006)	(0.009)	(0.010)	(0.011)
msize	-0.004	0.020*	-0.029**	-0.005
	(0.007)	(0.011)	(0.015)	(0.014)
mnew	0.021	0.026	0.020	-0.054
	(0.038)	(0.047)	(0.100)	(0.127)
mprod	-0.005	-0.010	-0.034***	0.012
	(0.005)	(0.007)	(0.011)	(0.011)
mexport	0.052***	0.067***	0.035	0.031
	(0.010)	(0.015)	(0.023)	(0.020)
mcoop	0.076***	0.075***	0.065***	0.053***
	(0.008)	(0.013)	(0.014)	(0.014)
Number of observations	42492	20307	13045	9139
Log likelihood	-12932.5	-7037.2	- 3826.9	- 1978.5

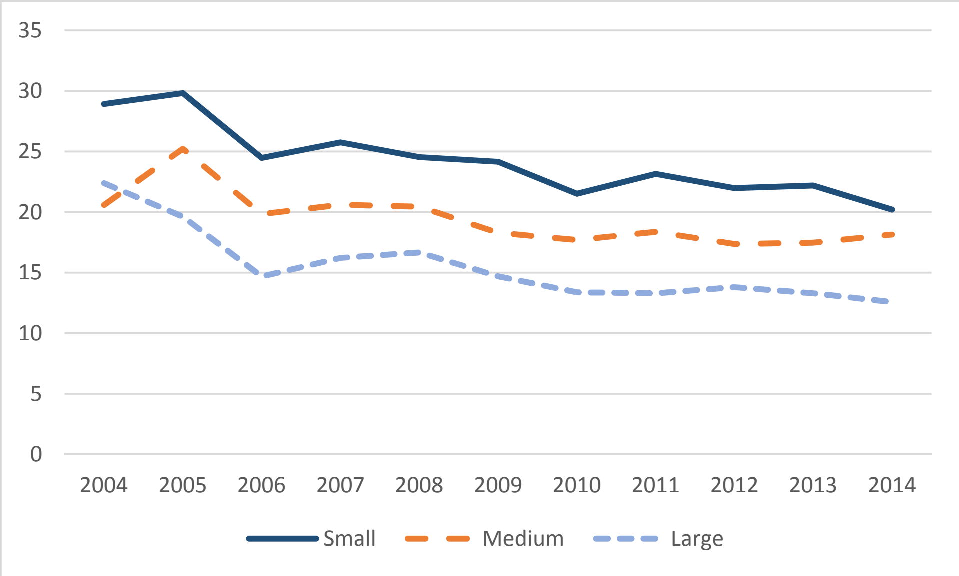
Notes: (1) The coefficients reported are the marginal effects computed at mean values. Clustered standard errors are presented in parentheses; ***, **, * = statistically significant at the 99, 95 and 90% levels. (2) All estimations include a constant, industry fixed effects based on 43 unreported sector dummies, and year dummies.

Table 3: Correlated random effects probit estimations for being a continuous innovator: sectoral differences

	(1) Low Tech Manuf.	(2) Medium-low Tech Manuf.	(3) Medium high and high tech Manuf.	(4) Low tech services	(5) High tech services
Regional BERD/GDP (log)	0.002 (0.015)	0.030** (0.015)	0.021*** (0.007)	0.017 (0.016)	0.005 (0.007)
Regional POP (log)	0.010 (0.010)	-0.004 (0.011)	0.002 (0.006)	0.015 (0.014)	0.005 (0.007)
Regional MANUF (log)	0.024 (0.028)	-0.014 (0.032)	0.013 (0.013)	-0.026 (0.024)	-0.010 (0.011)
SIZE (log)	0.027 (0.026)	0.057** (0.029)	0.021* (0.011)	0.050* (0.029)	0.011 (0.011)
DOMGROUP	0.016 (0.015)	0.017 (0.017)	0.020** (0.008)	-0.007 (0.022)	-0.001 (0.010)
FOREIGN	-0.004 (0.024)	-0.005 (0.022)	-0.013 (0.012)	0.017 (0.033)	0.017 (0.018)
NEW	-0.030 (0.056)	0.183*** (0.063)	0.035 (0.033)	0.006 (0.191)	0.019 (0.022)
PROD(log)	0.032** (0.015)	0.046*** (0.017)	0.006 (0.007)	0.022 (0.022)	-0.007 (0.006)
EXPORT	-0.006 (0.023)	-0.029 (0.032)	-0.006 (0.014)	0.004 (0.034)	-0.010 (0.009)
COOP	-0.008 (0.014)	0.029* (0.016)	0.005 (0.008)	0.010 (0.021)	-0.002 (0.009)
C_Inno_1	0.239*** (0.016)	0.265*** (0.019)	0.198*** (0.010)	0.287*** (0.024)	0.172*** (0.011)
C_Inno_0	0.072*** (0.016)	0.094*** (0.019)	0.062*** (0.010)	0.104*** (0.024)	0.063*** (0.011)
msize	0.010 (0.026)	-0.026 (0.030)	0.005 (0.012)	-0.041 (0.029)	0.0001 (0.011)
mnew	0.048 (0.113)	-0.173 (0.152)	0.024 (0.089)	-0.170 (0.259)	0.044 (0.046)
mprod	-0.040** (0.017)	-0.041** (0.020)	-0.006 (0.010)	-0.011 (0.025)	0.007 (0.007)
mexport	0.047 (0.032)	0.044 (0.039)	0.041** (0.020)	0.026 (0.041)	0.064*** (0.015)
mcoop	0.104*** (0.024)	0.035 (0.026)	0.076*** (0.013)	0.052 (0.034)	0.074*** (0.015)
Number of observations	6805	4932	14131	3016	9728
Log likelihood	-2452.9	-1737.3	- 3796.9	- 1065.8	- 2566.2

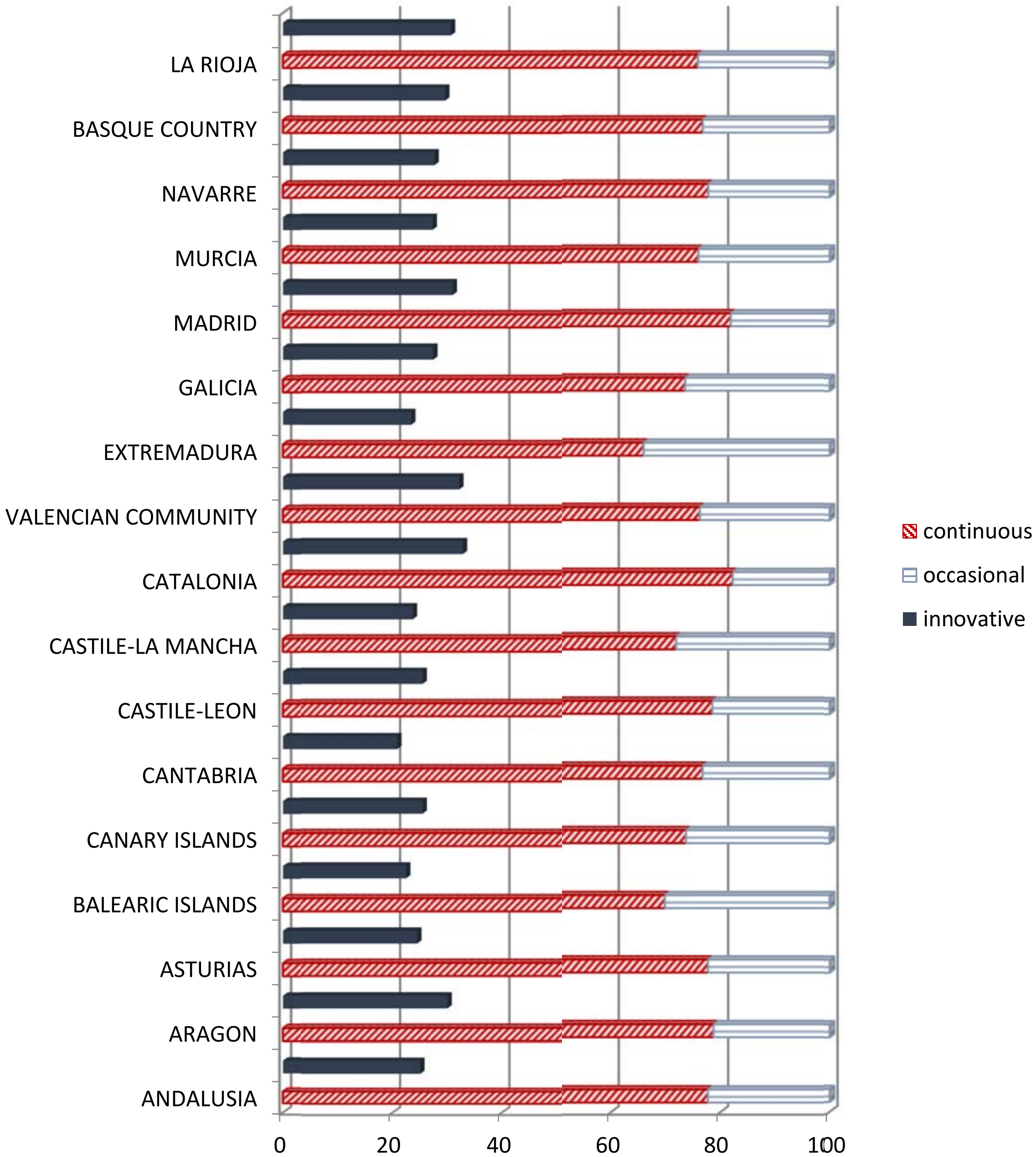
Notes: (1) The coefficients reported are the marginal effects computed at mean values. Clustered standard errors are presented in parentheses; ***, **, * = statistically significant at the 99, 95 and 90% levels. (2) All estimations include a constant, industry fixed effects based on 43 unreported sector dummies, and year dummies.

Figure 1. Percentage of occasional innovators



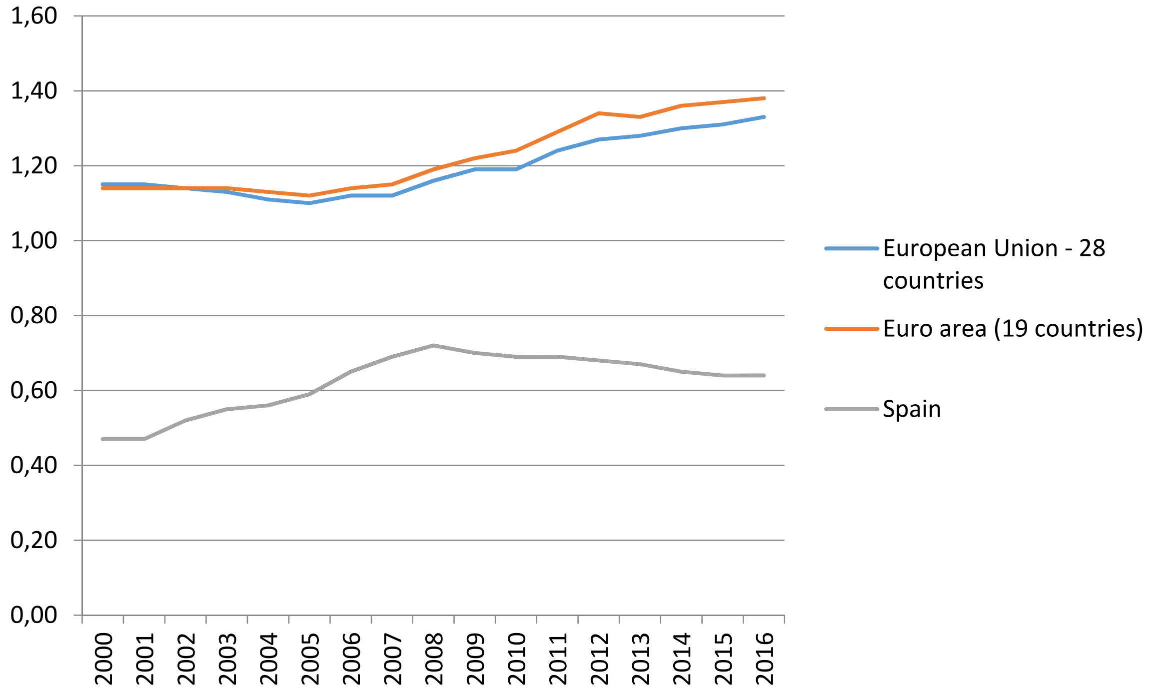
Source: PITEC

Figure 2. The share of innovative firms and continuous and occasional innovators by region



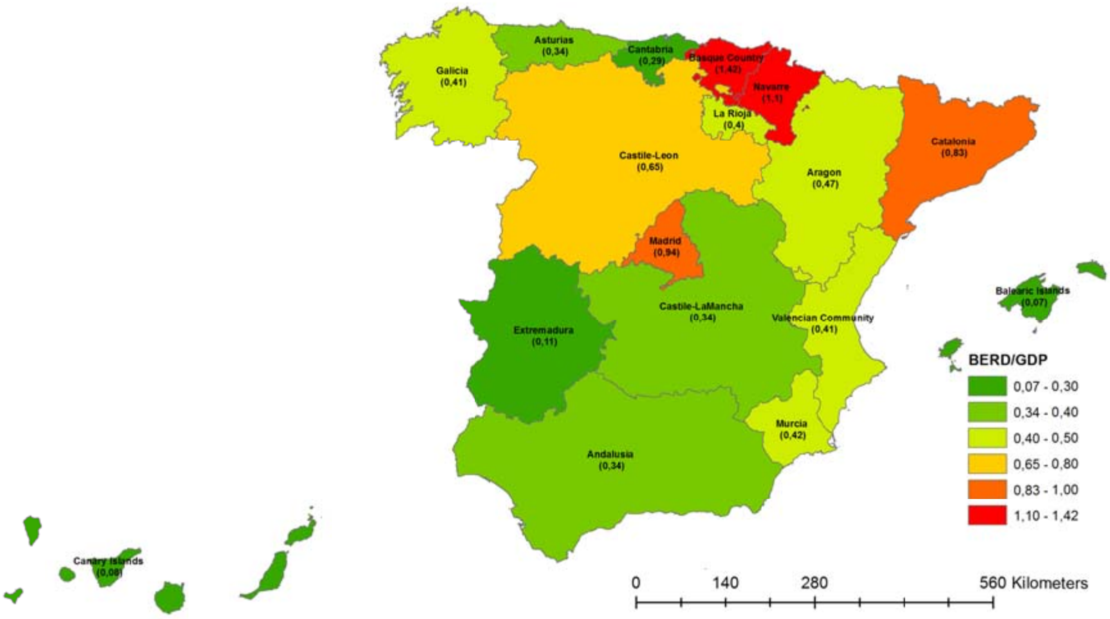
Source: INE – Encuesta sobre Innovación and PITEC

Figure 3. Evolution of BERD as percentage of GDP



Source: Eurostat

Figure 4. BERD intensity by region: 2016



Source: Eurostat

Appendix Table 1: Explanatory variable description and summary statistics

Variable	Definition	Mean	Std. dev.
SIZE	Log (total number of employees)	4.15	1.54
DOMGROUP	Dummy variable taking 1 if the company belongs to a domestic business group and 0 otherwise	0.31	0.46
FOREIGN	Dummy variable taking 1 if the company belongs to a foreign business group and 0 otherwise	0.12	0.33
NEW	Dummy variable taking 1 if the company has been created during the survey year or the two previous years and 0 otherwise	0.01	0.10
PROD	Log (turnover/total number of employees)	11.8	1.01
EXPORT	Dummy variable taking 1 if the company reports sales in international markets and 0 otherwise	0.75	0.43
COOP	Dummy variable taking 1 if the company reports cooperation with partners outside the own business group and 0 otherwise	0.43	0.50
FONPUBLI	Percentage of internal R&D expenditure financed via public funds	12.8	23.3
Regional BERD/GDP	Log of regional BERD dived by regional GDP	-0.36	0.58
Regional POP	Log of regional total population	15.1	0.78
Regional MANUF	Log of share of regional manufacturing in total regional GDP	2.72	0.42

Appendix Table 2: Correlated random effects probit estimations for being a continuous innovator: including continuous external R&D engagement and different lags

	(1) Incl. >2 years cont. external R&D	(2) Incl. >3 years cont. external R&D	(3) Incl. >4 years cont. external R&D	(4) 2 year lag	(5) 4 year lag
Regional BERD/GDP (log)	0.012*** (0.004)	0.012*** (0.004)	0.013*** (0.004)	0.012*** (0.005)	0.012*** (0.004)
Regional POP (log)	0.003 (0.003)	0.004 (0.003)	0.003 (0.003)	0.004 (0.003)	0.004 (0.004)
Regional MANUF (log)	0.003 (0.007)	0.004 (0.007)	0.004 (0.007)	0.003 (0.007)	0.003 (0.007)
SIZE (log)	0.023*** (0.007)	0.023*** (0.007)	0.024*** (0.007)	0.024*** (0.007)	0.024*** (0.007)
DOMGROUP	0.011** (0.005)	0.012** (0.005)	0.012** (0.005)	0.012** (0.005)	0.012** (0.005)
FOREIGN	0.001 (0.008)	-0.0003 (0.008)	-0.001 (0.008)	-0.001 (0.008)	-0.001 (0.008)
NEW	0.033* (0.018)	0.026 (0.018)	0.027 (0.018)	0.026 (0.018)	0.026 (0.018)
PROD(log)	0.005 (0.004)	0.006 (0.004)	0.007 (0.004)	0.006 (0.004)	0.006 (0.004)
EXPORT	-0.007 (0.007)	-0.008 (0.007)	-0.009 (0.008)	-0.007 (0.008)	-0.007 (0.008)
COOP	0.008* (0.005)	0.007 (0.005)	0.006 (0.005)	0.006 (0.005)	0.006 (0.005)
C_Inno_1	0.204*** (0.005)	0.210*** (0.005)	0.214*** (0.006)	0.219*** (0.005)	0.219*** (0.006)
C_Inno_0	0.061*** (0.006)	0.066*** (0.006)	0.069*** (0.006)	0.073*** (0.006)	0.073*** (0.006)
msize	-0.006 (0.007)	-0.005 (0.007)	-0.005 (0.007)	-0.004 (0.007)	-0.004 (0.007)
mnew	0.006 (0.037)	0.017 (0.037)	0.017 (0.038)	0.021 (0.038)	0.022 (0.038)
mprod	-0.001 (0.005)	-0.003 (0.005)	-0.004 (0.005)	-0.005 (0.005)	-0.005 (0.005)
mexport	0.051*** (0.010)	0.052*** (0.010)	0.052*** (0.010)	0.052*** (0.010)	0.052*** (0.010)
mcoop	0.082*** (0.008)	0.079*** (0.008)	0.080*** (0.008)	0.076*** (0.008)	0.076*** (0.008)
Number of observations	42492	42492	42492	42492	42492
Log likelihood	-12532.6	-12678.4	-12758.7	-12932.8	-12932.4

Notes: (1) The coefficients reported are the marginal effects computed at mean values. Clustered standard errors are presented in parentheses; ***, **, * = statistically significant at the 99, 95 and 90% levels. (2) All estimations include a constant, industry fixed effects based on 43 unreported sector dummies, and year dummies.

Appendix Table 3: Correlated random effects probit estimations for being a continuous innovator: with NUTS 1 fixed effects and further regional controls

	(1) All firms	(2) Manuf.	(3) Services	(4) Manuf.	(5) Manuf.
Regional BERD/GDP (log)	0.023** (0.010)	0.044*** (0.013)	-0.011 (0.016)	0.041** (0.017)	0.041** (0.017)
Regional POP (log)	-0.008 (0.007)	-0.019* (0.010)	0.007 (0.010)	-0.018* (0.010)	-0.020** (0.010)
Regional MANUF (log)	-0.013 (0.023)	-0.058 (0.037)	0.042 (0.030)	-0.057 (0.037)	-0.053 (0.038)
Regional GDP per capita (log)				0.017 (0.062)	0.017 (0.062)
Regional Area (log km^2)					0.006 (0.007)
SIZE (log)	0.024*** (0.007)	0.029*** (0.010)	0.017* (0.009)	0.029*** (0.010)	0.029*** (0.010)
DOMGROUP	0.013** (0.005)	0.019*** (0.007)	0.0001 (0.008)	0.019*** (0.007)	0.019*** (0.007)
FOREIGN	-0.001 (0.008)	-0.009 (0.010)	0.002 (0.016)	-0.009 (0.010)	-0.009 (0.010)
NEW	0.026 (0.018)	0.043 (0.027)	0.011 (0.023)	0.043 (0.027)	0.043 (0.027)
PROD(log)	0.006 (0.004)	0.019*** (0.006)	-0.004 (0.006)	0.019*** (0.006)	0.019*** (0.006)
EXPORT	-0.007 (0.008)	-0.011 (0.012)	-0.003 (0.010)	-0.011 (0.012)	-0.011 (0.012)
COOP	0.006 (0.005)	0.006 (0.006)	0.005 (0.008)	0.006 (0.006)	0.006 (0.006)
C_Inno_1	0.219*** (0.006)	0.220*** (0.008)	0.221*** (0.009)	0.220*** (0.008)	0.220*** (0.008)
C_Inno_0	0.073*** (0.006)	0.070*** (0.008)	0.066*** (0.009)	0.070*** (0.008)	0.070*** (0.008)
msize	-0.004 (0.007)	0.002 (0.011)	-0.006 (0.010)	0.002 (0.011)	0.002 (0.011)
mnew	0.020 (0.038)	0.003 (0.066)	0.037 (0.046)	0.004 (0.066)	0.005 (0.066)
mprod	-0.005 (0.005)	-0.020*** (0.008)	0.006 (0.007)	-0.020*** (0.008)	-0.020*** (0.008)
mexport	0.052*** (0.010)	0.043*** (0.016)	0.054*** (0.014)	0.044*** (0.016)	0.044*** (0.016)
mcoop	0.077*** (0.008)	0.077*** (0.011)	0.072*** (0.013)	0.078*** (0.011)	0.078*** (0.011)
NUTS 1 fixed effects	Y	Y	Y	Y	Y
Number of observations	42492	25875	16594	25875	25875
Log likelihood	-12930.0	-7996.8	-4901.5	-7996.8	-7996.4

Notes: (1) The coefficients reported are the marginal effects computed at mean values. Clustered standard errors are presented in parentheses; ***, **, * = statistically significant at the 99, 95 and 90% levels. (2) All estimations include a constant, industry fixed effects based on 43 unreported sector dummies, and year dummies.