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Internal and External Determinants of Radical and Incremental Innovation in SMEs: the case of Catalonia*

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Abstract

There is a major concern in economic literature about innovation, which is the interaction between internal and external factors.. In this paper those activities are hypothesized as being determined by some territorial characteristics like labour skills, technological infrastructure, educational facilities, agglomeration economies and industrial structure. This assumption allows understanding why those innovative activities are not spread across space and are located into specific areas. We use a detailed survey containing microdata for 497 SMEs located in Catalonia.

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1. Introduction

A multitude of contributions over the last two decades have now made clear that innovation and economic growth go hand in hand. However, despite the importance of innovation being generally recognised, no unifying theory has yet been proposed on what the main determinants of innovation activities are. Studies which focused just on 'intra-firm' determinants reached different, and sometimes contrasting, results, which in turn led other researchers to study the role of 'external' factors and in particular firm location and co-location with other local actors.

The spatial distribution of innovative activities is an issue that has been puzzling authors for a long time. Why do innovative activities locate in some places and not others? What are the reasons that trigger and sustain the concentration of innovation in certain areas? Traditionally, the answer to this question has been related to the presence of 'agglomeration economies' being these either 'Marshallian specialization' economies (Marshall, 1919) or 'Jacobian diversification' economies (Jacobs, 1969). By clustering together, firms, especially if small, can reduce the costs and risks associated with innovation activities by exploiting external economies generated by a pool of common production factors (such as local infrastructures, specialised local labour etc.). However, over the years several different theories have emerged offering more insights into the phenomenon.

Although these theories are often seen as competing, most of them are, in fact, complementary as they stress different aspects of the same issue. Contributions in the fields of evolutionary economics (Caniels, 2000), international business (Cantwell and Iammarino, 2003), management science (Porter, 1990), economic geography (Simmie, 2002; Acs, 2002), new industrial areas (Scott, 1988; Saxenian, 1994) are all linked by the effort to understand the reasons for the differences in the spatial distribution of innovative activities and in particular the role of agglomeration economies, and local externalities (mainly in the form of *knowledge spillovers*). The idea that knowledge spillovers among firms co-located in the same local area was popularised in the 1990s (e.g. Glaeser et al., 1992) but it is by no means new, as it dates back to both Marshall (1890) and Schumpeter (1942). Two main shortcomings of this body of literature are, however, the difficulty to measure knowledge spillovers - given their intangible nature[1] - and the definition of 'local' area. How far does knowledge spills-over? And, consequently, what is the most appropriate spatial unit of analysis (Black, 2006)?

Another key issue is how to measure innovation. The two main approaches to measure innovation are either using innovation inputs or the innovation output. On the inputs side, indicators such as R&D employment (Porter and Stern, 1999); R&D expenditures (Adams, 2002); employment in creative sectors (Fingleton et al., 2003) or HT manufacturing (Maggioni, 2002; Malecki, 1985) have been used. On the output side, by far the most common indicator is patents (e.g. Faggian and McCann, 2006; Criscuolo, 2005; Breschi, 2000 and Guerrero and Sero, 1997 for the case of Spain). The problems with these standard indicators, however, are well-known[2]. Patents especially are a very imperfect way of measuring regional innovation as a large number of innovations are not patented at all or are not patented in the location where they actually occur. An alternative way of measuring innovation output is to rely on innovation surveys. Although innovation surveys are not a perfect way to measure innovation either, as they rely heavily on the subjective responses by firms, they do represent a significant step forwards if compared with patent data. As Ratanawaraha and Polenske (2007) point out: "*Innovation counts obtained from innovation surveys are supposedly more representative of innovative outputs than patents as they directly measure the final output from the innovation process*". This was also recognised by the OECD (1997) which encouraged governments to support initiatives aimed at collecting primary data on innovative activities.

[1] On this point see e.g. Krugman (1991a and 1991b).
[2] See Carter (2007) for a comprehensive review of methods to measure innovation and their related problems.

Unfortunately, information on innovation is not reported neither in censuses nor in other administrative data[3] (Carter, 2007) so innovation surveys are normally conducted by academics on a smaller scale. DeBresson (1996) led a cross-country effort to collect innovation data directly from the establishments. Data were collected in Italy, Greece, France, Canada and China. This first attempt was then followed by others in other countries, such as Baptista and Swann (1998) and De Propris (2002) for the case of UK.

Following the idea by Ratanawaraha and Polenske (2007), in this paper we use primary data on innovation collected via a survey of small-medium enterprises (SME) in Catalunya. The survey was sponsored and carried out by the Catalan association of small and medium size employers (PIMEC) and provides us not only with information on the number of innovations but also on the type of innovations introduced (i.e. product vs. process innovation and incremental vs. radical innovations). This is important as many critics of innovation surveys have pointed out that one of their major drawbacks is that these surveys just 'count' the number of innovations but do not '*distinguish between major or minor, path-breaking and incremental changes'* (Carter, 2007). No survey of this kind has been carried out in Spain before.

In considering the factors fostering innovation, we draw upon the work by Arauzo (2005) and Capello and Faggian (2005) and consider the interaction of both 'internal' (firm) determinants and 'external' (territorial) variables. Our spatial unit of analysis are the 41 Catalan counties.

The paper is organised as follows: firstly we present a review of the most relevant literature on the spatial distribution of innovative activities. Secondly, we analyse the effects of clustering of economic activities over innovation, using both a theoretical and empirical approach. This is followed by a discussion of the data and methodology used and the main results of our modelling process. The final section presents some preliminary conclusions and further avenues for future research.

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[3] One noticeable exception to this is the Community Innovation Survey in the UK which is carried out by the Department for Business, Innovation & Skills.

2. Theoretical background

The spatial distribution of innovative activities is an issue that has been puzzling authors for a long time. Why do innovative activities locate in some places rather than others? What are the reasons that trigger and sustain the concentration of innovation in certain areas? Traditionally, the answer to this question has been related to the presence of Marshallian 'agglomeration economies' (Marshall, 1919). By clustering together, firms, especially if small, can reduce the costs and risks associated with innovation activities by exploiting external economies generated by a pool of common production factors (such as local infrastructures, specialised local labour etc.). However, over the years several different theories have emerged offering more insights into the phenomenon. Although these theories are often seen as competing, most of them are, in fact, complementary as they stress different aspects of the same issue. Contributions in the fields of evolutionary economics (Caniels, 2000), international business (Cantwell and Iammarino, 2003), management science (Porter, 1990), economic geography (Simmie, 2002; Acs, 2002), new industrial areas (Scott, 1988; Saxenian, 1994) are all linked by the effort to understand the reasons for the differences in the spatial distribution of innovative activity and in particular the role of agglomeration economies, and local externalities (mainly in the form of knowledge spillovers).

As a result of the theoretical interest on the determinants of location of innovative activities combined with the availability of more sophisticated technology and data, a plethora of empirical studies has appeared in the last two decades. Most of the initial work came from outside continental Europe, starting from the USA where the main case study was Silicon Valley (Larsen and Rogers, 1984; Saxenian, 1994) followed by other areas such as Boston (Castells and Hall, 1994) and Southern California (Scott, 1993); going to the Cambridge area (Castells and Hall, 1994) and the M4 Corridor (Breheny and McQuaid, 1987) in the UK and Tokyo and Tsukuba in Japan (Castells and Hall, 1994). More recently, however, empirical contributions on the spatial distribution of innovation have started flourishing in Europe too (see for instance Simmie, 2001, where case studies from five different European countries are presented).

If we assume that innovation depends on knowledge spillovers across firms and individuals, it is important to analyse if those spillovers have some kind of spatial limits (Feldman, 1994a and 1994b; Jaffe, 1989). This is an important issue because allows to better determine the spatial level (regional, local, etc.) at which the analysis should be performed. Recent contributions from New Economic Geography (Fujita et al., 1999) have highlighted that economic activities are highly concentrated due to the existence of such knowledge externalities but there is very few empirical evidence about the intensity and the geographical boundaries of those externalities. Usually, scholars conclude in a broad way that knowledge transfers work better at a local level than between more distant locations (Pavitt, 1987), but it is not easy to better identify such knowledge generation frontiers.

Such knowledge externalities are not only responsible of innovations and also generate economic growth. In this sense, there is plenty of empirical evidence that shows that some regions are able to growth faster than others and that those differences can be explained in terms of innovative capabilities (Acs, 2002) but this phenomena may be addressed following different approaches: the *new economic geography* (Krugman, 1991b), the *new growth theory* (Romer, 1990) and the *new economics of innovation* (Nelson, 1993). The *new economic geography* approach is about determinants of spatial concentration of economic activities in a small number of sites, without taking into account growth and innovation issues. The *new growth theory* deals with economic growth processes but not considering both spatial and knowledge issues as main determinants of growth. Finally, the *new economics of innovation* analyses institutions involved in knowledge generation, but from a non spatial point of view and also not considering the effect of innovation over economic growth. As Acs (2002) suggests, there is clearly a gap in the literature since previous points have been traditionally analyzed from an isolated approach, while they are certainly related. Therefore, an analysis aiming to identify innovation processes at a regional / local level must consider an integrated approach to this phenomenon. A possible solution to solve this bias could be the "regional knowledge production equation", as Acs (2002) points out.

3. Data and methodology

Our data on firm innovative activities come from a unique employer-employee survey carried out with the help and support of the Small and Medium Size Employers Association in Catalonia (PIMEC - *Micro, petita i mitjana empresa de Catalunya*) between September 2005 and May 2006. A focus group made up of employers and experts was initially set up to help developing and customizing the survey to the specificities of each sector. A pilot survey was also carried out implementing the recommendations of the focus group.

Four types of questionnaires were developed and distributed to different groups of workers within each firm, i.e. general manager, managers, supervisors and core non-management employees. The questionnaire for general managers included questions on the main characteristics of the firm (size, ownership, degree of internationalization), evolution and position in the market, process technology, product strategy and innovation activities, HR practices and work orgnization. The questionnaire for managers, supervisors and core employees consisted of a detailed investigation on the nature and content of their jobs. Questions ranged from human capital and other specific characteristic of the worker, to a comprehensive description of the workplace, both in contractual terms (working hours, earnings, type of contract…) and in terms of what the job entailed (competences required, required time to reach the optimum level of productivity in the job, degree of intensity, degree of freedom to organize tasks). Firms were first approached by telephone to gain participation and once they agreed on it, questionnaires were sent by postal mail and picked up personally by a courier. Our final sample consists of 361 firms (about 17% of the universe) belonging to 6 different manufacturing sectors (Food & beverages, Rubber & plastics, Fabricated metal products, exc. Machinery, Machinery & equipment, Office, accounting & computing machinery and Furniture). With regard the firm dimension of the data sat, it is representative at both sectoral and provincial level and we also checked the consistency of our sample with respect some key aspects of the firm, among others, size and productivity. It is more difficult to give an appraisal of the representativeness of the sample at the employee dimension as we don't have an external source of what would be the universe from which the sample should be drawn. We have, however, the firm self reported number of employees within the three occupational groups we interviewed, and we could reach almost 63% of them.

The survey had a specific section to measure product innovation activities carried out by the firm over the last two years. Firms provided information on whether they had introduced any innovation at all, and also which type of innovation, classified in a five item list from radical (a complete new product) to marginal (just a change in how the product was introduced into the market). Note that our information on the type of product innovations is not just whether they introduced any but the specific number and the percentage of sales that they represent on current turnover.

The primary survey data on firms were then combined with secondary data on the characteristics of their location. To build the territorial dataset, we combined the database from Trullén and Boix (2005) on Catalan municipalities, data from the Catalan Statistical Institute (IDESCAT) and the Catalan Cartographical Institute (ICC), and finally data from Hernández et al. (2005).[4] The territorial units used in the database building process were the 41 *comarques* (counties) in Catalonia[5], which represent a quite detailed level of analysis[6]. Traditionally, the analysis of the spatial determinants of innovative activities – both from the USA and Europe - has been carried out at a much larger scale, i.e. larger administrative or functional areas (e.g. Jaffe et al., 1993 for the USA and Autant-Bernard, 2001a, 2001b for the case of France). Very little has been said about smaller spatial units such as counties.

Our final database includes a variety of information on different aspects of the *comarques,* such as the spatial distribution of economic activities, commuting

[4] See Table A.1 (Appendix) for a description of the explanatory variables.
[5] Catalonia is an autonomous region of Spain with about 7 million inhabitants (15% of the Spanish population) and an area of 31,895 km^2. It contributes 19% of Spanish GDP. The average area of Catalan municipalities is 19.6 km^2. The capital of Catalonia is the city of Barcelona.
[6] The average area of the Catalan *comarques* is 781 km^2.

patterns, population characteristics (including education, age distribution, gender, etc.), land use, housing and infrastructures.

4. Methodology

Since we had information not only on the number of innovations implemented by each firms, but also their ‘nature’ (i.e. incremental vs. radical), we developed two separate models for incremental and radical innovations. It was indeed clear from the initial pooled regression (and maybe not unexpectedly) that the determinants of the two were quite different.

As our dependent variable was the number of innovations (and not simply whether firms were innovative or not) Count Data Models (CDM) were the most suitable methodology. The most well-known CDM is the Poisson model, but this model suffers from two major drawbacks. Firstly, it assumes equidispersion in the data, i.e. equality between the mean and the variance (as there is only one parameter in the model). Secondly, its results are invalidated by a large number of ‘zero’ values in the dependent variable.

The equidispersion assumption does not fit most real data. Very often data shows *overdispersion*, i.e. a variance well above the value of the mean. As such, the conventional Poisson mean-variance restriction may produce seriously biased parameter estimates (see Cameron and Trivedi, 2005 and Wang et al., 1996). As Table 1 shows our dependent variables were clearly overdispersed with a standard deviation three and five times the mean for incremental and radical innovations respectively.

[Insert Table 1 about here]

To accommodate for overdispersion and alternative to the Poisson model is a *mixture model*, which explicitly models heterogeneity among observations by adding an extra parameter, function of *unobserved* heterogeneity. In other words, while the Poisson models assumes that the mean, μ_i, is equal:

$$\mu_i = \exp(\mathbf{x}_i\beta) = E[y_i \mid \mathbf{x}_i] = Var[y_i \mid \mathbf{x}_i] \quad (1)$$

a mixture model assumes that:

$$\mu_i^* = E[y_i \mid \mu_i, \nu_i] = \mu_i \nu_i \quad (2)$$

where the $\nu_i = \exp(\varepsilon_i)$ and therefore:

$$\mu_i^* = \exp(\mathbf{x}_i\beta)\exp(\varepsilon_i) \quad (3)$$

Assuming that ν_i is *iid* with $E[\nu_i] = 1$ and $Var[\nu_i] = \sigma_\nu^2$ it can be proved (see Cameron and Trivedi, 1998) that:

$$E[y_i \mid \mathbf{x}_i] = \mu_i < Var[y_i \mid \mathbf{x}_i] = \mu_i[1 + \sigma_\nu^2 \mu_i] \quad (4)$$

The negative binomial model is a specific case of mixture models in which $\exp(\varepsilon_i)$ is supposed to be drawn from a gamma distribution.

Our data also show evidence of the 'excessive zeros' (for radical innovations 65% of firms reported zero innovations while for incremental ones was 75%) problem so that the negative binomial in its basic form still would provide us with biased estimates. Lambert (1992) introduced the idea of 'zero-inflated' count models. These are two-step models. The first step is used to model the probability of belonging to the zero-group vs. the non-zero group (a binary process) while the second step is a traditional count model (either Poisson or negative binomial regression). Formally, the density function becomes (see Cameron and Trivedi, 2005):

$$g(y) = \begin{cases} f_1(0) + (1 - f_1(0)) f_2(0) & \text{if y=0} \\ (1 - f_1(0)) f_2(y) & \text{if } y \geq 1 \end{cases} \quad (5)$$

where $f_1(.)$ is a logit model and $f_2(.)$ is, in our case, a negative binomial density.

Hence the explicit form of our final model, in the form of a 'zero inflated negative binomial' (from now on referred to as ZINB), can be written as:

$$\Pr(Inn{=}1 \mid z_i) = \frac{e^{-z_i\gamma}}{1 + e^{-z_i\gamma}} \qquad (6)$$

where $\mathbf{z_i}$ is a set of 'inflation' variables, which separates innovative and non-innovative firms.

$$\Pr(y_i \mid x_i) = \frac{\Gamma(y_i + \alpha^{-1})}{y_i!\,\Gamma(\alpha^{-1})}\left(\frac{\alpha^{-1}}{\alpha^{-1} + e^{-x_i\beta}}\right)^{\alpha^{-1}}\left(\frac{e^{-x_i\beta}}{\alpha^{-1} + e^{-x_i\beta}}\right)^{y_i} \qquad (7)$$

where Γ indicates the standard gamma function, α determines the degree of dispersion in the predictions (the larger α, the more spread are the data), and $\mathbf{x_i}$ is a set of explanatory variables believed to influence the number of innovations implemented by each firm

Both, the 'inflation' variables, $\mathbf{z_i}$, and the second-stage binomial regression variables, $\mathbf{x_i}$, include not only internal firm characteristics, but also external, location-specific, characteristics. The inflation variables are a sub-sample for the whole vector of explanatory variables and are those hypothesized to explain decisions to innovate in terms of which required characteristics to innovate are.

[Insert Table 2 about here]

Our expectations were for counties with a high density of high-tech workers (TERRITORIAL HUMAN CAPITAL) and R&D infrastructures (TECHNOLOGICAL CENTRES) to be able to foster the innovative capacity of firms. Concretely, firms need to be close to areas with a high density of skilled labor, in view that this is key issue for carrying out innovation activities, as well as it is of big importance to have good accessibility to R&D infrastructures where knowledge is created. Moreover, being located in a cluster of firms belonging to the same sector (CLUSTER) should also make it easier to exchange knowledge and access the necessary technological infrastructures to enhance innovation (Feldman, 1994b) and to benefit from localisation economies (Baptista and Swann, 1998). In any case, in view that extant empirical evidence is contradictory[7] we can not strongly anticipate the specific effect of being inside a cluster over innovative performance.

Additionally, location-specific amenities, such as being close to the coast (COAST) could potentially, attract more skilled individuals (Woodward et al., 2006) and, therefore, indirectly increase the number of innovations[8]. Proximity to larger cities (e.g., province capitals) has also been considered, as having access to main infrastructures, services, R&D services, specialised suppliers and public administrations is sometimes key in developing certain kinds of innovations. We therefore expect that a higher distance from the province capitals (DISTANCE PROVINCE CAPITAL) would lower the number of innovations produced. Nevertheless, there is empirical evidence (Orlando and Verba, 2005) that clarifies the effect of bigger urban areas and suggests that proximity to such areas is positive for innovation is emerging fields where knowledge spillovers are stronger but, at the same time, proximity to smaller (lets say, less congested areas) favours innovative activities in mature fields.

With regard to the firm level variables, we expect that firms competing in more competitive markets will have to rely more on being innovative. We proxy this hypothesis by introducing in the equation the exporting intensity (European sales) and two controls: size and industry. We also want to capture how the investments in developing internal expertise help to achieve high levels of innovative capacity. To do so, we include in the model the human capital level of the firm and their process technological level (as a way to generate knowledge spillovers between process and product innovation). Finally, we deal with two additional issues usually stressed in the literature. First, the financial

[7] Concretely, while for De Propris (2002) being in a cluster has no effect over innovation activities, Baptista and Swann (1998) find a positive relationship explained in terms of positive effects of location externalities.

[8] The idea behind this supposition is that a nice place to live is a better place to innovate. So, areas with some natural amenities (e.g., shoreline areas) have some advantages in terms of potential innovations or increases on workers' productivity (Jeppesen et al., 2002). Although approaches to such amenity oriented issues are quite heterogeneous, most of them try to proxy the existence of local quality of life as in Woodward et al. (2006) where the amenity index used includes temperature, sunshine, humidity, topographic variation and water area.

constraints to invest in product development (Returns) and secondly, the strategic (long time) dimension of developing new products (Product Strategy).

Previous expected effects were referred to both firms' internal and external characteristics without any kind of interaction, but in real life things use to be more complex and often internal characteristics of firms interact with the characteristics of the area where such firm is located. Therefore it is important to control not only for these internal / external characteristics, but also for the possible interactions extant among them. In this sense, Hervas-Oliver and Albors-Garrigos (2009) analyse the Castelló ceramic cluster in Spain and conclude that the interaction between firm's internal resources and firm's external resources enhances innovation activities and that this phenomena is more prone to occur inside a cluster.[9] Accordingly, there is some kind of complementarity between internal and external resources but some kind of absorptive capacity is needed in order to benefit from such complementarities. This is a key assumption, given that, as Hervas-Oliver and Albors-Garrigos (2009, p.277) say "(…) exploitation of external resources by firms is necessary but not sufficient. In fact, internal resources limit the acquisition of external knowledge and affect innovation. This threshold effect means that the access to certain external resources requires a minimum level of (absorptive capacity) internal resources". Therefore, apart from the specific effects that stock of (internal and external) knowledge has, it is more important to focus on the interaction between both sources and to how firm's ability to capture external knowledge depends on it's own internal knowledge sources.

5. Results

Table 3 presents the results for the models predicting the determinants of the number of radical and incremental product innovations. There are three aspects that are worth commenting.

[9] It is important to notice that inside the cluster analysed by Hervas-Oliver and Albors-Garrigos (2009) innovations are typically supplier-driven with a medium technology level, so generalisations of their conclusions to other types of clusters should be applied with care.

[Insert Table 3 about here]

First of all, our results clearly indicate that it is necessary to analyze both radical and incremental innovation in separate models, not just because the model predicting radical innovation seems to perform slightly better, but most importantly because these two phenomenon's seem to respond to different logics and, hence, firms and territories should have to develop different strategies to spur these two activities. This is an expected result since dynamics of both types of innovations are so different. Concretely, while radical innovations consist on important changes on products, incremental innovations consist only on smaller modifications. So, differences on the characteristics, process and inputs required by those innovative activities also imply that their determinants are not exactly the same and although they share some of them, the weight and directions of their influence also differ.

Secondly, we can also observe in our results that both firm and territorial characteristics play an important role in the process of product innovation. This is an important outcome of this paper and implies that it is essential to analyze the interaction between both levels (and explore, for instance whether they are complements or substitutes and, in this case, which the trade off is). So it is important to take into account not only firm ability to innovate (in terms of its own resources) but also the environment where the firm is located (in terms of the resources available outside the firm).

Finally, our results show that the ZINBM model seems to adjust correctly to the characteristics of the data. Therefore, firms initially commit on developing new products and, afterwards, depending on how successful are in exploiting the resources put in motion, they will develop more or fewer new and improved products. In other words, innovation activities are not just a random process but most likely a highly planned process that must be strategically approached to be successful.

If we look at the details of the estimation technique, the ZINBM procedure used consists on two different stages: the first one (presented here at the bottom of the table) is about the variables that explain the zeros, i.e., the firms where there are no innovations (those are the inflation variables); the second one is about the variables that explain the intensity of the innovations carried out by the firms (i.e., the number of innovations). So, while at the second section (i.e., inflation) positive (negative) and significant values means higher (lower) number of zeros, at the first section (firm variables and territorial variables) positive (negative) values means higher (lower) number of innovations.

Turning our attention to a more detailed analysis of the results presented in Table 3, it seems that the model predicting innovation at the incremental level is estimated slightly more precisely than the model for radical innovation. Similarities between both types of innovation are more evident in the first part of the model (predicting the probability of engaging in any type of innovation; i.e., the inflate section). Thus, what helps (or makes difficult) to be innovative (in terms of the decision to innovate) is similar across the range of product novelty, but is less so when we consider how successful (intensity) are the efforts in developing new or improved products. Most likely this result reflects that radical innovations are more complicated to develop than incremental and require a set of more complex inputs that not all firms can manage to put together.

Firstly, we will concentrate on what determines the existence of innovations, no matter their number. If we look at the spatial variables we find both expected and unexpected results. As it seems logical, higher the distance to the most important urban areas (proxied by province capitals) higher the cases in which there are no innovations (although the coefficients are quite small and even not significant for the incremental innovations). This means that firms that are far away from such "important" cities experience more difficulties to get innovations (so, they have a lower likelihood of innovating). But, surprisingly, higher is the number of technological centres in the same county (radical ad incremental), higher is the number of no-innovations. So, our preliminary results show that research centres reduce the innovation activity, which is, to some extent, an unexpected outcome. Nevertheless, there are some possible hypotheses to explain those results: the firms' innovative strategies (if the research centres carry out innovative activities firms do not need to do so, so there is some kind of substitution process), a failure of the tech centres (this is about public policies promoting knowledge transfer), the types of relationships between firms and tech centres (whether they have developed sufficient linkages with local productive systems), the industry characteristics of tech centres (whether they are specialised in concrete activities or they do cover a wide range of scientific areas) and so on. Therefore, it seems that due to firm's decisions or due to public research policies, there is a lack of connectivity between these firms and extant public research centres located close to them. Also in the same sense it is surprising that clustering has no significant effect on innovation activity in terms of innovate vs. not innovate.

Firms that use a more complex process technology and have a more skilled workforce present a higher probability of engaging in product innovation. Clearly, knowledge accumulation is a key determinant of product innovation. However, in the second part of the model (when intensity is measured) the quantity of human capital at the firm level has a negative impact on the number of radical innovations introduced over the last two years. It is interesting to observe that the proxy for firm profitability (returns to assets) has a negative impact on the probability of being innovative (radical innovations). This could be at first sight contra intuitive, but can clearly be understood if we consider that a product has a life cycle and once it has been successfully introduced in the market the firm has little incentive in modifying it because wants to recoup all the product developing costs. Also, we have to consider that our sample is made up of small and medium size firms that quite often can not handle a large number of products. On the contrary, the impact of this variable on the intensity of the innovation activity is positive and significant for radical innovation. This is consistent with the empirical research that has showed that there are financial restrictions to firms' innovation activity.

Secondly, we will focus on what determines the intensity (number) of innovations. At this point the results are closer to those expected since, for instance, higher is the territorial human capital around firms higher is the number of innovations (although the variable is only significant for radical innovations). This result could be easily explained in terms of spillover effects among innovative firms.

The research centres variable provides again surprising results since it reduces innovation intensity (radical innovations). This result reinforces our previous argument about which is the role played by such centres and until which point those are efficiently integrated into their local production systems. Although this is a contra intuitive result, in terms of policy implications it suggests to check whether Catalan policy in terms of public research centres is appropriate and provides useful solutions to firms according to their expectations.

Clustering increases innovation intensity but only for incremental innovations. At this point we should emphasize that empirical evidence on the effect of clustering over innovation activation is not clear. Although it is hypothesized to have a positive effect since clustering makes easier the accessibility to some technological infrastructure that enhances innovation (Feldman, 1994b), empirical findings point out that it is important to take into account specific relationships among firms and R&D institutions. As an example De Propris (2002) show that for West Midlands (UK) clustering does not influence positively and significatively innovative outcomes. From our data it is not possible to asses the type of relationships among firms and tech centres, but we could argue that this contra intuitive result could be explained in terms of firm strategies about being engaged in R&D activities with tech centres from outside the region. Unfortunately this strategy implies that firms are not full benefiting of agglomeration economies.

The spatial position of the county also matters in terms of innovative behaviour. Concretely, while higher is the distance to the capital of the province lower is the innovation activity (innovate vs. not innovate) but higher is the distance higher is the expected number of innovations (incremental innovations). Although this variable is not significant for radical innovations, results for incremental ones indicate some kind of sprawl of innovative activities in terms that firms need to be sufficiently far away for bigger urban areas trying to not suffering from disagglomeration economies, but they also need to be close enough in order to get benefits from agglomeration economies.

Finally, regarding natural amenities, while being at the seaside has a positive effect on radical innovations, it has a negative effect on incremental ones. This later result could explained both in terms of non economical issues about environmental amenities related with quality of life (attractiveness of seaside areas) and in terms of better transport infrastructures at seaside.

Although we are not directly controlling for internal – external interactions, it is important to take into account that usually it is not enough to have enough internal capabilities and external resources, but what is important is the way how they interact. So, as Hervas-Oliver and Albors-Garrigos (2009) point out, complementarities between internal and external resources are a key issue for assuring innovative activities. Accordingly, spatial proximity among firms, research centres and specialised clusters is not enough, given that it is also necessary to get an appropriate interaction among all these agents. Therefore, the existence of both internal and external resources is a necessary but not a sufficient condition.

6. Conclusions

This paper contributes to the extant literature on firm innovation by demonstrating that both internal and external characteristics of firms (as well as the interactions among them) must be taken into account when analysing firm innovation determinants. So, it is important to reach some kind of complementarities between the internal capabilities of the firm (as, for instance, skills of their employees or financial resources, among others) and the economic, geographical and institutional characteristics of their environment (as, for instance, the existence of high-tech firms in the same area or the distance to main cities, among others). With respect to the territorial variables, and rather surprisingly, some of them come out either non significant or with a negative impact on the propensity to innovate. On a general approach, we can interpret this result as indicating that a firm decides to innovate or not depending on their internal resources. As we introduced above, our hypothesis is that firms decide strategically whether to innovate or not, and, in consequence, they can not rely only in external/internal resources to base such a decision. However, once they have decided that their strategic approach to the market will be based on innovative products (more than in prices) being surrounded by a territory that offers inputs as skilled human capital will help to be successful.

According to firm's innovation determinants, we have assumed that them could be classified into strictly "internal" (firm's approach of determinants of innovation at firm's level), "external - territorial" (regional based approach on regional determinants of firm's innovation considering tacit knowledge) and "external – relational" (firm's approach on externals sources of codified knowledge). This distinction allows going further from traditional divide between internal an external approaches to innovation determinants and to take into account that innovation activities at firm level depend on *i*) internal characteristics of the firm as size, strategies or technological intensity, among others; *ii*) external characteristics of the area where the firm is located as the accessibility to technological centres, clusters or skilled labour, among others and *iii*) interactions with external firms and institutions that rely on firm's internal resources.

Notwithstanding, we have also found evidence of the theory of absorptive capacity, which is about complementarities between internal and external knowledge sources[10], but we should have in mind that this theory also suggests that in order to take advantage of external knowledge it is crucial to rely on a strong internal knowledge sources, which usually implies to carry out internal R&D activities (Busom and Fernández-Ribas, 2008).

[10] In any case, it is important to point out that absorptive capacity is about incorporating external knowledge using internal knowledge sources, but that external not necessary is referred to the geographical area where the firm is located.

Additionally, a distinction must be drawn between radical and incremental innovations. Incremental innovations are a more complex (and heterogeneous) phenomenon of which little is known despite its importance. In this paper we have approached them in a symmetric way due to comparison purposes, but additional work is needed in order to get specific models for each type of innovations.

Previous results have some important policy implications since firm innovative strategies' must focus not only on improving their innovative assets, but also on choosing the most appropriate sites for enhancing such activities. At the same time, public administrations could better map the expected results of their innovation supporting policies by taking into account the innovative outputs of supported firms according to both their internal characteristics and their geographical location. Finally, we should notice that there is already room for new contributions focusing on how firms are able to use their internal resources to get benefit of their external environment and increase their innovation activities.

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Tables

Table 1: Summary statistics of the dependent variables

	No valid. Obs.	Mean	St. Deviation	Skewness
RADICAL INNOVATIONS	297	3.42	17.43	8.29
INCREMENTAL INNOVATIONS	267	5.16	14.76	4.29

Source: Our elaboration on PIMEC survey data

Table 2: Explanatory variables: definition and sources

(firm variables)		
Variable	**Definition**	**Source**
EUROPEAN SALES	Percentage of sales to European customers	PIMEC survey
PRODUCT STRATEGY	Dummy variable equal 1 if the manager stated that the firm had a formal product strategy	PIMEC survey
TECHNOLOGICAL INTENSITY	Number and type of technologies possessed by the firms (list of eight different production technologies)	PIMEC survey
SECTOR	Dummy for each industry: Food & beverages, Rubber & plastics, Fabricated metal products, exc. Machinery, Machinery & equipment, Office, accounting & computing machinery and Furniture	PIMEC survey
FIRM HUMAN CAPITAL	Percentage of core employees (production workers) with college education or higher vocational education	PIMEC survey
FIRM SIZE	Number of employees	PIMEC survey
RETURNS	Sale-cost ratio	PIMEC survey
(territorial variables)		
Variable	**Definition**	**Source**
TERRITORIAL HUMAN CAPITAL	Percentage of labour at high-tech manufacturing firms	Trullén and Boix (2005)
COAST	Shore-line areas	IDESCAT
TECHNOLOGICAL CENTRES	Number of technological centres	Trullén and Boix (2005)
DISTANCE PROVINCE CAPITAL	Distance (km) to the closest province capital	ICC
CLUSTER	Dummy variable about if the firm is inside a cluster of its own industry	Own elaboration from Hernández et al. (2005)

Source: Our elaboration on PIMEC survey data

Table 3: Innovation determinants (Zero Inflated Negative Binomial Model: ZINBM)[a]

	Radical Innovations (RADICAL)	Incremental Innovations (INCREMENTAL)
Firm variables		
EUROPEAN SALES	-0.137 (-0.07)	-2.566 *** (-6.04)
PRODUCT STRATEGY	0.631 * (2.36)	-0.869 *** (4.98)
TECHNOLOGICAL INTENSITY	0.247 (1.48)	0.363 * (2.06)
FIRM HUMAN CAPITAL	-1.872 *** (-3.86)	2.808 *** (5.44)
FIRM SIZE	0.0117 (0.06)	0.410 *** (4.15)
RETURNS	0.0476 *** (4.23)	0.0948 * (1.96)
Territorial variables		
TERRITORIAL HUMAN CAPITAL	88.990 ** (2.93)	7.897 (0.16)
COAST	0.960 * (2.45)	-0.724 *** (3.40)
TECHNOLOGICAL CENTRES	-0.0295 ** (3.04)	-0.0201 (1.06)
DISTANCE PROVINCE CAPITAL	1.17e+05 (1.32)	2.41e-05 * (2.02)
CLUSTER	-0.704 (1.50)	0.946 *** (6.14)
CONST.	-0.073 (0.07)	0.303 (0.62)
Inflate variables (firm)		
RETURNS	1.077 ** (2.83)	0.519 (1.21)
TECHNOLOGICAL INTENSITY	-0.901 *** (3.70)	-0.667 * (2.35)
FIRM HUMAN CAPITAL	-1.753 *** (-4.39)	-0.640 (-1.10)
Inflate variables (territory)		
TERRITORIAL HUMAN CAPITAL	34.76 (1.17)	109.9 (1.51)
TECHNOLOGICAL CENTRES	0.0490 *** (4.82)	0.0134 * (2.34)
DISTANCE PROVINCE CAPITAL	4.16e+05 *** (6.16)	7.09e+06 (1.19)
CLUSTER	0.353 (1.03)	-0.257 (0.69)
CONST.	-1.108 *** (4.27)	0.950 * (2.40)
N	263	270
Nonzero obs.	92	42
Zero obs.	171	228
Log pseudolikelihood	-497.05	-239.92
/lnalpha	0.432 * (2.57)	-0.704 (1.26)
alpha	1.56 (0.267)	0.494 (0.277)

[a] Note: The dependent variable is the number of radical innovations (RADICAL) and incremental innovations (INCREMENTAL).
(***) Significance at 1%, (**) significance at 5% and (*) significance at 10%. Standard errors between brackets.

Source: Our elaboration