Innovation, Heterogeneous Firms, and the Region. Evidence from Spain.

Enrique López-Bazo[1]

Elisabet Motellón[1, 2]

1 AQR, University of Barcelona
Avda Diagonal 690. 08034 Barcelona. Spain
Email: elopez@ub.edu
ORCID: 0000-0002-4654-8237
Corresponding author

2 Universitat Oberta de Catalunya
Avda. Tibidabo 39-43. 08035 Barcelona. Spain
Email: emotellon@uoc.edu
ORCID: 0000-0002-5461-2825

Abstract:

This paper investigates the role of regional factors in innovation performance, controlling for firms' absorptive capacity and other sources of firm heterogeneity. The findings for a sample of firms in Spain support the hypothesis that regional determinants matter, though their role is subtler than is frequently assumed. Rather than exerting a direct influence on firms' innovation, the regional context moderates the effect of internal determinants, particularly of the firms' absorptive capacity. The results indicate that the type of relevant interactions differs for product and process innovation and that they only operate for SMEs, being negligible for large firms.

Keywords: product innovation, process innovation, firm, multilevel modelling, Spanish regions

JEL codes: D21, 031, R10, R15

1. **Introduction**

Innovation is central to firm performance and competitiveness; consequently, it has been claimed to be a key ingredient for the growth prospects of a territory. As a result, stimulating firms' innovation has become a priority on the agenda of agencies and institutions aiming to promote sustained regional growth and development (European Commission, 2014). To this end, many studies have aimed to identify the factors that are likely to increase firms' propensity to perform innovation activities and to succeed in such a process. Broadly speaking, a distinction can be made between the factors that are internal to the firm and those that operate at the level of the region in which the firm is located (Sternberg and Arndt, 2001). Whereas almost all studies have agreed that internal determinants exert a substantive effect, much less consensus exists regarding the contribution of the external or regional factors. Against this background, this paper aims to provide additional evidence on the contribution of external regional factors to firms' innovation performance. As indicated by Beugelsdijk (2007), more empirical analyses at the regional level for the European Union and the United States are required to confirm or disprove the still-inconclusive empirical evidence. In a similar vein, Fitjar and Rodríguez-Pose (2015) stated that the mechanisms by which the regional context shapes the learning capacity of firms is still poorly understood.

The main objective of the paper is to test the hypothesis that the role played by regional factors is subtler than has been assumed in most of the previous literature. Rather than exerting a direct effect on firm innovation performance, it is assumed that the regional context intertwines with internal factors related to firms' absorptive capacity (Cohen and Levinthal, 1990). The effect on innovation performance of firms' absorptive capacity is, therefore, assumed to vary across regions depending on environmental determinants. Besides, the paper hypothesizes that the contribution of regional factors varies with the size of the firm, innovation in large firms being less dependent on a favourable context. Hence, the paper provides novel evidence on the contribution of the internal and external determinants of firms' innovation for large and for small and medium firms separately.

Some additional features make this study valuable. First, a comprehensive sample of firms in the Spanish regions is used to assess the effect of regional determinants on the probability of innovating in products and in processes. The share of innovative firms varies widely between regions in Spain, which makes it interesting to investigate whether the origin of the differences lies in disparities in the regional context or whether they are mostly due to regional differences in firms' internal determinants. Second, in contrast to several previous studies, the firm-level dataset includes a rich set of firm characteristics, which allows this study to control for several sources of firm heterogeneity. This avoids confounding the effect of external determinants with that of (omitted) firm characteristics. Third, multilevel models are estimated to accommodate the hierarchical structure of the data. This type of model has been claimed to be the most appropriate specification for estimating the contribution of regional factors to firm innovation (Srholec, 2010), although the number of studies following this approach is still small.

The rest of the paper is organized as follows. The next section briefly reviews the previous evidence on the contribution of internal and regional factors to firms' innovation and discusses the hypotheses of the study. Section 3 sketches the multilevel model used to obtain the estimates of the effect of the internal and external determinants, while the data set and the main variables are introduced in section 4. The results for the entire sample of firms and those distinguished by size are presented and discussed in section 5. Finally, section 6 concludes.

2. Review of 'the Firm versus the Regional Determinants of Innovation' Literature

Innovation has been shown to be a crucial determinant of the market opportunities of firms (Crepon, Duguet, and Mairesse, 1998; Geroski, Machin, and Van Reenen, 1993; Griffith, Huergo, Mairesse, and Peters, 2006; Hall and Mairesse, 1995), also playing a fundamental role in the growth prospects of regional economies (Audretsch and Feldman, 1996; Crescenzi, 2005; Rodríguez-Pose and Crescenzi, 2008; Vogel, 2015). This has generated great interest in the analysis of the determinants of innovation, including those that are internal to the firm and those corresponding to the territory in which the firm operates. The internal factors that influence the innovation performance of a firm include its technological competences, human resources and organizational capabilities, and other features, such as firm size and market concentration (e.g. Vega-Jurado, Gutiérrez-Gracia, Fernández-De-Lucio, and Manjarrés-Henríquez, 2008). In addition to the internal determinants that affect a firm's ability to innovate, factors that are specific to the location in which the firm operates can have an impact on its innovation behaviour. The presence of a highly skilled labour force, an appropriate industrial mix, an enabling institutional framework for innovation, and the availability of local infrastructures conducive to innovation, such as universities and research institutions, are some of the external factors that have been proposed to explain the differences in the innovation behaviour of firms located in different regions (Beugelsdijk, 2007; Dautel and Walther, 2013; Sternberg and Arndt, 2001). Hot spots characterized by a high degree of concentration of these external determinants and innovative firms have been analysed widely in the literature under different denominations (Ibrahim, Fallah, and Reilly, 2009): ‘industrial districts’ (Scott and Storper, 2003), ‘technological clusters’ (Saxenian, 1994), ‘learning regions’ (Gertler, 2001), ‘innovation milieus’ (Keeble and Wilkinson, 1999), and ‘regional innovation systems’ (Cooke, 2001). All of them share the idea that a mix of universities and research institutes, R&D expenditures, and a regional innovation policy are fundamental for the innovation performance of the region. In other words, the regional environment is crucial for firms’ innovation behaviour (Beugelsdijk, 2007), motivating the design of regional innovation strategies aiming to improve the environmental determinants of innovation (Love and Roper, 2001).

Most of the empirical evidence supporting the effect of external factors has been obtained from case studies or by exploiting aggregate regional data, frequently used to estimate the so-called regional knowledge production function (e.g. Fritsch and Slavtchev, 2011; Ponds, Van Oort, and Frenken, 2010). However, the conclusions drawn from the former approach are difficult to generalize beyond the limits of the particular cases under analysis, whereas the ecological fallacy is likely to apply to the latter (Beugelsdijk, 2007). It can be argued that there is dissociation between the level that is relevant to the process of innovation, the level of the firm, and the level for which the evidence is obtained, that of the region. Consequently, conclusions about the effect that external factors have on firms’ innovation performance should be drawn from evidence obtained by means of firm-level data rather than from the aggregate regional level. In this regard the study by Sternberg and Arndt (2001) is the first of a group of recent studies aiming to disentangle the contributions of internal and external determinants of innovation by combining firm-level with region-level data. They claimed that it is the set of characteristics of the firm rather than the regional context that accounts for most of the differences across regions in innovation. Their results for a sample of small- and medium-sized enterprises (SMEs) in a number of European regions confirmed that firm-specific determinants are more important than external regional factors, leading them to suggest that regional innovation policy should emphasize enhancing the innovation capabilities of firms in the region rather than improving the innovation environment in general. Similar evidence has been reported by Beugelsdijk (2007) and Smit, Abreu, and De Groot (2015) for Dutch firms, Vega-Jurado et al. (2008) for Spanish manufacturing firms, Wang and Lin (2013) for Chinese ICT firms, and Lee and Rodríguez-Pose (2014) for UK SMEs.

By and large, these studies have shown that internal determinants are more important for firms' ability to innovate than regional factors, such as the R&D intensity, the structure of the economy, the presence of research institutions, or different types of agglomeration economies. They have counteracted the tendency to overemphasize the role of the regional context and claimed the importance of accounting for firm heterogeneity in the internal determinants of innovation. However, other recent studies, acknowledging that firms' characteristics are important, have concluded that geography also matters considerably. Love and Roper (2001) reported that the region affects the efficiency with which R&D, technology transfer, and networking are translated into innovation outputs in Germany, Ireland, and the UK. The results for firms in the region of Flanders led Czarnitzki and Hottenrott (2009) to conclude that the availability of highly skilled labour and proximity to suppliers matter for firms' innovation, whereas the evidence reported by Srholec (2010) from firms in the Czech Republic indicates that the quality of the regional innovation system and some social characteristics influence the likelihood to innovate. Dautel and Walther (2013) also provided support for a link between agglomeration externalities and innovation output from a sample of firms located in Luxembourg, and Naz, Niebuhr, and Peters (2015) obtained a positive association between the innovation of German firms and the regional R&D activity, though there was no significant effect of the regional endowment of human capital.

A drawback shared by almost all the previous studies is that they did not consider the interactions between firm characteristics and context variables. However, regional factors may be important in shaping the effect of firms' R&D activities and of other internal characteristics associated with innovation. In this regard the previous evidence suggests that R&D spillovers are more abundant in regions with a high concentration of knowledge activities and that the formation of networks may depend on firm characteristics such as size and ownership (see Love and Roper, 2001 and references therein). As far as we know, the study by Srholec (2010) was the first to take on board clearly the interactions between firm characteristics and regional context variables (cross-level interactions). His results show a significant effect of the interaction between the measure of the strength of the regional innovation system and some firm characteristics (particularly size). However, it is important to mention that the number of internal determinants considered by Srholec (2010) is rather limited. In fact, none of the four firm characteristics in that study corresponds to a direct measure of a firm's technological activity. Conversely, we hypothesize that the efficiency of internal activities may vary depending on the context of the region in which the firm operates. This aligns with the analysis of the effect of technological collaboration and the local context on firms' ability to innovate reported by Fitjar and Rodríguez-Pose (2015).

Their results, obtained from a sample of firms in the five largest city regions of Norway, show that local R&D expenditures and education have no direct effect on firms' innovation but that they strongly shape the returns to collaboration in terms of the innovation activity. In this study we extend the internal–external interaction hypothesis to firm innovation activities other than technological collaboration.

An aspect that has been considered extensively when analysing innovation is the size of the firm. Competing arguments have been proposed to support a higher propensity to innovate of both small and large firms. After decades of empirical studies, the evidence remains mixed, which suggests that there is not an optimal firm size for innovation. However, recent studies have stressed that the determinants of innovation are likely to differ between large and small firms (e.g. Rogers, 2004). In the particular case of external factors, it might be assumed that small firms are more sensitive to the regional context than large firms (Wang and Lin, 2013). In this regard Karlsson and Olsson (1998) argued that small firms are locally based and strongly influenced by their environment. Contrary to large firms, which have the means to access the updated technical knowledge available worldwide, small firms largely depend on the existence of local networks that provide economies of scale (Rogers, 2004 and references therein). The evidence provided by Beugelsdijk (2007) and Naz et al. (2015) supports this assumption for Dutch and German firms, respectively. Based on these arguments, the analysis in this paper tests the hypothesis that SMEs are more sensitive than large firms to the regional context, even when it operates by shaping the effect of firms' absorptive capacity.

Finally, it is worth mentioning that an interesting feature of the empirical studies that assessed the effect of internal and external factors on firms' innovation is that they used data with a hierarchical structure. The first level corresponds to the firm micro-data, and the second level accounts for the regional context in which the firm is located. In this context multilevel modelling (e.g. Snijders and Bosker, 2011; Van Oort, Burger, Knoben, and Raspe, 2012) potentially offers a more complete perspective, as the analysis combines the determinants of innovation at the firm and at the regional level (Gupta, Tesluk, and Taylor, 2007). In contrast to multilevel models, standard single-level models assume that firm observations are independent, which means ignoring the dependence that exists between firms that are located in the same region. Nevertheless, as far as we know, Srholec (2010) and Naz et al. (2015) are the only studies to have used multilevel models to assess the contribution of the internal and regional determinants of firms' innovation. Srholec (2010) even argued that the nested structure of the firm-level data used in this literature is straightforwardly derived from the concept of the regional innovation system.[1]

Against this background this paper uses a multilevel model (sketched in the next section) and a comprehensive sample of firms in all the Spanish regions to test whether i) internal factors, particularly absorptive capacity, account for most of the variability in firms' innovation performance, ii) the regional context also has an effect, although it is only through the interaction with firms' absorptive capacity, and iii) large firms are less sensitive to the regional context than SMEs.

3. **Empirical Specification: Mixed-Effect Logit**

A mixed-effect logit specification is used to test the hypotheses regarding the effect of internal and external factors on firms' innovation. The term mixed effects refers to the inclusion in the model of both fixed and random effects. In the case of this study, the fixed effects correspond to the observed firm and regional characteristics, whereas the random term accounts for intra-region correlation, that is, correlation between firms located in the same region caused by unobservable factors. The starting point is a hierarchical specification for the latent variable $Innov_{ir}^{*}$, which is the propensity to innovate of firm *i* (i=1,…, n_r) located in region *r* (r=1,…,17):[2, 3]

$$Innov_{ir}^{*} = \beta_{0r} + \sum_{k=1}^{K} \beta_{kr} F_{kir} + \varepsilon_{ir} \qquad (1)$$

where F_{kir} (k=1,…, K) denotes the value for firm *i* in region *r* of each of the variables that account for the firm's absorptive capacity and the controls for the other sources of firm heterogeneity. β_{0r} and β_{kr} are, respectively, the intercept and the vector of slopes for each region *r*. These parameters are allowed to vary across regions depending on the set of external factors (R_{jr} , j=1,…, J) and random components (u_{0r} and u_{kr}, k=1,…, K):

$$\begin{aligned} \beta_{0r} &= \gamma_{00} + \sum_{j=1}^{J} \gamma_{0j} R_{jr} + u_{0r}\,, \quad u_{0r} \sim N\left(0, \sigma_{u_{0r}}^{2}\right) \\ \beta_{kr} &= \gamma_{k0} + \sum_{j=1}^{J} \gamma_{kj} R_{jr} + u_{kr}\,, \quad u_{kr} \sim N\left(0, \sigma_{u_{kr}}^{2}\right) \end{aligned} \qquad (2)$$

Substituting the equations for β_{0r} and β_{kr} in equation (1) for the propensity to innovate results in:

$$\begin{aligned} Innov_{ir}^{*} = \gamma_{00} &+ \sum_{j=1}^{J} \gamma_{0j} R_{jr} + \sum_{k=1}^{K} \gamma_{k0} F_{kir} + \sum_{k=1}^{K} \sum_{j=1}^{J} \gamma_{kj} R_{jr} F_{kir} \\ &+ \varepsilon_{ir} + u_{0r} + \sum_{k=1}^{K} u_{kr} F_{kir} \end{aligned} \qquad (3)$$

From the resulting specification, it is clear that the propensity to innovate that does not depend on the observed internal determinants (captured by the intercept in equation 1, β_{0r}) varies depending on the observed contextual factors (R_{jr}) and on unobservables in each region, captured by the random term u_{0r}. This error term accounts for the correlation between firms located in the same region. Similarly, the effect of absorptive capacity and the other firm controls are allowed to vary depending on a fixed-effect component, given by the cross-level interaction between the internal and the external factors ($\gamma_{kj}R_{jr}F_{kir}$), and a random component ($u_{kr}F_{kir}$). The coefficients associated with the contextual regional factors, γ_{0j}, and with the cross-level interaction between internal and contextual factors, γ_{kj}, are the crucial elements for testing the main hypothesis in this paper. Actually, the hypothesis on the moderating effect of external factors on the impact of absorptive capacity is supported when the parameters of the corresponding interactions differ from zero.

Given that the propensity to innovate is a latent variable that cannot be observed, we use the traditional correspondence between this type of variable and the binary response variables for firm innovation (in product and process) defined using the information available in the dataset (*Innov*=1 if $Innov^*>0$ and 0 otherwise). More precisely, under the assumption that firm errors, ε_{ir}, are distributed as logistic, with mean 0 and variance $\pi^2/3$, and independent of the random components u_{0r} and u_{kr}, the corresponding multilevel mixed-effects logit model is given by:

$$\text{prob}\left(Innov_{ir} = 1 \middle| F_{kir}, R_{jr}, u_{0r}, u_{kr}\right) = H(\nu) \tag{4}$$

where

$$\nu = \gamma_{00} + \sum_{j=1}^{J} \gamma_{0j} R_{jr} + \sum_{k=1}^{K} \gamma_{k0} F_{kir} + \sum_{k=1}^{K} \sum_{j=1}^{J} \gamma_{kj} R_{jr} F_{kir} + u_{0r} + \sum_{k=1}^{K} u_{kr} F_{kir}$$

Innov denotes an observed binary measure of innovation and *H* the logistic cumulative distribution function, $H(\nu) = \exp(\nu) / [1 + \exp(\nu)]$. The parameters of the specification in (4) are estimated by a maximum likelihood procedure. More details and a discussion regarding the properties of the estimator given the number of firms and regions used in the empirical exercise are provided in the online Appendix A.

4. **Data and Variables**

The study of the effect of the internal and external determinants of firms' innovation requires the use of firm-level data combined with aggregate data for the regions under analysis. For the former type of information, this study exploits data from the Innovation in Companies Survey (ICS), produced by the Spanish Statistical Office (INE). The ICS is produced according to the methodological rules in the OECD's Oslo Manual, being closely linked to the Spanish sample of the Community Innovation Survey. It contains comprehensive information on innovation activities for a representative sample of firms in Spain. In addition, it provides detailed information on firm characteristics, including employment, the sector of activity, the type of ownership, and the NUTS2 region in which the firm is located. Firms with at least 10 employees in all branches of activity are included in the ICS sample, which is representative of the population of firms in each of the Spanish NUTS2 regions.[4] Although the ICS has been produced on a yearly basis since 2002, it consists of repeated cross-sections, which means that firms are not traceable over different years. This prevents this paper from controlling for unobserved firm heterogeneity in the empirical exercise. However, it can be argued that the large amount of information on firms' characteristics contained in the ICS allows it to control for most of the firm heterogeneity. The results provided in the rest of the paper correspond to the 2005 wave of the ICS for firms in the manufacturing sector.

As for the external factors, the source of information for each of the NUTS2 regions is the INE. It should be mentioned that, to minimize the risk of endogeneity, the aggregate regional indicators used in the study refer to 2003. It is also worth noting that using data for one country eliminates the risk of country-specific differences in the institutional setting contaminating the evidence on the effect of the internal and regional determinants (Beugelsdijk, 2007).

The definition of the measures of firms' innovation along with that of each of its internal and external determinants is provided in Table B1 in Appendix B. Among the several measures on innovation available from the ICS, this paper focuses on product and process innovations. Following the guidelines in the Oslo Manual, the ICS defines product innovation as the introduction of new or significantly improved goods or services. Likewise, process innovation is defined as the implementation of new or significantly improved production processes, distribution methods, or support activities for the goods and services of the firm.

The determinants of innovation that are internal to the firm are clustered into two groups. On the one hand are the factors that proxy for its absorptive capacity, which include expenditures on R&D as a percentage of firm sales, performing R&D activities continuously, and cooperating in innovation with other agents. In addition, and consistent with recent suggestions on the role of human capital as a key element of absorptive capacity (e.g. Qian, Acs, and Stough, 2013), the firm's share of highly skilled workers is included in this category. The other group includes controls for several sources of firm heterogeneity that have been shown to affect innovation, such as size, activity in the export market, foreign ownership, being a new firm, having merged with another firm, being part of an enterprise group, and the sector of activity.

Since the decision of a firm to innovate takes place some time before the innovation is observed, whenever possible the variables that account for the internal factors are constructed using the information available in the ICS 2005 referring to two years earlier (i.e. 2003). This also mitigates the effect of the likely simultaneity between some of these variables and the measures of innovation (e.g. size, exports, and highly skilled labour).

The aggregate magnitudes used to proxy for the effect of the external regional factors are described in the block at the bottom of Table B1. Among the long list of candidates, this paper includes four measures that have frequently been used in similar previous studies (e.g. Beugelsdijk, 2007; Love and Roper, 2001; Srholec, 2010; Sternberg and Arndt, 2001): the region's R&D effort, proxied by gross R&D expenditures over GDP; the amount of urbanization/agglomeration, as measured by the share of urban population; the availability of a pool of highly skilled individuals in the region, as measured by the share of the region's population with a university degree; and the per capita GDP, an all-in-one measure of the potential effect that the socio-economic context may have on firms' innovation. For the reasons stated above, in the case of the internal determinants, we use the values of these variables measured in 2003.

A description of the variables under analysis is reported in Table C1 of Appendix C. It can clearly be observed that the share of innovative firms varies substantially between regions, as do the measures of firms' absorptive capacity and those of internal and external determinants. This makes Spain an interesting case study.

5. **Results**

This section presents the results of the estimation of the effects of the internal and regional determinants of firm innovation and tests the hypotheses in the study. To do so, the following strategy is implemented:

1. First, the most parsimonious version of the mixed-effects logit model, which only includes the intercept and the random regional components, is estimated. It is used to assess the contribution of the between-regions component to the total variability in the propensity to innovate and to test the significance of the random effects. The results are presented in the columns labelled as (i) in Tables 1 and 2.
2. Next, the internal and external determinants are included, separately, as fixed effects in the mixed-effects logit model. The goal is to obtain preliminary evidence of the contribution of these groups of factors to firms' innovation and to check whether they account for the unobserved regional variability captured by the random component. The results are in the columns labelled as (ii) and (iii) for the internal and external factors, respectively.
3. Finally, the mixed-effects model that includes the internal and external factors simultaneously is estimated. In one case no interactions between internal and

external factors are considered – the column labelled as (iv) – whereas in another the interactions between the contextual variable GERD (gross R&D expenditures over GDP in the region) and the proxies for the firm's absorptive capacity are included – the column labelled as (v). It should be mentioned that models that included the interactions with the other regional factors were also estimated. However, they are not reported as the results revealed that all of them make a negligible contribution to the explanation of the propensity to innovate in product and in process (the corresponding coefficients are not statistically significant).[5]

It should be acknowledged that the analysis assumes that the unobservables that affected the location choice of the firm do not distort the estimate of the impact of external factors. As in all previous studies, doubts could be cast regarding the impact of selection or spatial sorting of firms. Therefore, the interpretation of the estimates relies on the assumption that the comprehensive set of firm controls included in the analysis minimizes the sources of independent unobservable factors that may bias the estimate of the effect of the measures of absorptive capacity and, particularly, of external factors. Similarly, the assumption of exogeneity of the region-level magnitudes would be violated if individual firms' decisions changed its context. To overcome this possibility, the analysis reasonably assumes that no single firm is important enough to produce a significant modification in the region's innovative environment. In any case it should be kept in mind that regional magnitudes are measured lagged by two years with the aim of minimizing such a source of endogeneity. Finally, high regional stratification of firms is another potential drawback, as it may confound the internal characteristics and external factors. In the limit it may be the case that similar firms locate just in a single region, making the identification of both types of effects impossible. An inspection of the data revealed that this is not the case in the sample of Spanish firms; that is, there is enough overlapping in the distribution of firms' characteristics across regions to identify the effect of external factors with sufficient precision.

Full Sample of Firms

The estimates obtained using product innovation as the measure of a firm's innovative output are shown in Table 1. The naïve specification, which only includes the intercept with its corresponding random effect – column (i) – reveals that most of the variability in the propensity to innovate in product originates from differences between firms rather than between regions. To be precise, the value of the intraclass correlation (ICC) indicates that the regional dimension only accounts for about 4% of the total variability.[6] This is a clear indication that the internal determinants play a much more substantive role than the contextual factors in explaining the differences across firms in product innovation. Nevertheless, the estimate of the random component of the intercept confirms that regional variability in the propensity to innovate in product is significant. The results of the specification that includes the internal firm determinants are reported in column (ii). It is apparent that three out of the four measures of absorptive capacity increase the probability of product innovation, the exception being the firm's R&D expenditures, the coefficient of which is not statistically significant. As for the other internal determinants, the coefficients are significantly positive for the size of the firm, exporting, and being a newly created firm. Additionally, the probability of innovating in product varies widely across sectors, as indicated by the joint significance of the corresponding dummy variables. Conversely, these estimates suggest no significant variation due to foreign participation, having merged, and belonging to a group of firms. In any case the overall contribution of the internal determinants is highly significant, as indicated by the joint significance test. It is also interesting to note that the inclusion of the internal determinants decreases the portion of the variance of the propensity to innovate in product associated with the regional dimension to a value of 0.4%. Correspondingly, the variance of the intercept also decreases, although this random component is still significant.

< TABLE 1 NEAR HERE >

The estimates of the mixed-effects model including only the external determinants are reported in column (iii). The coefficients of these factors are jointly significant, although it can be observed that this is only due to the contribution of the region's R&D effort (proxied by GERD). The estimate of the coefficient for this regional factor indicates that an increase in the R&D expenditures over the region's GDP ratio leads to higher chances of innovating in product for the firms in the region. The decrease in the ICC and in the variance associated with the intercept indicates that a large part of the regional variability is in fact explained by the contextual determinants. However, there is still a significant part that remains unexplained. Therefore, neither the internal nor the external factors in isolation account for the entire variability across regions in firms' propensity to innovate in product. The results in the last two columns of Table 1 show that it is the combination of the two sets of factors that explains this variability. In fact, a detailed inspection of the results in columns (iv) and (v) provides support for the major hypothesis in this study. It can be observed that the direct effect of the external factors turns out to be non-significant when one controls for differences across firms in absorptive capacity and in the other internal determinants – column (iv). Based on this specification, one might be inclined to conclude that product innovation depends only on internal determinants, with contextual factors playing a negligible role. However, the results obtained in the last column of Table 1, which allow for the interaction between the measures of absorptive capacity and GERD, confirm that the role played by the regional context is subtler than the one represented by the specification that only allows for a direct effect of contextual factors.[7] To be clear, there is significant interaction between the region's R&D effort and two of the absorptive capacity measures. On the one hand, the effect of expenditures on R&D made by the firm increases with the region's R&D effort. It should be noted that this significant effect for the firm's R&D expenditures was not revealed by estimates of the specifications that do not account for the interaction with the regional context. On the other hand, the results reveal that the regional context, as proxied by the R&D effort, moderates the effect on product innovation of cooperation.

The corresponding marginal effects were computed from the coefficient estimates to assess the size of the impact of these two measures of firms' absorptive capacity and its variation with the region's R&D effort. They are depicted in Figures D1 and D2 of Appendix D. It is apparent that the effect of increasing the ratio of R&D expenditures over sales on the propensity to innovate in product is rather low, even for large values of GERD (a 1 percentage point increase in the R&D expenditure ratio – for which the average value in the sample is 1.13% – increases the probability of innovating only by about 1 percentage point). It even becomes negative for low values of GERD, which does not seem reasonable from an economic point of view. In any case the small size of the effect suggests a negligible impact of increasing the R&D expenditures when GERD is particularly low.[8] Conversely, the marginal effects confirm that cooperation is a crucial element for the success of activities aiming to innovate in product in all firms.

However, it is even more important for firms located in regions with a weak R&D context than for those in regions characterized by a favourable innovative environment. Being involved in cooperation increases the probability of product innovation by up to 20 percentage points in innovation-friendly environments, while the size of its effect increases to more than 30 percentage points for firms in regions with a low R&D effort.

It is also worth noting that the inclusion of internal and external factors with the interactions fully accounts for the unobserved regional variability, as revealed by the low value of the ICC (less than 0.1% of the total remaining variability is attributable to the unexplained regional component) and the insignificance of the random component of the intercept.

The results of the analysis of the determinants of process innovation lead to similar conclusions. The estimates of the naïve specification in column (i) of Table 2 indicate that only 1.8% of the total variability in the propensity to innovate in process corresponds to the regional dimension. Although the random variation in the intercept is statistically significant, the small value of the ICC confirms that the need to account for firms' heterogeneity is even more important in the case of process innovation. As shown in column (ii), absorptive capacity plays a crucial role in explaining the differences in the propensity to innovate in process. Despite the estimated coefficient for R&D expenditures not being statistically significant, the results indicate that firms that engage in R&D continuously, cooperate in innovation, and employ highly skilled workers have far more chances of innovating in process than similar firms that do not. Meanwhile, the results from the specification that just includes regional factors reveal that the only significant effect is that for GERD. As in the case of product innovation, a higher ratio of R&D expenditures over the region's GDP is associated with an increased probability of process innovation. However, neither the internal nor the external determinants in isolation account completely for the regional random component in the intercept. Actually, as shown in the following columns of results in Table 2 and contrary to the evidence reported for product innovation, the combination of the two sets of determinants cannot fully explain the regional variability in the propensity to innovate in process. This confirms the importance of estimating the effect of the internal and external determinants of innovation through a mixed-effect model. This is despite the amount of total variability assigned to the random regional component, that is, unexplained by the observed internal and external determinants, being as low as 0.14% in the specification that includes the interaction between GERD and absorptive capacity.

< TABLE 2 NEAR HERE >

The estimates for the specification with the interactions reported in column (v) confirm the importance of the effects discussed above for firms' absorptive capacity as well as those for size, exports, and being a new firm.[9] In all cases these internal characteristics substantially increase the probability of innovating in process. By contrast, there is no significant effect for foreign ownership, having merged, and being in an enterprise group. As for the role played by the regional context, the analysis of the estimates in column (v) suggests that the positive influence of three of the measures of absorptive capacity could be moderated by the regional context, measured in terms of the aggregate R&D effort. To be more precise, the marginal effects depicted in Figure D3 in Appendix D indicate that the impact on process innovation for a firm increasing its R&D expenditures is higher in regions with a weak innovative context. However, as in the case of product innovation, it should be stressed that the size of the effect is rather limited for the range of values of GERD observed in the Spanish regions. As for cooperation, Figure D4 shows that the gap in the probability of innovating in process between firms that cooperate and those that do not varies with GERD. Specifically, the impact of cooperation appears to be larger in regions in which the R&D environment is less favourable. In any case the coefficient of the interaction of cooperation is only marginally significant, which in turn affects the significance of the difference between the marginal effects for low and high values of GERD. Something similar applies to the case of highly skilled workers. The marginal effects for this variable in Figure D5 clearly show that the size of its impact on the probability of process innovation is rather small (not significantly different from zero) and barely varies over GERD.

Overall, the evidence reported so far confirms the crucial role played by the firms' absorptive capacity in innovation, both in product and in process. It also supports the hypothesis that regional determinants matter, though their role is subtler than is frequently assumed. Rather than having a direct influence on firms' innovation, the regional context would moderate the effect exerted by firms' absorptive capacity, particularly through its influence on the impact of cooperation. The results also suggest that the indirect influence of the regional context could be stronger for product than for process innovation.[10]

Large Firms versus SMEs

The evidence provided so far has been obtained for the entire sample of Spanish firms, but it may be argued that the effect of the internal and particularly the external factors can vary with size. More precisely, the hypothesis in this paper is that SMEs are more sensitive to the interaction between the innovative context of the region in which they are located and their absorptive capacity, whereas a greater availability of internal resources in large firms makes them less dependent on these type of interactions. To test this hypothesis, the specifications discussed above for product and process innovations are estimated separately using the samples of large firms (LFs) and SMEs. Firms with 250 or more employees comprise the group of large firms, while SMEs are those employing between 10 and 249 workers. A further distinction between medium- (50 to 249 employees) and small-sized (10 to 49 employees) firms is considered to account for the likely heterogeneity of effects within SMEs.[11] For the sake of brevity, only the results for the preferred specification that includes the internal and external effects, with the interaction between GERD and the measures of absorptive capacity, are reported in Table 3. For the same reason, only estimates of coefficients involving the external factors are reported. The full set of results is available in Tables F1 and F2 of Appendix F.

< TABLE 3 NEAR HERE >

For both product and process innovation, direct and interaction effects of the external factors in the set of LFs are clearly negligible. By contrast, there are highly significant impacts for SMEs. In fact, the comparison with the results for the entire sample of firms in Tables 1 and 2 suggests that most of the effects associated with the regional context correspond to its impact on SMEs. The further distinction within this group reveals additional interesting insights. In the case of product innovation, the endowment of human capital in the region seems to work against the probability of innovation in medium-size firms (MFs). For this group of firms, the region's R&D effort also exerts a negative influence on the return to the employment of highly skilled labour. None of these effects is observed for the group of small firms (SFs). Conversely, the significant interaction with the own R&D expenditures and cooperation observed for the SMEs seems to be exclusively due to the effect of the regional context in SFs. Likewise, in the case of process innovation, it is observed that the negative effect of the regional endowment of education is restricted to MFs. However, the most interesting feature is the distribution of the impact of the interactions. The group of MFs seems to be the only one responsible for the moderating influence of GERD on the effect of highly skilled labour, whereas the significant interaction between GERD and firms' R&D expenditures is solely observed in the group of SFs.

Overall, the evidence from the sample of Spanish firms confirms the hypothesis that the effect on innovation of the regional context is essentially restricted to SMEs. It also indicates that the mechanisms at work may even differ for the medium- and small-sized firms.[12]

6. **Conclusions**

The evidence provided in this paper contributes to the literature aiming to estimate the effect of the regional determinants of innovation using firm-level data. Unlike most previous studies, this one includes a large sample of representative firms in a set of regions that are characterized by sizeable disparity in innovation rates, accounts for firms' absorptive capacity and several other sources of firm heterogeneity, minimizes the risk of confounding the effect of (omitted) internal determinants with that of the regional context, and considers that regional factors are likely to have a subtler effect on firms' innovation performance by moderating the influence of firms' absorptive capacity. It also supports multilevel modelling as the most appropriate strategy to account for the nested structure of the firm-level data used in this literature.

The results from the sample of manufacturing firms located in the Spanish regions confirms that most of the variability in innovation performance is attributable to the firm dimension rather than to differences between regions. The estimates from the multilevel model suggest a strong contribution of firms' absorptive capacity. When controlling for the measures of absorptive capacity and the rest of the internal controls, the results reveal negligible direct effects of the proxies for the regional context. However, a subtler regional effect arises when cross-level interactions are considered, confirming the main hypothesis in this paper. In particular, significant coefficients were obtained for the interaction of firm expenditures on R&D and cooperation with the aggregate R&D effort, both for product and for process innovation. In addition, for the latter there is a significant interaction with the highly skilled labour used by firms. In any case a detailed analysis of the effect size revealed that the strongest influence of the regional context is exerted on the impact of cooperation on product innovation. Cooperation with partners increases the chances of innovating in product for firms in all regions, but its effect is far more important in regions with a weak innovative context. In other words cooperation could be a successful way to overcome the constraints imposed by a poor innovative environment.

The evidence obtained from the samples of large firms and SMEs suggests that what is driving the effect of the regional context in the entire sample of Spanish firms is in fact the response caused by these external factors in the innovation outcome of SMEs. Innovation in large firms seems to be independent of the context of the regions in which they are located. By contrast, SMEs may benefit from improvements in the regional context, although the mechanism is likely to be subtler than the one highlighted in most of the extant literature and differ for the medium- and small-sized firms.

An immediate policy implication of these results is that interventions aiming to improve the regional context for innovation should pay detailed attention to the characteristics of the firms in the region, since the effectiveness of the policy may vary considerably with firms' absorptive capacity. This means that the same type of intervention may lead to different results in different regions, depending on the firms' composition, and that even within a region, the effect is likely to vary across firms. Besides, policy makers should be aware that policies aiming to improve the regional innovative environment would have a negligible direct and indirect influence on large firms' innovation. By contrast, improving the regional context is likely to enhance the mechanisms of absorptive capacity for SMEs, which would result in more frequent innovation for a fixed amount of internal resources devoted to innovation activities. Therefore, the results in this paper suggest that innovation policies that are designed and implemented taking into account the characteristics of the population of firms in the region are likely to be more effective in stimulating innovation than the so-called one-size-fits-all interventions.

As mentioned at the beginning of section 5, the evidence obtained in this study relies on some assumptions to identify the effect of external factors on firms' innovation that are debatable. The estimates of the effect of the regional context could be questioned if the study failed to control for selection, there was close to perfect regional stratification of firms depending on their characteristics, and/or the measures of the regional context were largely affected by individual firm decisions. Although it has been argued that, in contrast to previous analyses, the study has tried to minimize the distorting influence of these typical drawbacks when working with observational data, the authors are cautious when it comes to deriving causal effects for the external factors. Being aware that having access to experimental data in this field is rather difficult, the second-best option would be to exploit longitudinal data for samples of firms to identify the effect of the context on firms' innovation through observations of firms that move from one region to another. Unfortunately, panel data sets providing rich information on innovation activities and the location of the firm are still scant. On the other hand, additional evidence from other economies would be helpful to confirm or disprove the results about the importance of the interaction between the firms' absorptive capacity and the regional innovative context. Similarly, further analyses should investigate whether regional factors exert the same effect on different types of firms. The evidence in this paper suggests that the impact varies with the size of the firm, but the same could also apply to other dimensions, such as the age of the firm (which has not been investigated in this paper due to the lack of information for this variable in the dataset).

Acknowledgments

This work was supported by the Spanish Ministry of Economics and Competitiveness, National Program of R&D, under grant ECO2014-59493-R, and the project "Redes de colaboración tecnológica e innovación. Determinantes y efectos sobre la competitividad de las empresas españolas" funded by the Fundación BBVA "I Convocatoria de Ayudas a Proyectos de Investigación 2014 (área de socioeconomía)".

Notes

---

[1] Footnote 5 in Beugelsdijk (2007) indicates that a multilevel model was estimated as a robustness check following the suggestion of a reviewer. However, the corresponding results are not reported in that paper.

[2] See Guo and Zhao (2000) for the derivation of the multilevel model for binary outcomes through a latent variable conceptualization.

[3] n_r is the number of firms in the sample for each region *r*, as shown in the last column of Table 1.

[4] The set of NUTS2 Spanish regions is composed of the 17 autonomous communities. They enjoy high levels of political and financial autonomy, including competences in the promotion of R&D and innovation.

[5] The results for the most general specification that allows for the presence of the random component in the slopes of the measures of firms' absorptive capacity are not provided. Convergence of the estimation procedure was not achieved under the usual reasonable conditions in such a complex model with several level-1 and level-2 variables, and the corresponding interactions, in the sample of firms used in this study. Nonetheless, the estimation of simplified versions of the model revealed that the random component of the slopes was not significant in all the cases. This suggests that the interaction between internal and external determinants accounts for the entire regional variability in the effect of firms' absorptive capacity on innovation.

[6] ICC is a measure of the degree of association between any pair of firms located in the same region. It is close to 0 when the regional random component of innovation is negligible. A pure fixed-effects model is preferred in that case. Otherwise, the specification should account for the random variation at the regional level.

[7] The specification that includes the interaction between the absorptive capacity and the entire set of regional variables was also estimated. However, the corresponding test of significance of the interactions in which GERD was not involved indicated that the constrained specification reported in column (v) of Table 1 was preferred (p-value of the test equals 0.12).

[8] It is reasonable to assume that the effect of expenditures on R&D is capped at zero, since there is no reason to expect a decline in the propensity to innovate for a firm that increases its R&D activities. The worst situation in that case would be that the propensity remained unchanged. In this regard it should be noted that the specification used to obtain the estimates does not preclude a negative marginal effect of R&D expenditures for low values of GERD.

[9] As with product innovation, the specification that includes the interaction between absorptive capacity and the entire set of regional variables was also estimated for process innovation. In this case the p-value of the corresponding test of significance of the interactions in which GERD was not involved equals 0.13, indicating that the coefficients of those interactions are not significant.

[10] It can be argued that the effect of the regional factors could be driven exclusively by the largest (most developed) regions. As a sort of robustness check, an anonymous reviewer suggested removing the firms in Catalonia from the sample. Tables E1 and E2 in Appendix E summarize the results obtained in this case, which are qualitatively similar to those described in the main text.

[11] The authors thank an anonymous reviewer for this suggestion.

[12] The arguments discussed above regarding the limited size of the effect of R&D expenditures and highly skilled labour also apply to the results that distinguish by the dimension of the firm. In a nutshell the largest effect is that of the influence of the

region's context on the impact of cooperation on product innovation in SMEs and, more precisely, in small firms.

References

Audretsch, D. B., & Feldman, M. P. (1996). R&D spillovers and the geography of innovation and production. *American Economic Review, 86,* 630–640.

Beugelsdijk, S. (2007). The regional environment and a firm's innovative performance: a plea for a multi-level interactionist approach. *Economic Geography, 83,* 181–199.

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly, 35,* 128–185.

Cooke, P. (2001). Regional innovation systems, clusters, and the knowledge economy. *Industrial and Corporate Change, 10,* 945–974.

Crepon, B., Duguet, E., & Mairesse, J. (1998). Research, innovation and productivity: An econometric analysis at the firm level. *Economics of Innovation and New Technology, 7,* 115–158.

Crescenzi, R. (2005). Innovation and regional growth in the enlarged Europe: the role of local innovative capabilities, peripherality and education. *Growth and Change, 36,* 471–507.

Czarnitzki, D., & Hottenrott, H. (2009). Are local milieus the key to innovation performance?. *Journal of Regional Science, 49,* 81–112.

Dautel, V., & Walther, O. (2013). The geography of innovation in a small metropolitan region: An intra-regional approach in Luxembourg. *Papers in Regional Science, 93,* 703–725.

European Commission. (2014). *Investment for jobs and growth. Promoting development and good governance in EU regions and cities. Sixth report on economic, social and territorial cohesion*. Luxembourg: Publications Office of the European Union.

Fitjar, R. D., & Rodríguez-Pose, A. (2015). Networking, context and firm-level innovation: Cooperation through the regional filter in Norway. *Geoforum, 63,* 25–35.

Fritsch, M., & Slavtchev, V. (2011). Determinants of the efficiency of the regional innovation systems. *Regional Studies, 45,* 905–918.

Geroski, P., Machin, S., & Van Reenen, J. (1993). The profitability of innovating firms. *Rand Journal of Economics, 24,* 198–211.

Gertler, M. S. (2001). Best practice? Geography, learning and the industrial limits to strong convergence. *Journal of Economic Geography, 1,* 5–26.

Griffith, R., Huergo, E., Mairesse, J., & Peters, B. (2006). Innovation and productivity across four European countries. *Oxford Review of Economic Policy, 22,* 483–498.

Guo, G., & Zhao, H. (2000). Multilevel modelling for binary data. *Annual Review of Sociology, 26,* 441–462.

Gupta, A. K., Tesluk, P. E., & Taylor, M. S. (2007). Innovation at and across multiple levels of analysis. *Organization Science, 18,* 885–897.

Hall, B., & Mairesse, J. (1995). Exploring the relationship between R&D and productivity in French manufacturing firms. *Journal of Econometrics, 65,* 263–293.

Ibrahim, S. E., Fallah, M. H., & Reilly, R. R. (2009). Localised sources of knowledge and the effect of knowledge spillovers: an empirical study of inventors in the telecommunications industry. *Journal of Economic Geography, 9,* 405–431.

Karlsson, C., & Olsson, O. (1998). Product innovation in small and large enterprises. *Small Business Economics, 10,* 31–46.

Keeble, D., & Wilkinson, F. (1999). Collective learning and knowledge development in the evolution of regional clusters of high technology SMEs in Europe. *Regional Studies, 33,* 295–303.

Lee, N., & Rodríguez-Pose, A. (2014). Innovation in creative cities: Evidence from British small firms. *Industry and Innovation, 21,* 494–512.

Love, J. H., & Roper, S. (2001). Location and network effects on innovation success: Evidence for UK, German and Irish manufacturing plants. *Research Policy, 30,* 643–661.

Naz, A., Niebuhr, A., & Peters, J. C. (2015). What's behind the disparities in firm innovation rates across regions? Evidence on composition and context effects. *The Annals of Regional Science, 55,* 131–156.

Ponds, R., Van Oort, F., & Frenken, K. (2010). Innovation, spillovers and university–industry collaboration: an extended knowledge production function approach. *Journal of Economic Geography, 10,* 231–255.

Qian, H., Acs, Z. J., & Stough, R. R. (2013). Regional systems of entrepreneurship: the nexus of human capital, knowledge and new firm formation. *Journal of Economic Geography, 13,* 559–587.

Rodríguez-Pose, A., & Crescenzi, R. (2008). Research and development, spillovers, innovation systems, and the genesis of regional growth in Europe. *Regional Studies, 42,* 51–67.

Rogers, M. (2004). Networks, firm size and innovation. *Small Business Economics, 22,* 141–153.

Saxenian, A. (1994). *Regional advantage*. Cambridge, MA: Harvard University Press.

Scott, A. J., & Storper, M. (2003). Regions, globalization, development. *Regional Studies, 37,* 579–609.

Smit, M. J., Abreu, M. A., & De Groot, H. L. F. (2015). Micro-evidence on the determinants of innovation in the Netherlands: The relative importance of absorptive capacity and agglomeration externalities. *Papers in Regional Science, 94,* 249–272.

Snijders, T., & Bosker, R. (2011). *Multilevel analysis. An introduction to basic and advanced multilevel modeling* (2nd ed.). London: SAGE.

Srholec, M. (2010). A multilevel approach to geography of innovation. *Regional Studies, 44,* 1207–1220.

Sternberg, R., & Arndt, O. (2001). The Firm or the region: What determines the innovation behavior of European firms?. *Economic Geography, 77,* 364–382.

Van Oort, F. G., Burger, M. J., Knoben, J., & Raspe, O. (2012). Multilevel approaches and the firm-agglomeration ambiguity in economic growth studies. *Journal of Economic Surveys, 26,* 468–491.

Vega-Jurado, J., Gutiérrez-Gracia, A., Fernández-De-Lucio, I., & Manjarrés-Henríquez, L. (2008). The effect of external and internal factors on firms' product innovation. *Research Policy, 37,* 616–632.

Vogel, J. (2015). The two faces of R&D and human capital: Evidence from Western European regions. *Papers in Regional Science, 94,* 525–551.

Wang, C. C., & Lin, G. C. (2013). Dynamics of innovation in a globalizing China: regional environment, inter-firm relations and firm attributes. *Journal of Economic Geography, 13,* 397–418.

Table 1. Estimates for product innovation. Full sample.

Internal factors	(i)	(ii)	(iii)	(iv)	(v)
R&D expend.		0.001		0.001	-0.098***
		(0.001)		(0.001)	(0.018)
R&D cont.		2.220***		2.219***	2.360***
		(0.059)		(0.059)	(0.200)
Coop.		1.343***		1.345***	1.953***
		(0.064)		(0.064)	(0.207)
High-skilled		0.011***		0.011***	0.017***
		(0.002)		(0.002)	(0.005)
Size (log)		0.082***		0.081***	0.093***
		(0.025)		(0.025)	(0.025)
Export		0.498***		0.498***	0.495***
		(0.049)		(0.049)	(0.049)
Foreign own.		-0.154		-0.154	-0.125
		(0.145)		(0.145)	(0.144)
New firm		3.270***		3.269***	3.295***
		(0.355)		(0.355)	(0.355)
Merge		0.056		0.052	0.050
		(0.187)		(0.186)	(0.186)
Group Nat.		-0.057		-0.055	-0.058
		(0.067)		(0.067)	(0.067)
Group Internat.		0.129		0.128	0.128
		(0.149)		(0.149)	(0.148)
Sectors		YES***		YES***	YES***
External factors					
GERD			0.713***	0.185	0.254*
			(0.233)	(0.144)	(0.143)
Urban			-0.002	-0.000	-0.000
			(0.005)	(0.003)	(0.003)
Human Cap.			0.010	-0.022	-0.026
			(0.021)	(0.015)	(0.016)
GDPpc			0.001	0.009	0.013
			(0.029)	(0.020)	(0.021)
R&D expend.*GERD					0.118***
					(0.021)
R&D cont.*GERD					-0.210
					(0.176)
Coop.*GERD					-0.597***
					(0.184)
High-skilled*GERD					-0.006
					(0.004)
Significance of FE coefficients (Wald tests)					
All variables				2997***	3025***
Internal factors		2963***		2931***	632***
External factors			30.10***	2.953	4.428
External & interactions					43.06***
Interactions					40.47***
Random Effects					
var(cons.)	0.142	0.014	0.041	0.006	0.003
LR test	300.4***	15.10***	47.94***	0.776	0.104
ICC	0.0414	0.0044	0.0122	0.0018	0.0009
Log-Lik	-8717	-6522	-8708	-6521	-6495
Observations	14074	14074	14074	14074	14074

Notes: Standard errors in parenthesis. ICC denotes intraclass correlation, the ratio of the between-region variance to the total variance. *** p<0.01, ** p<0.05, * p<0.1.

Table 2. Estimates for process innovation. Full sample.

Internal factors	(i)	(ii)	(iii)	(iv)	(v)
R&D expend.		0.000		0.000	0.073***
		(0.001)		(0.001)	(0.016)
R&D cont.		1.415***		1.414***	1.524***
		(0.056)		(0.056)	(0.187)
Coop.		1.672***		1.672***	1.993***
		(0.064)		(0.064)	(0.208)
High-skilled		0.004***		0.004***	0.013***
		(0.001)		(0.001)	(0.004)
Size (log)		0.139***		0.139***	0.147***
		(0.022)		(0.022)	(0.023)
Export		0.386***		0.385***	0.378***
		(0.044)		(0.044)	(0.044)
Foreign own.		-0.189		-0.189	-0.171
		(0.133)		(0.133)	(0.132)
New firm		1.180***		1.181***	1.171***
		(0.262)		(0.262)	(0.265)
Merge		0.213		0.211	0.212
		(0.167)		(0.167)	(0.167)
Group Nat.		-0.066		-0.065	-0.072
		(0.061)		(0.061)	(0.061)
Group Internat.		0.086		0.087	0.081
		(0.137)		(0.137)	(0.136)
Sectors		YES***		YES***	YES***
External factors					
GERD			0.476***	0.078	0.227*
			(0.166)	(0.133)	(0.132)
Urban			-0.004	-0.002	-0.002
			(0.003)	(0.003)	(0.002)
Human Cap.			0.002	-0.016	-0.019*
			(0.015)	(0.012)	(0.011)
GDPpc			0.017	0.018	0.025
			(0.021)	(0.016)	(0.015)
R&D expend.*GERD					-0.044***
					(0.009)
R&D cont.*GERD					-0.157
					(0.155)
Coop.*GERD					-0.307*
					(0.182)
High-skilled*GERD					-0.009**
					(0.004)
Significance of FE coefficients (Wald tests)					
All variables				2140***	2173***
Internal factors		2129***		2103***	549.6***
External factors			28.63***	2.124	7.159
External & interactions					41.52***
Interactions					38.88***
Random Effects					
var(cons.)	0.060	0.010	0.017	0.007	0.005
LR test	170.7***	18.27***	27.99***	5.036**	2.888**
ICC	0.0179	0.0030	0.0052	0.0020	0.0014
Log-Lik	-9269	-7801	-9261	-7800	-7775
Observations	14074	14074	14074	14074	14074

Notes: Standard errors in parenthesis. ICC denotes intraclass correlation, the ratio of the between-region variance to the total variance. *** p<0.01, ** p<0.05, * p<0.1.

Table 3. Estimates of the effect of external factors by firm size.

	Product Innovation				Process Innovation			
External factors	**LFs**	**SMEs**	**MFs**	**SFs**	**LFs**	**SMEs**	**MFs**	**SFs**
GERD	-0.882	0.260*	0.345	0.200	0.211	0.221	0.338	0.173
	(0.657)	(0.158)	(0.240)	(0.169)	(0.610)	(0.143)	(0.235)	(0.155)
Urban	0.002	0.000	0.002	-0.001	-0.006	-0.001	-0.005	0.000
	(0.008)	(0.003)	(0.004)	(0.003)	(0.007)	(0.003)	(0.004)	(0.003)
Human Cap.	-0.023	-0.022	-0.062***	-0.015	0.004	-0.019	-0.047***	-0.011
	(0.031)	(0.015)	(0.014)	(0.018)	(0.029)	(0.012)	(0.016)	(0.013)
GDPpc	0.068	0.007	0.043*	0.004	-0.005	0.025	0.048*	0.020
	(0.062)	(0.020)	(0.024)	(0.023)	(0.057)	(0.017)	(0.026)	(0.018)
R&D expend.*GERD	-0.247	0.110***	0.045	0.114***	0.122	-0.044***	0.040	-0.060***
	(0.212)	(0.022)	(0.090)	(0.026)	(0.150)	(0.010)	(0.033)	(0.018)
R&D cont.*GERD	0.287	-0.129	0.121	-0.221	0.039	-0.167	-0.463*	0.003
	(0.544)	(0.191)	(0.295)	(0.273)	(0.507)	(0.168)	(0.261)	(0.242)
Coop.*GERD	-0.604	-0.513**	-0.419	-0.611**	-0.212	-0.262	-0.445	-0.095
	(0.556)	(0.200)	(0.297)	(0.276)	(0.523)	(0.197)	(0.305)	(0.264)
High-skilled*GERD	0.003	-0.005	-0.018**	0.001	-0.013	-0.008**	-0.015**	-0.006
	(0.021)	(0.004)	(0.008)	(0.005)	(0.019)	(0.004)	(0.008)	(0.005)
Significance of FE coefficients (Wald tests)								
All variables	247.4***	2617***	1043***	1544***	168.6***	1867***	762.2***	1063***
Internal factors	57.1***	544.7***	171.2***	365.3***	44.21***	464.6***	192.6***	285.9***
External factors	3.450	3.758	20.43***	1.680	0.688	5.876	9.498**	5.207
External & interactions	10.53	34.58***	28.50***	25.82***	1.928	37.49***	21.58***	20.45***
Interactions	2.588	31.56***	7.45	23.76***	1.255	35.48***	11.12**	18.58***
Random Effects								
var(cons.)	0.000	0.007	0.000	0.001	0.000	0.007	0.007	0.006
LR test	0.000	0.931	0.000	0.0126	0.000	4.984**	1.185	0.967
ICC	0.000	0.0020	0.000	0.0003	0.000	0.0021	0.0021	0.0017
Log-Lik	-454.9	-6018	-2182	-3787	-515.3	-7240	-2542	-4659
Observations	958	13114	4530	8584	958	13114	4530	8584

Notes: Standard errors in parenthesis. LF: 250 and more employees; SMEs: 10 to 249 employees; MF: 50 to 249 employees; SF: 10 to 49 employees. Specifications included all the internal factors listed in Tables 1 and 2. ICC denotes intraclass correlation, the ratio of the between-region variance to the total variance. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

APPENDIX A

Estimation of the Mixed-Effects Logit and Number of Firms and Regions

A Maximum Likelihood (ML) procedure, implemented in the Stata command `melogit`, is used to estimate the parameters of the mixed-effects logit specifications. In this regard, there is an issue that deserve a comment. The total number of observations (14,074 firms) in our study is large enough to guarantee the large sample properties of the estimators based on ML. However, in the case of multilevel mixed-effects models there is a debate on the minimum number of level-1 observations and level-2 groups, and on the properties of the estimator when these numbers are small. Although the number of firms in each region is far beyond what has been stated as problematic in the literature, the limited number of regions used in this study may pose an impediment for the quality of the estimates (e.g. Srholec, 2010). In this regard, it needs to be said that the previous literature is not conclusive about the minimum sample size requirements. Maas and Hox (2005) showed that 50 groups or less leads to downward biased estimates of the standard error of the level-2 variance, which causes over-rejection of the hypothesis of insignificant random effects. In contrast, their simulations revealed that neither the regression coefficients nor the variance components are estimated with bias even when the number of groups is as low as 5. The standard errors of the regression coefficients are also estimated accurately. In a similar vein, the comprehensive simulation exercise in Stegmueller (2013) proves that the bias of the ML estimation of the coefficients of the individual and group level variables in a discrete choice model is negligible for a number of groups similar to the one in our exercise. It also shows that the corresponding confidence intervals are only marginally affected for this number of groups. Summing up, our results based on the samples of firms for the 17 Spanish regions are likely to provide accurate estimates of the fixed-effects coefficients of the internal and external determinants of innovation, including the cross-level interactions, as well as of the corresponding confidence intervals. This is particularly important given the interest of this study in testing if there is a direct and/or an indirect impact of the contextual determinants on firm innovation. In turn, one ought to keep in mind that the estimated random effects variance, and particularly, the estimate of its standard error are likely to be biased. More specifically, the hypothesis of insignificance of the random effects is likely to be over-rejected.

Maas, C. J. M., & Hox, J. J. (2005). Sufficient sample sizes for multilevel modelling. *Methodology, 1,* 86–92.

Srholec, M. (2010). A multilevel approach to geography of innovation. *Regional Studies, 44,* 1207–1220.

Stegmueller, D. (2013). How many countries for multilevel modeling? A comparison of frequentist and Bayesian approaches. *American Journal of Political Science, 57,* 748–761.

APPENDIX B

Table B1. Definition and description of the variables in the analysis.

Measures of innovation		
Product innovation	=1 if the firm innovated in product in the surveyed period, 2003-2005 =0 otherwise	32.43 (0.39)
Process innovation	=1 if the firm innovated in process in the surveyed period, 2003-2005 =0 otherwise	38.13 (0.41)
Internal factors		
R&D expenditures	Expenditures on R&D activities over total sales	1.16 (4.77)
R&D continuous	=1 if the firm declared to perform R&D activities continuously =0 if the firm declared to perform R&D activities occasionally or not at all	20.20 (0.34)
Cooperation in innovation	=1 if the firm was involved in any form of cooperation in the innovation activity =0 otherwise	14.28 (0.29)
Highly skilled labour	Share of firm's employees with tertiary education in 2003	9.37 (14.07)
Size	Number of employees in the firm in 2003	92.86 (403.99)
Export	=1 if the firm exported in 2003 =0 otherwise	47.75 (0.42)
Foreign ownership	=1 if foreign capital owns at least 50% of the firm =0 otherwise	7.74 (0.23)
New firm	=1 if the firm was created during the 2003-2005 period =0 otherwise	0.53 (0.06)
Merge	=1 if the firm merge another firm resulting in an increase of at least 10% in turnover =0 otherwise	1.38 (0.10)
National group	=1 if the firm is part of a national enterprise group =0 otherwise	15.20 (0.30)
International group	=1 if the firm is part of an international enterprise group =0 otherwise	7.62 (0.22)
Sectors	A set of dummy variables for 11 manufacturing sectors. For each sector a dummy variable is defined (=1 if the firm belongs to the sector; =0 otherwise)	
External factors		
GERD	Intramural R&D expenditures in the region as percentage of regional GDP, in 2003	1.02 (0.37)
Urban	Percentage of population in the region living in cities greater than 100K inhabitants, in 2003	40.15 (14.19)
Human Capital	Share of population aged 25-64 years in the region who have successfully completed tertiary education, in 2003	26.16 (5.17)
GDPpc	Gross domestic product per capita at current market prices in the region, in 2003	19.53 (3.59)

Notes: Proportion of firms with the corresponding characteristics for the binary variables. Average in the sample of firms for continuous variables. Standard deviation in parenthesis.

APPENDIX C

Differences across Regions in Innovation and its Determinants

The proportion of innovative firms in the entire sample of manufacturing firms in Spain is moderate: 32 and 38 per cent, for product and process innovations respectively. But what really supports the aim of this paper is that the share of innovative firms varies substantially between regions, as it does the measures of firm's absorptive capacity and the external factors. Table C1 summarises this information for the sample of firms in each region. Catalonia is the region with the largest share of manufacturing firms that declared to innovate in product (43 per cent), followed by Madrid, the Basque Country and Navarre (about 36 per cent). In contrast, only 15 per cent of firms in Extremadura and 11 per cent in the Balearic Islands did it. The share is rather low (less or about than one fourth) as well in other regions such as Castile La Mancha, Andalusia, Asturias, and Murcia. A similar picture is deduced from the figures on the share of firms that innovated in process (around half of the firms in Catalonia versus less than one third in e.g. the two island regions, Extremadura, Asturias, and Castile La Mancha).

Interestingly, absorptive capacity, as measured by the four indicators used in this study, seems to be more abundant in regions in which the proportion of innovative firms is high, whereas it is scarce in those with low numbers of innovative firms. The average firm in Madrid, Catalonia, Navarre and the Basque Country clearly outperforms the representative firm in the other regions in terms of the ratio expenditures on R&D over total sales. In fact, the ratio is particularly low in the two island regions and also in Asturias, Castile La Mancha and Cantabria. Similarly, the share of firms performing R&D activities continuously is between one quarter and one third in Catalonia, the Basque Country, and Madrid, which is far beyond the numbers in low innovative regions (less and about 10 per cent). Analogous disparities are observed as regard the proportion of firms that cooperate in innovation activities, whereas figures for the average share of highly skilled workers reveal that this type of labour is much more frequent in firms located in regions at the top of the innovation ranking; the opposite being also true. Overall, these figures suggest that regions differ sharply in the characteristics of their firms' population, in particular with respect to those that determine the firm's absorptive capacity.[1] They also confirm, at the aggregate level, the positive relationship between absorptive capacity and innovation.

The values for the external variables in each region are displayed in the last block of columns in Table C1. They provide clear evidence on the existence of outstanding regional disparities in the environmental factors that have been told to affect firm's innovation. Once again, R&D intensity is much higher in regions with a large share of innovative firms (1.7 per cent of GDP in Madrid and 1.4 per cent in the Basque Country versus 0.23 per cent in the Balearic Islands and 0.42 in Castile La Mancha). Regions also differ as regard urban population and the endowment of human capital. However, the relationship with the share of innovative firms is not as clear for these magnitudes. For instance, the share of urban population in Catalonia, which is the region with the largest share of innovative firms, is below that in some regions with a much lower share of innovative firms (e.g. Asturias and Murcia). Similarly, the value of the measure of human capital in Catalonia is similar and even below that in less innovative regions (e.g. Aragon and Castile Leon). Finally, the per capita GDP figures reproduce the well-known regional disparities in productivity and income per capita in Spain. As mentioned before, they are supposed to capture the effect of other external determinants of innovation that are not accounted for by the other three indicators.

[1] The description of the other internal to the firm determinants of innovation is not included here for reasons of space. In general, regions with the largest share of innovative firms are those in which a more favourable endowment of the factors that facilitates innovation is more abundant (e.g. larger size, activity in export markets). Results are available from the authors upon request.

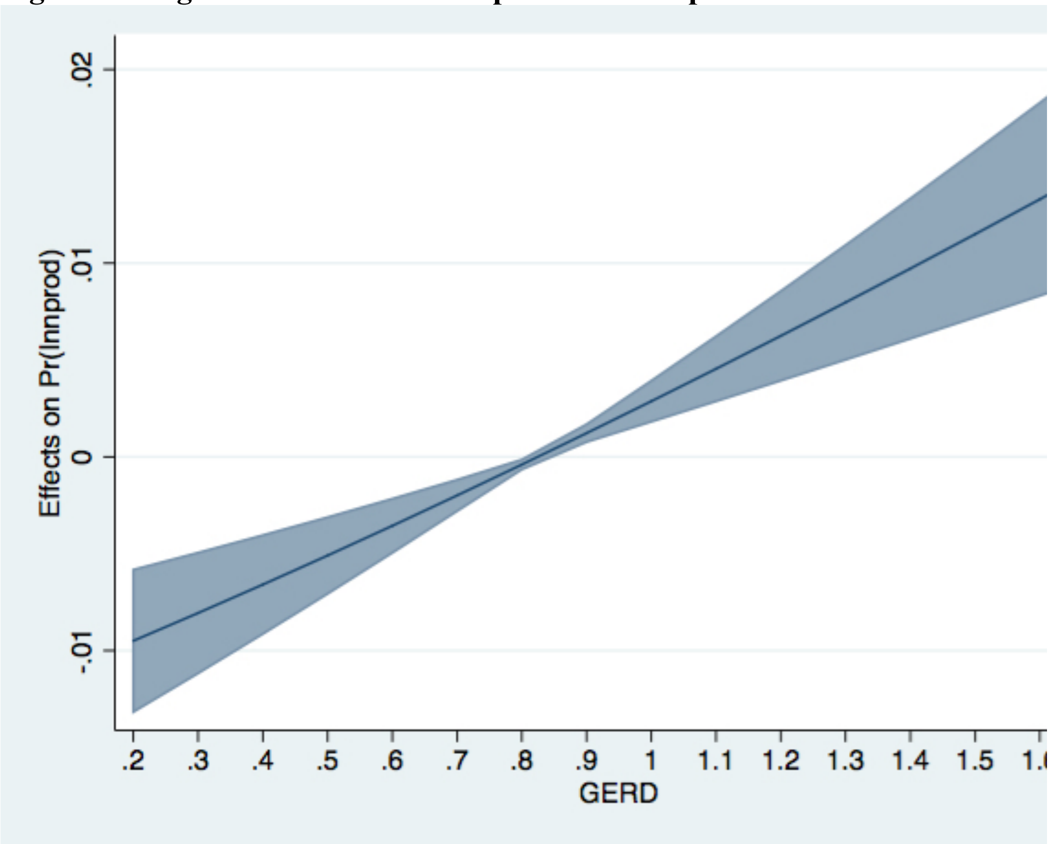
Table C1. Descriptive of the main variables in the Spanish regions.

	Innovation		Absorptive Capacity				External factors				Obs.
	Product	Process	R&D exp.	R&D cont.	Coop.	High-skilled	GERD	Urban	Human Cap.	GDPpc	
Andalusia	24.1	34.1	0.82	11.3	7.5	7.8	0.85	38	21	14.2	1099
Aragon	29.1	35.8	0.93	17.4	13.5	8.9	0.70	51	28	19.9	684
Asturias	25.6	31.5	0.46	11.6	12.1	9.0	0.67	45	24	15.9	406
Balearic Isl.	11.4	21.5	0.13	3.7	2.7	4.4	0.23	39	19	21.3	219
Canary Isl.	20.3	28.6	0.09	4.6	3.7	6.1	0.52	39	21	17.4	217
Cantabria	25.7	31.9	0.54	11.8	11.1	8.9	0.45	34	27	18.0	323
Castile Leon	28.4	34.8	1.31	14.2	14.5	8.9	0.86	32	27	17.3	647
Castile La Mancha	23.1	30.0	0.40	8.9	8.0	5.9	0.42	9	18	14.7	540
Catalonia	42.8	46.9	1.60	31.5	15.8	11.1	1.27	43	26	22.4	3118
Valencia	33.1	38.5	1.10	17.9	15.4	8.2	0.83	33	21	17.6	1796
Extremadura	15.1	26.5	0.83	7.3	10.0	8.2	0.62	13	19	12.2	219
Galicia	29.0	32.7	0.97	16.2	13.9	7.5	0.85	23	23	14.8	794
Madrid	35.8	37.4	1.61	26.3	15.8	11.9	1.69	75	33	24.6	1279
Murcia	26.4	30.9	0.69	11.7	9.3	7.0	0.68	46	22	15.8	538
Navarre	34.7	41.0	1.55	20.4	18.2	10.8	1.34	33	34	23.4	593
Basque Country	35.5	42.7	1.43	27.2	23.7	11.0	1.39	36	36	23.0	1276
La Rioja	25.8	35.6	0.68	12.9	11.7	8.8	0.63	49	26	20.6	326

Note: Figures in % excepting GDPpc in thousand €.

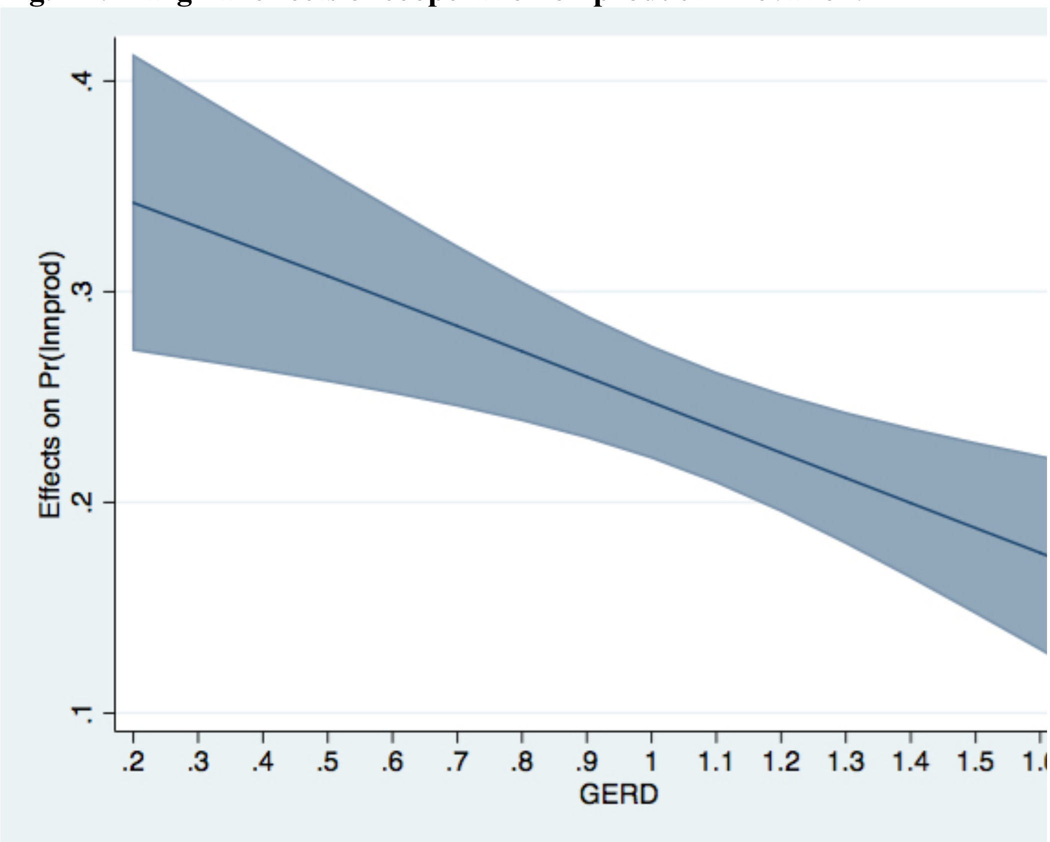
APPENDIX D

Fig. D1. Marginal effects of R&D expenditures on product innovation.



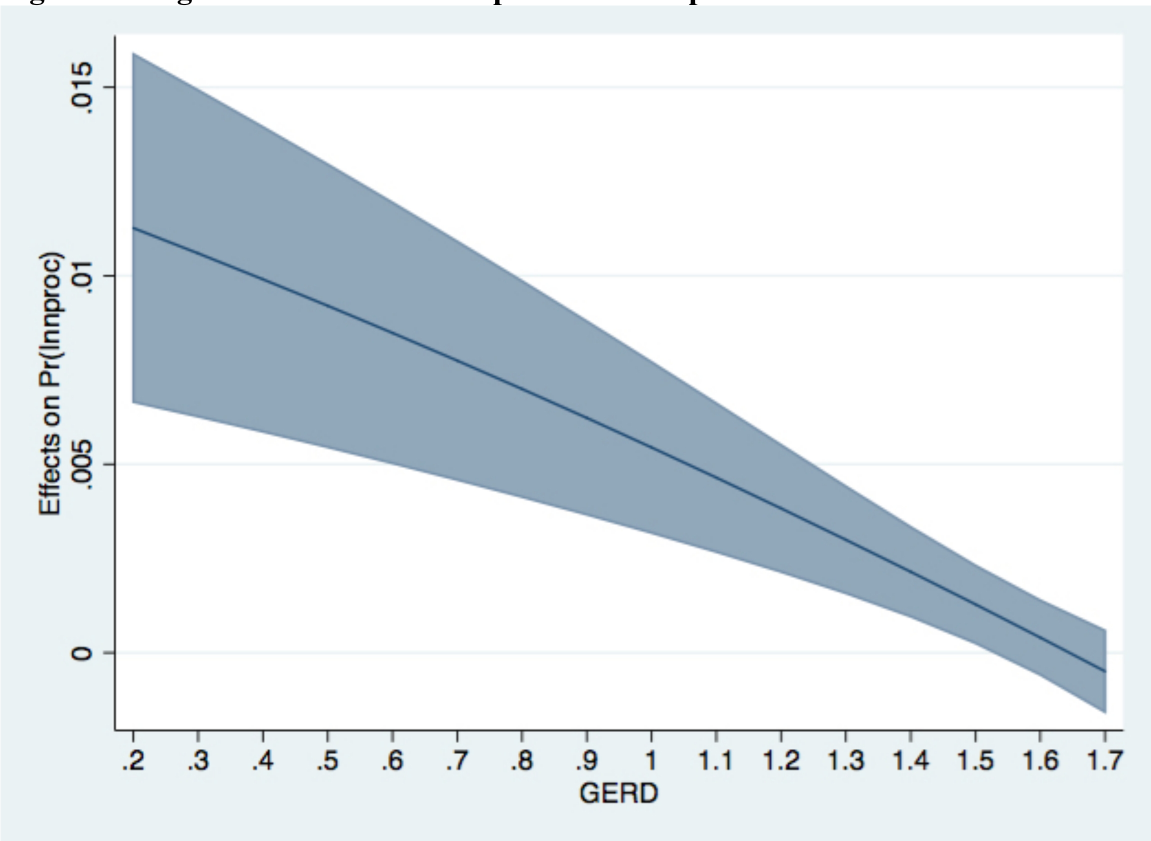
Note: Marginal effects computed from estimates in Table 2. The highlighted area denotes de 95% confidence interval.

Fig. D2. Marginal effects of cooperation on product innovation.



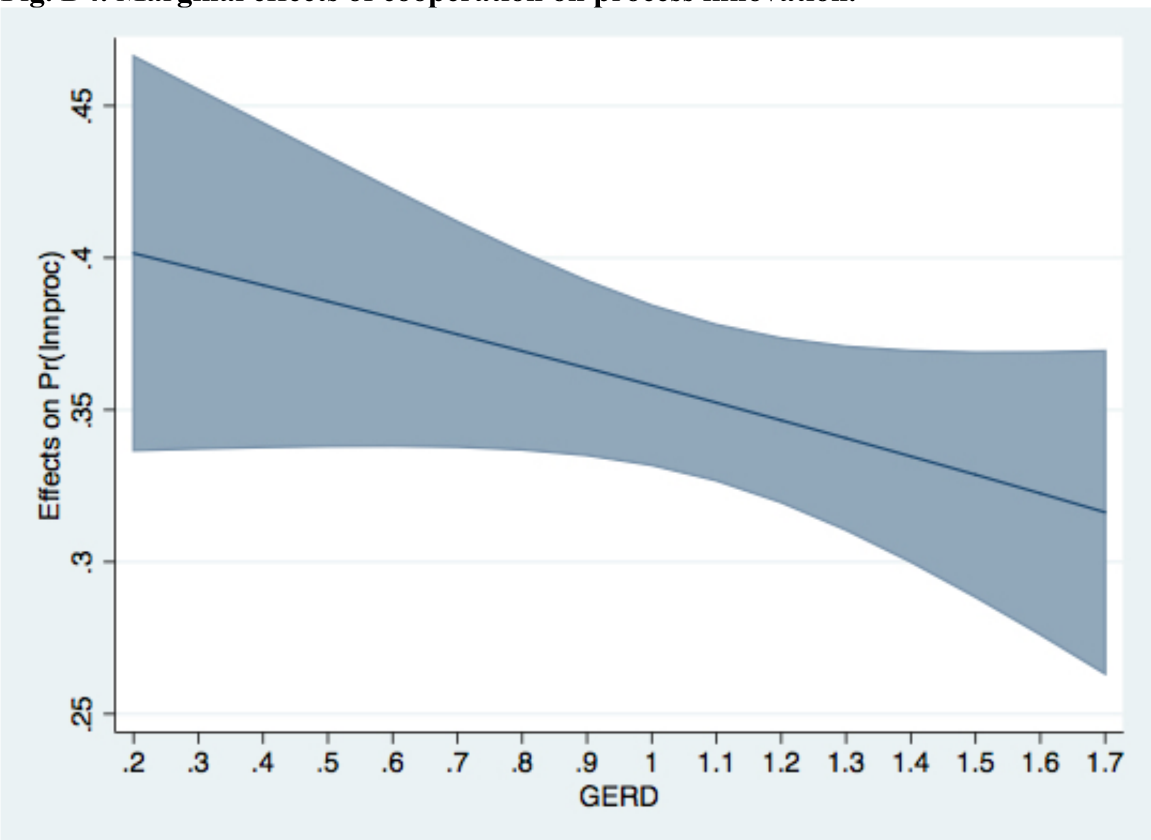
Note: Marginal effects computed from estimates in Table 2. The highlighted area denotes de 95% interval.

Fig. D3. Marginal effects of R&D expenditures on process innovation.



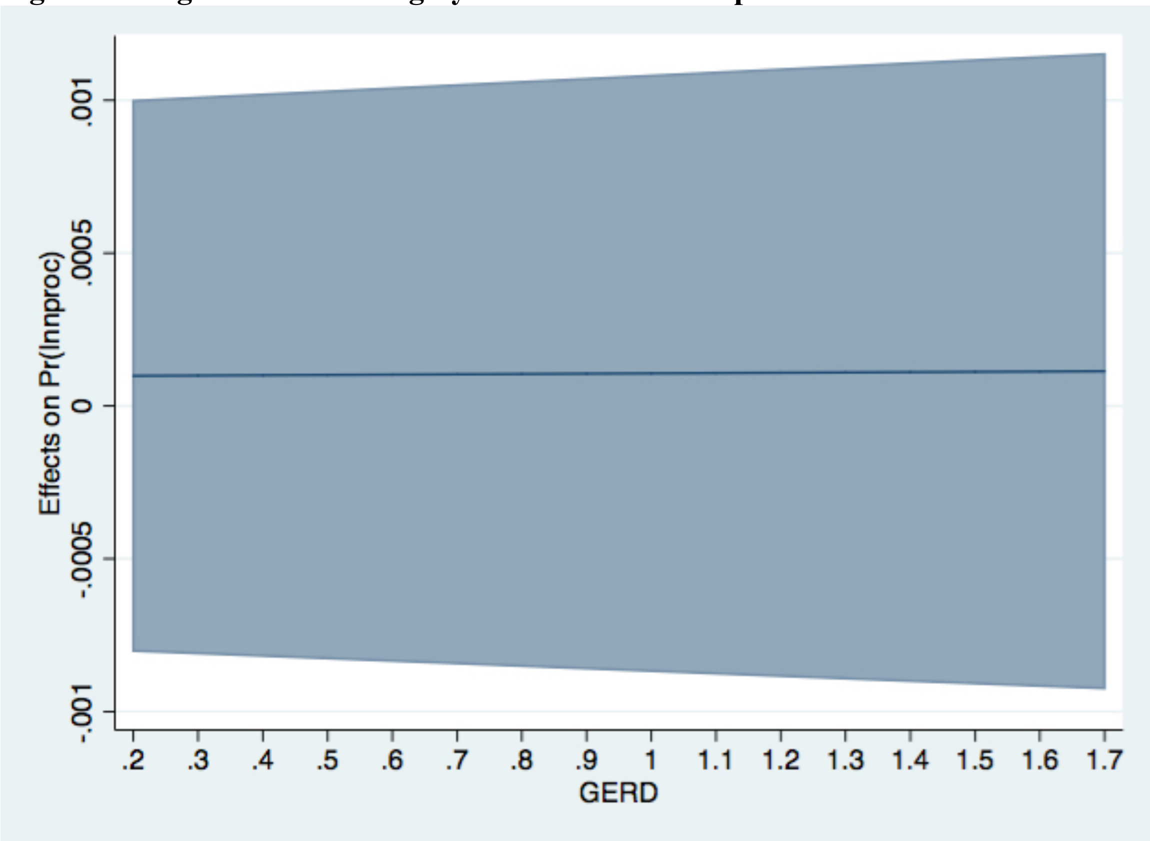
Note: Marginal effects computed from estimates in Table 3. The highlighted area denotes de 95% confidence interval.

Fig. D4. Marginal effects of cooperation on process innovation.



Note: Marginal effects computed from estimates in Table 3. The highlighted area denotes de 95% confidence interval.

Fig. D5. Marginal effects of highly skilled workers on process innovation.



Note: Marginal effects computed from estimates in Table 3. The highlighted area denotes de 95% confidence interval.

APPENDIX E

Robustness of Results to the Exclusion of Firms in Catalonia

It could be argued that the results regarding the effects of the regional factors are exclusively driven by the largest (most developed) regions. In this regard, figures in Table C1 of Appendix C suggest that the sample of firms in Catalonia could be playing a prominent role in the results discussed so far. To check if this is the case, the results were obtained with the sample of firms in all Spanish regions but Catalonia.[2] They are summarised in the first column of Tables E1 and E2, for product and process innovation respectively. It can be observed that in the case of the former type of innovation the only difference worth mentioning is the decrease in the coefficient of the interaction between R&D expenditures and GERD that, in any case, remains highly significant. Conversely, for process innovation, the size and significance of the effect of this interaction remains similar when excluding the Catalan firms. The only interesting difference in this case has to do with the significance of the coefficients of the interactions involving cooperation and highly skilled workers, which is somewhat higher when Catalan firms are included in the sample.

Altogether, this evidence indicates that the effect of the interaction between the firm's absorptive capacity and the region's R&D effort is not exclusively driven by a low number of the most innovative regions in Spain, although their contribution is undoubtedly substantial. The results are also qualitatively similar to those discussed in the main text when the analysis distinguishes by firms of different size.

[2] The authors thank an anonymous reviewer for suggesting this robustness check. It should be indicated that excluding the firms in more regions would have decrease severely the number of territorial units in the analysis, affecting the properties of the estimation of the parameters of the multilevel models.

Table E1. Estimates for product innovation. Excluding firms in Catalonia.

Internal factors	All sizes	LFs	SMEs	MFs	SFs
R&D expend.	-0.043***	0.459	-0.037**	0.129	-0.047**
	(0.015)	(0.344)	(0.015)	(0.100)	(0.020)
R&D cont.	2.211***	1.574**	2.170***	1.864***	2.255***
	(0.199)	(0.707)	(0.214)	(0.342)	(0.304)
Coop.	1.963***	1.902***	1.890***	1.735***	2.054***
	(0.207)	(0.717)	(0.222)	(0.335)	(0.303)
High-skilled	0.015***	-0.035	0.015***	0.029***	0.009
	(0.005)	(0.036)	(0.005)	(0.010)	(0.006)
Size (log)	0.086***	-0.071	0.073**	-0.066	0.216***
	(0.029)	(0.156)	(0.034)	(0.094)	(0.066)
Export	0.505***	0.043	0.523***	0.492***	0.538***
	(0.056)	(0.249)	(0.057)	(0.096)	(0.072)
Foreign own.	-0.169	-0.200	-0.108	0.079	-0.534
	(0.182)	(0.366)	(0.213)	(0.258)	(0.384)
New firm	3.202***	-	3.194***	1.243	3.635***
	(0.379)		(0.380)	(0.949)	(0.451)
Merge	0.167	-0.377	0.239	-0.056	0.600*
	(0.220)	(0.620)	(0.237)	(0.319)	(0.356)
Group Nat.	-0.076	0.210	-0.108	-0.046	-0.104
	(0.078)	(0.275)	(0.083)	(0.110)	(0.130)
Group Internat.	0.237	0.728*	0.053	0.063	0.256
	(0.185)	(0.399)	(0.218)	(0.266)	(0.398)
Sectors	YES***	YES*	YES***	YES***	YES***
External factors					
GERD	0.171	-0.887	0.169	0.447*	0.065
	(0.170)	(0.675)	(0.184)	(0.257)	(0.180)
Urban	0.001	0.001	0.001	-0.001	-0.000
	(0.003)	(0.009)	(0.003)	(0.004)	(0.003)
Human Cap.	-0.011	-0.028	-0.010	-0.085***	0.005
	(0.017)	(0.056)	(0.018)	(0.021)	(0.018)
GDPpc	-0.004	0.072	-0.007	0.0773**	-0.021
	(0.023)	(0.098)	(0.024)	(0.033)	(0.024)
R&D expend.*GERD	0.052***	-0.228	0.045**	-0.003	0.058**
	(0.019)	(0.223)	(0.018)	(0.083)	(0.024)
R&D cont.*GERD	-0.066	0.276	0.004	0.160	-0.117
	(0.182)	(0.561)	(0.200)	(0.311)	(0.290)
Coop.*GERD	-0.649***	-0.645	-0.555***	-0.433	-0.717**
	(0.192)	(0.563)	(0.212)	(0.317)	(0.292)
High-skilled*GERD	-0.003	0.016	-0.001	-0.015*	0.005
	(0.004)	(0.023)	(0.004)	(0.008)	(0.006)
Significance of FE coefficients (Wald tests)					
All variables	2176***	177***	1884***	746***	1096***
Internal factors	557***	50.52***	466.5***	165***	305.1***
External factors	1.629	3.816	1.489	18.85***	1.548
External & interactions	20.48***	9.579	14.04*	26.77***	13.42*
Interactions	18.73***	2.631	12.55**	5.752	12.13**
Random Effects					
var(cons.)	0.006	0.000	0.009	0.000	0.000
LR test	1.134	0.000	2.223*	0.000	0.004
ICC	0.0019	0.0000	0.0028	0.0000	0.0001
Log-Lik	-4979	-318.0	-4639	-1618	-2984
Observations	10956	674	10280	3400	6880

Notes: Standard errors in parenthesis. LFs: 250 and more employees; SMEs: 10 to 249 employees; MFs: 50 to 249 employees; SFs: 10 to 49 employees. ICC denotes intraclass correlation, the ratio of the between-region variance to the total variance. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table E2. Estimates for process innovation. Excluding firms in Catalonia.

Internal factors	**All sizes**	**LFs**	**SMEs**	**MFs**	**SFs**
R&D expend.	0.079***	-0.206	0.079***	-0.029	0.109***
	(0.017)	(0.233)	(0.017)	(0.029)	(0.021)
R&D cont.	1.533***	1.105*	1.593***	2.046***	1.285***
	(0.188)	(0.652)	(0.202)	(0.303)	(0.281)
Coop.	1.948***	1.605**	1.976***	2.332***	1.638***
	(0.210)	(0.680)	(0.225)	(0.350)	(0.297)
High-skilled	0.013***	0.036	0.012***	0.017*	0.011*
	(0.004)	(0.033)	(0.005)	(0.009)	(0.005)
Size (log)	0.144***	-0.209	0.124***	0.044	0.263***
	(0.026)	(0.143)	(0.030)	(0.086)	(0.058)
Export	0.396***	0.583***	0.393***	0.271***	0.441***
	(0.050)	(0.225)	(0.052)	(0.086)	(0.065)
Foreign own.	-0.158	0.216	-0.286	-0.342	-0.212
	(0.168)	(0.347)	(0.195)	(0.241)	(0.347)
New firm	1.277***	-	1.261***	-1.122	1.551***
	(0.292)		(0.294)	(1.168)	(0.316)
Merge	0.363*	0.054	0.390*	0.237	0.583*
	(0.199)	(0.536)	(0.214)	(0.286)	(0.326)
Group Nat.	-0.106	-0.119	-0.124*	-0.110	-0.072
	(0.070)	(0.254)	(0.074)	(0.100)	(0.116)
Group Internat.	0.185	-0.236	0.258	0.524**	-0.095
	(0.170)	(0.374)	(0.200)	(0.247)	(0.368)
Sectors	YES***	YES	YES***	YES***	YES***
External factors					
GERD	0.139	0.394	0.124	0.217	0.087
	(0.135)	(0.623)	(0.146)	(0.227)	(0.181)
Urban	-0.001	-0.010	-0.000	-0.003	0.001
	(0.002)	(0.008)	(0.003)	(0.003)	(0.003)
Human Cap.	-0.008	-0.033	-0.007	-0.019	-0.001
	(0.012)	(0.052)	(0.013)	(0.019)	(0.017)
GDPpc	0.010	0.045	0.007	0.006	0.007
	(0.017)	(0.090)	(0.018)	(0.030)	(0.022)
R&D expend.*GERD	-0.048***	0.146	-0.047***	0.049	-0.065***
	(0.010)	(0.156)	(0.010)	(0.039)	(0.013)
R&D cont.*GERD	-0.251	-0.071	-0.280	-0.564**	-0.119
	(0.162)	(0.522)	(0.177)	(0.275)	(0.249)
Coop.*GERD	-0.225	-0.169	-0.205	-0.479	0.041
	(0.191)	(0.537)	(0.208)	(0.318)	(0.280)
High-skilled*GERD	-0.007*	-0.023	-0.007*	-0.014*	-0.004
	(0.004)	(0.021)	(0.004)	(0.008)	(0.005)
Significance of FE coefficients (Wald tests)					
All variables	1635***	122***	1401***	561***	804***
Internal factors	510***	36.93**	435.7***	179***	269***
External factors	1.501	1.404	0.873	2.413	2.243
External & interactions	39.60***	3.515	36.42***	22.35***	31.04***
Interactions	38.38***	2.073	35.77***	11.61**	30.51***
Random Effects					
var(cons.)	0.003	0.000	0.004	0.000	0.007
LR test	0.755	0.000	1.590	0.000	1.777*
ICC	0.0008	0.0000	0.0013	0.0000	0.0022
Log-Lik	-5959	-357.9	-5584	-1893	-3655
Observations	10956	674	10280	3400	6880

Notes: Standard errors in parenthesis. LFs: 250 and more employees; SMEs: 10 to 249 employees; MFs: 50 to 249 employees; SFs: 10 to 49 employees. ICC denotes intraclass correlation, the ratio of the between-region variance to the total variance. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

APPENDIX F

Table F1. Estimates by firm size. Large firms versus SMEs.

	Product Innovation		Process Innovation	
Internal factors	**LFs**	**SMEs**	**LFs**	**SMEs**
R&D expend.	0.494	-0.091***	-0.163	0.073***
	(0.311)	(0.018)	(0.207)	(0.016)
R&D cont.	1.489**	2.306***	1.150*	1.559***
	(0.686)	(0.214)	(0.636)	(0.200)
Coop.	1.923***	1.878***	1.488**	2.008***
	(0.711)	(0.220)	(0.663)	(0.222)
High-skilled	-0.005	0.017***	0.020	0.013***
	(0.031)	(0.005)	(0.028)	(0.005)
Size (log)	-0.025	0.081***	-0.153	0.141***
	(0.130)	(0.030)	(0.118)	(0.026)
Export	0.219	0.509***	0.688***	0.356***
	(0.209)	(0.051)	(0.190)	(0.046)
Foreign own.	-0.243	-0.064	-0.107	-0.187
	(0.294)	(0.166)	(0.276)	(0.152)
New firm	-	3.285***	-	1.159***
		(0.356)		(0.267)
Merge	-0.517	0.172	-0.027	0.227
	(0.472)	(0.202)	(0.403)	(0.183)
Group Nat.	0.264	-0.076	-0.085	-0.092
	(0.230)	(0.072)	(0.215)	(0.064)
Group Internat.	0.790**	-0.075	-0.172	0.109
	(0.326)	(0.173)	(0.303)	(0.157)
Sectors	YES**	YES***	YES	YES***
External factors				
GERD	-0.882	0.260*	0.211	0.221
	(0.657)	(0.158)	(0.610)	(0.143)
Urban	0.002	0.000	-0.006	-0.001
	(0.008)	(0.003)	(0.007)	(0.003)
Human Cap.	-0.023	-0.022	0.004	-0.019
	(0.031)	(0.015)	(0.029)	(0.012)
GDPpc	0.068	0.007	-0.005	0.025
	(0.062)	(0.020)	(0.057)	(0.017)
R&D expend.*GERD	-0.247	0.110***	0.122	-0.044***
	(0.212)	(0.022)	(0.150)	(0.010)
R&D cont.*GERD	0.287	-0.129	0.039	-0.167
	(0.544)	(0.191)	(0.507)	(0.168)
Coop.*GERD	-0.604	-0.513**	-0.212	-0.262
	(0.556)	(0.200)	(0.523)	(0.197)
High-skilled*GERD	0.003	-0.005	-0.013	-0.008**
	(0.021)	(0.004)	(0.019)	(0.004)
Significance of FE coefficients (Wald tests)				
All variables	247.4***	2617***	168.6***	1867***
Internal factors	57.1***	544.7***	44.21***	464.6***
External factors	3.450	3.758	0.688	5.876
External & interactions	10.53	34.58***	1.928	37.49***
Interactions	2.588	31.56***	1.255	35.48***
Random Effects				
var(cons.)	0.000	0.007	0.000	0.007
LR test	0.000	0.931	0.000	4.984**
ICC	0.000	0.0020	0.000	0.0021
Log-Lik	-454.9	-6018	-515.3	-7240
Observations	958	13114	958	13114

Notes: Standard errors in parenthesis. LFs: 250 and more employees; SMEs: 10 to 249 employees. New firm was excluded during the estimation procedure for the subsample of large firms as only two of them in the sample were created in the period and both were innovative firms. ICC denotes intraclass correlation, the ratio of the between-region variance to the total variance. *** p<0.01, ** p<0.05, * p<0.1.

Table F2. Estimates for medium and small firms.

	Product Innovation		Process Innovation	
Internal factors	**MFs**	**SFs**	**MFs**	**SFs**
R&D expend.	0.121	-0.094***	-0.023	0.098***
	(0.108)	(0.021)	(0.027)	(0.022)
R&D cont.	1.848***	2.372***	2.017***	1.257***
	(0.342)	(0.303)	(0.301)	(0.283)
Coop.	1.719***	1.994***	2.321***	1.716***
	(0.329)	(0.300)	(0.350)	(0.292)
High-skilled	0.028***	0.012*	0.017*	0.012**
	(0.010)	(0.006)	(0.009)	(0.005)
Size (log)	-0.051	0.254***	0.030	0.295***
	(0.082)	(0.058)	(0.075)	(0.051)
Export	0.491***	0.509***	0.302***	0.367***
	(0.085)	(0.064)	(0.076)	(0.057)
Foreign own.	0.043	-0.230	-0.291	0.063
	(0.202)	(0.297)	(0.188)	(0.264)
New firm	1.644*	3.664***	-1.325	1.436***
	(0.859)	(0.415)	(1.140)	(0.284)
Merge	-0.021	0.484	0.085	0.479*
	(0.270)	(0.304)	(0.248)	(0.274)
Group Nat.	-0.063	0.007	-0.060	-0.051
	(0.095)	(0.112)	(0.086)	(0.100)
Group Internat.	-0.019	-0.014	0.349*	-0.148
	(0.210)	(0.320)	(0.194)	(0.285)
Sectors	YES***	YES***	YES***	YES**
External factors				
GERD	0.345	0.200	0.338	0.173
	(0.240)	(0.169)	(0.235)	(0.155)
Urban	0.002	-0.001	-0.005	0.000
	(0.004)	(0.003)	(0.004)	(0.003)
Human Cap.	-0.062***	-0.015	-0.047***	-0.011
	(0.014)	(0.018)	(0.016)	(0.013)
GDPpc	0.043*	0.004	0.048*	0.020
	(0.024)	(0.023)	(0.026)	(0.018)
R&D expend.*GERD	0.045	0.114***	0.040	-0.060***
	(0.090)	(0.026)	(0.033)	(0.018)
R&D cont.*GERD	0.121	-0.221	-0.463*	0.003
	(0.295)	(0.273)	(0.261)	(0.242)
Coop.*GERD	-0.419	-0.611**	-0.445	-0.095
	(0.297)	(0.276)	(0.305)	(0.264)
High-skilled*GERD	-0.018**	0.001	-0.015**	-0.006
	(0.008)	(0.005)	(0.008)	(0.005)
Significance of FE coefficients (Wald tests)				
All variables	1043***	1544***	762.2***	1063***
Internal factors	171.2***	365.3***	192.6***	285.9***
External factors	20.43***	1.680	9.498**	5.207
External & interactions	28.50***	25.82***	21.58***	20.45***
Interactions	7.45	23.76***	11.12**	18.58***
Random Effects				
var(cons.)	0.000	0.001	0.007	0.006
LR test	0.000	0.0126	1.185	0.967
ICC	0.000	0.0003	0.0021	0.0017
Log-Lik	-2182	-3787	-2542	-4659
Observations	4530	8584	4530	8584

Notes: Standard errors in parenthesis. MFs: 50 to 249 employees; SFs: 10 to 49 employees. New firm was excluded during the estimation procedure for the subsample of large firms as only two of them in the sample were created in the period and both were innovative firms. ICC denotes intraclass correlation, the ratio of the between-region variance to the total variance. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.