Innovation, heterogeneous firms and the region: evidence from Spain

Enrique López-Bazo\textsuperscript{a} \textsuperscript{b} and Elisabet Motellón\textsuperscript{b} \textsuperscript{c}

\textbf{ABSTRACT}
Innovation, heterogeneous firms and the region: evidence from Spain. \textit{Regional Studies}. 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 small and medium-sized enterprises, being negligible for large firms.

\textbf{KEYWORDS}
product innovation; process innovation; firm; multilevel modelling; Spanish regions

\textbf{RÉSUMÉ}
L’innovation, les entreprises hétérogènes et la région: des résultats provenant de l’Espagne. \textit{Regional Studies}. Cet article examine le rôle des facteurs régionaux quant à la performance en matière d’innovation, contrôlant la capacité d’absorption et d’autres caractéristiques de l’hétérogénéité des entreprises. Les résultats provenant d’un échantillon d’entreprises espagnoles confirment l’hypothèse selon laquelle les facteurs déterminants régionaux sont importants, bien que leur rôle soit plus subtil que l’on ne suppose souvent. Plutôt que d’influencer directement l’innovation des entreprises, le contexte régionale modère l’effet des facteurs déterminants internes, notamment pour ce qui est de la capacité d’absorption des entreprises. Les résultats laissent voir que le type d’interactions pertinentes varie pour l’innovation de produit par rapport à l’innovation de procédé et qu’elles ne s’appliquent qu’aux petites et moyennes entreprises, étant négligeables pour les grandes entreprises.

\textbf{MOTS-CLÉS}
innovation de produit; innovation de procédé; entreprise; modélisation multiniveaux; régions espagnoles

\textbf{CONTACT}
\textsuperscript{a}(Corresponding author) elopez@ub.edu
Regional Quantitative Analysis Research Group (AQR), University of Barcelona, Barcelona, Spain.
\textsuperscript{b} emotellon@uoc.edu
Regional Quantitative Analysis Research Group (AQR), University of Barcelona, Barcelona, Spain; and Universitat Oberta de Catalunya, Barcelona, Spain.

Supplemental data for this article can be accessed \url{https://doi.org/10.1080/00343404.2017.1331296}.
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 & Levinthal, 1990). The effect on the 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 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. The third section sketches the multilevel model used to obtain the estimates of the effect of the internal and external determinants, while the dataset and the main variables are introduced in the fourth section. The results for the entire sample of firms and those distinguished by size are presented and discussed in the fifth section. Finally, the sixth section concludes.

**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, & Maïresse, 1998; Geroski, Machin, & Van Reenen, 1993; Griffith, Huergo, Maïresse, & Peters, 2006; Hall & Maïresse, 1995), also playing a fundamental role in the growth prospects of regional economies (Audretsch & Feldman, 1996; Crescenzi, 2005; Rodríguez-Pose & 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, & 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 & Walther, 2014; Sternberg & 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, & Reilly, 2009): ‘industrial districts’ (Scott & Storper, 2003), ‘technological clusters’ (Saxenian, 1994), ‘learning regions’ (Gertler, 2001), ‘innovation milieu’ (Keeble & Wilkinson, 1999), and ‘regional innovation systems’ (Cooke, 2001). All share the idea that a mix of universities and research institutes, research and development (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 & 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 & Slavtchev, 2011; Ponds, Van Oort, & 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 a dissociation between the level that is relevant to the process of innovation, that 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 information and communication technology (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 Belgian 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 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 (Love & Roper, 2001, passim). As far as we know, 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 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 & 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, passim). 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 & Bosker, 2011; Van Oort, Burger, Knoben, & 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, Tesuk, & 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 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 (1) internal factors, particularly absorptive capacity, account for most of the variability in firms’ innovation performance; (2) the regional context also has an effect, although it is only through the interaction with firms’ absorptive capacity; and (3) large firms are less sensitive to the regional context than SMEs.

**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 \( \text{Inno}_{ij} \), which
is the propensity to innovate of firm $i$ $(i = 1, \ldots, n_r)$ located in region $r$ $(r = 1, \ldots, 17)$:\[\text{Innov}_{ir}^* = \beta_{0r} + \sum_{k=1}^{K} \beta_{kr} F_{kir} + e_{ir} \quad (1)\]

where $F_{kir}$ $(k = 1, \ldots, K)$ 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. $\beta_{0r}$ and $\beta_{kr}$ are, respectively, the intercept and vector of slopes for each region $r$. These parameters are allowed to vary across regions depending on the set of external factors ($R_{jr}, j = 1, \ldots, J$) and random components ($u_{0r}$ and $u_{kr}, k = 1, \ldots, K$):

$$\begin{align*}
\beta_{0r} &= \gamma_{00} + \sum_{j=1}^{J} \gamma_{0j} R_{jr} + u_{0r}, \quad u_{0r} \sim N(0, \sigma_{u0}^2) \\
\beta_{kr} &= \gamma_{k0} + \sum_{j=1}^{J} \gamma_{kj} R_{jr} + u_{kr}, \quad u_{kr} \sim N(0, \sigma_{ukr}^2) \quad (2)
\end{align*}$$

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

$$\begin{align*}
\text{Innov}_{ir}^* = \gamma_{00} + \sum_{j=1}^{J} \gamma_{0j} R_{jr} + \sum_{k=1}^{K} \gamma_{k0} F_{kir} \\
&\quad + \sum_{k=1}^{K} \sum_{j=1}^{J} \gamma_{kj} R_{jr} F_{kir} + e_{ir} + u_{0r} \\
&\quad + \sum_{k=1}^{K} u_{kr} F_{kir} \quad (3)
\end{align*}$$

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), $\beta_{0r}$) 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 ($\gamma_{0j} R_{jr}, \gamma_{k0} F_{kir}$), and a random component ($u_{kr} F_{kir}$). The coefficients associated with the contextual regional factors, $\gamma_{0j}$, and with the cross-level interaction between internal and contextual factors, $\gamma_{kj}$, 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 ($\text{Innov} = 1$ if $\text{Innov}^* > 0$, and 0 otherwise). More precisely, under the assumption that firm errors, $e_{ir}$, 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:

$$\text{prob}(\text{Innov}_{ir} = 1) = H(v) \quad (4)$$

where:

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

$$+ \sum_{k=1}^{K} u_{kr} F_{kir}$$

$\text{Innov}$ denotes an observed binary measure of innovation, and $H$ the logistic cumulative distribution function:

$$H(v) = \exp (v) /[1 + \exp (v)]$$

The parameters of the specification in equation (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 Appendix A in the supplemental data online.

**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 Organisation for Economic Co-operation and Development’s (OECD) *Oslo Manual (2005)*, 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 NUTS-2 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 NUTS-2 regions. 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 NUTS-2 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 in the supplemental data online. Among the several measures on innovation available from the ICS, this paper focuses on product and process innovations. Following the guidelines in OECD’s 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, & 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 sometime 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 in Appendix B in the supplemental data online. 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 & Roper, 2001; Srholec, 2010; Sternberg & Arndt, 2001): the region’s R&D effort, proxied by gross R&D expenditures over gross domestic product (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 in the supplemental data online. 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.

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:

- 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 ‘(i)’ in Tables 1 and 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 ‘(ii)’ and ‘(iii)’ for the internal and external factors, respectively.
- 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 ‘(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 ‘(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).4

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
### Table 1. Estimates for product innovation.

|                      | (i)     | (ii)     | (iii)    | (iv)     | (v)     |
|----------------------|---------|----------|----------|----------|---------|
| **Internal factors** |         |          |          |          |         |
| R&D expend.          | 0.001   | 0.001    | −0.098***|          |         |
|                      | (0.001) | (0.001)  | (0.018)  |          |         |
| R&D continuous       | 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*** |         |
|                      |         |          |          | (0.21)   |         |
| R&D continuous*GERD  |         |          |          | −0.210   |         |
|                      |         |          |          | (0.176)  |         |
| Coop.*GERD           |         |          |          | −0.597***|         |
|                      |         |          |          | (0.184)  |         |
| High-skilled*GERD    |         |          |          | −0.006   |         |
|                      |         |          |          | (0.004)  |         |

**Significance of fixed-effect coefficients (Wald tests)**

|                      |          |          |          |          |          |
|----------------------|----------|----------|----------|----------|----------|
| All variables        | 2963***  | 2997***  | 3025***  |          |          |
| Internal factors     | 2963***  | 2931***  | 632***   |          |          |
| External factors     | 30.10*** | 2.953    | 4.428    |          |          |
| External and interactions | 43.06*** | 40.47*** |          |          |
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. 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 products 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.

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 products 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 products. 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. To be clear, there is significant interaction between the region’s R&D effort and two of the absorptive capacity measures. On the one
Table 2. Estimates for process innovation.

|                | (i)     | (ii)    | (iii)   | (iv)    | (v)     |
|----------------|---------|---------|---------|---------|---------|
| **Internal factors** |         |         |         |         |         |
| R&D expend.     | 0.000   | 0.000   | 0.073***|         |         |
|                | (0.001) | (0.001) | (0.016) |         |         |
| R&D continuous  | 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 continuous*GERD|       | –0.157  |         |          |         |
|                |         | (0.155) |         |          |         |
| Coop.*GERD     | –0.307* |         |          |          |         |
|                | (0.182) |         |          |          |         |
| High-skilled*GERD|       | –0.009**|         |          |         |
|                | (0.004) |         |          |          |         |

**Significance of fixed-effects coefficients (Wald tests)**

|                | (2140***) | (2173***)|         |         |
|----------------|-----------|----------|---------|---------|
| **Internal factors** | 2129***   | 2103***  | 549.6***|         |
| **External factors** |          |          |         |         |
| **External and interactions** |          |          |         |         |
| **Interactions** |          |          |         |         |

(Continued)
hand, the effect of expenditures on R&D made by the firm increases with the region’s R&D effort. Note 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 in the supplemental data online. It is apparent that the effect of increasing the ratio of R&D expenditures over sales on the propensity to innovate in products is rather low, even for large values of GERD (a 1 percentage point increase in the R&D expenditure ratio – for which the average 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. 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 naive 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.

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

| External factors | Product innovation | Process innovation |
|------------------|--------------------|--------------------|
|                  | LF_ | SMEs | MFs | SFs | LF_ | 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 continuous *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 fixed-effects coefficients (Wald tests)

|                      | All variables | Internal factors | External factors | External and interactions | Interactions |
|----------------------|---------------|-----------------|-----------------|--------------------------|--------------|
|                      | 247.4***      | 57.1***         | 3.450           | 10.53                    | 2.588        |
|                      | 2617***       | 544.7***        | 3.758           | 34.58***                 | 31.56***     |
|                      | 1043***       | 171.2***        | 20.43***        | 28.58***                 | 7.45         |
|                      | 1544***       | 365.3***        | 1.680           | 25.82***                 | 23.76***     |
|                      | 168.6***      | 44.21***        | 0.688           | 1.928                    | 1.255        |
|                      | 1867***       | 464.6***        | 5.876           | 37.49***                 | 35.48***     |
|                      | 762.2***      | 192.6***        | 9.498**         | 21.58***                 | 11.12**      |
|                      | 1063***       | 285.9***        | 5.207           | 20.45**                  | 18.58**      |

Random effects

|                       | var(constant) | Likelihood ratio (LR) test | Intraclass correlation (ICC) | Log-likelihood | Observations |
|-----------------------|--------------|----------------------------|-----------------------------|---------------|--------------|
|                       | 0.000        | 0.000                      | 0.000                       | -454.9        | 958          |
|                       | 0.007        | 0.931                      | 0.0126                      | -6018         | 13,114       |
|                       | 0.000        | 0.0020                     | 0.0003                      | -2182         | 4350         |
|                       | 0.001        | 0.0126                     | 0.0003                      | -3787         | 8584         |
|                       | 0.000        | 4.984**                    | 0.0021                      | -515.3        | 958          |
|                       | 0.007        | 1.858                      | 0.0021                      | -7240         | 13,114       |
|                       | 0.006        | 4.984**                    | 0.0021                      | -2542         | 4530         |
|                       | 0.967        |                            |                            | -4659         | 8584         |
|                       | 0.017        |                            |                            |               |              |
|                       | 0.001        |                            |                            |               |              |

Notes: Standard errors are shown in parentheses. Large firms (LFs) = 250 and more employees; small and medium-sized enterprises (SMEs) = 10–249 employees; medium-size firms (MFs) = 50–249 employees; small firms (SFs) = 10–49 employees. Specifications included all the internal factors listed in Tables 1 and 2. Intraclass correlation is the ratio of the between-region variance to the total variance. **p < 0.01; *p < 0.05; p < 0.1.
R&D effort. To be more precise, the marginal effects depicted in Figure D3 in Appendix D in the supplemental data online 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 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, in both product and 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.9

Large firms versus small and medium-sized enterprises (SMEs)
The evidence provided so far was 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 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- (50–249 employees) and small-sized (10–49 employees) firms is considered to account for the likely heterogeneity of effects within SMEs.10 For 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 in the supplemental data online.

For both product and process innovation, direct and interaction effects of the external factors in the set of large firms 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-sized firms. 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. 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 small firms. Likewise, in the case of process innovation, it is observed that the negative effect of the regional endowment of education is restricted to medium-sized firms. However, the most interesting feature is the distribution of the impact of the interactions. The group of medium-sized firms 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 small firms.

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.11

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 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 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, for both product and 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, policymakers 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 of this paper suggest that innovation policies that are designed and implemented taking into account the fact that 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 above, 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 datasets 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 given 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 here due to lack of information on this variable in the dataset).

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

FUNDING

This work was supported by the Ministerio de Economía y Competitividad [grant number 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. Beugelsdijk (2007, n. 5) 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. The term $n_r$ is the number of firms in the sample for each region $r$, as shown in the last column of Table 1.

3. The set of NUTS-2 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.

4. 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 -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 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.

5. ICC is a measure of the degree of association between any pair of firms located in the same region. It is close to zero 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.

6. 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 (the \( p \)-value of the test is 0.12).

7. 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, note that the specification used to obtain the estimates does not preclude a negative marginal effect of R&D expenditures for low values of GERD.

8. 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 is 0.13, indicating that the coefficients of those interactions are not significant.

9. 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 in the supplemental data online summarize the results obtained in this case, which are qualitatively similar to those described in the main text.

10. The authors thank an anonymous reviewer for this suggestion.

11. 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 essence, 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.

Beugelsdijik, S. (2007). The regional environment and a firm’s innovative performance: A plea for a multi-level interactionist approach. *Economic Geography*, 83, 181–199. doi:10.1111/j.1944-8287.2007.tb00342.x

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly*, 35, 128–185. doi:10.2307/2393553

Cooke, P. (2001). Regional innovation systems, clusters, and the knowledge economy. *Industrial and Corporate Change*, 10, 945–974. doi:10.1093/icc/10.4.945

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. doi:10.1080/10438599800000031

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. doi:10.1111/j.1468-2257.2005.00291.x

Czarnitzki, D., & Hotz, K. (2009). Are local milieus the key to innovation performance? *Journal of Regional Science*, 49, 81–112. doi:10.1111/j.1467-9787.2008.00584.x

Dautel, V., & Walther, O. (2014). The geography of innovation in a small metropolitan region: An intra-regional approach in Luxembourg. *Papers in Regional Science*, 93, 703–725. doi:10.1111/pirs.12019

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.

Frijters, R. D., & Rodríguez-Pose, A. (2015). Networking, context and firm-level innovation: Cooperation through the regional filter in Norway. *Geoforum*, 63, 25–35. doi:10.1016/j.geoforum.2015.05.010

Fritsch, M., & Slavtchev, V. (2011). Determinants of the efficiency of the regional innovation systems. *Regional Studies*, 45, 905–918. doi:10.1080/00343400802251494

Geroski, P., Machin, S., & Van Reenen, J. (1993). The profitability of innovating firms. *R&D Journal of Economics*, 24, 198–211. doi:10.2307/2555757

Gertler, M. S. (2001). Best practice? Geography, learning and the institutional limits to strong convergence. *Journal of Economic Geography*, 1, 5–26. doi:10.1093/jeg/1.1.5

Griffith, R., Huergo, E., Mairesse, J., & Peters, B. (2006). Innovation and productivity across four European countries. *Oxford Review of Economic Policy*, 22, 483–498. doi:10.1093/oxrep/grp028

Guo, G., & Zhao, H. (2000). Multilevel modelling for binary data. *Annual Review of Sociology*, 26, 441–462. doi:10.1146/annurev.soc.26.1.441

Gupta, A. K., Teluk, P. E., & Taylor, M. S. (2007). Innovation at and across multiple levels of analysis. *Organization Science*, 18, 885–897. doi:10.1287/orsc.1070.0337

Hall, B., & Mairesse, J. (1995). Exploring the relationship between R&D and productivity in French manufacturing firms. *Journal of Econometrics*, 65, 263–293. doi:10.1016/0304-4076(94)01604-X
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. doi:10.1093/jeg/lbn049

Karlsson, C., & Olsson, O. (1998). Product innovation in small and large enterprises. *Small Business Economics*, 10, 31–46. doi:10.1023/A:1007970416484

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. doi:10.1080/0034340950081167

Lee, N., & Rodríguez-Pose, A. (2014). Innovation in creative cities: Evidence from British small firms. *Industry and Innovation*, 21, 494–512. doi:10.1080/13662716.2014.983748

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. doi:10.1016/S0048-7333(00)00098-6

Naz, A., Niebuhr, A., & Peters, J. C. (2015). What determines the innovation behavior of European firms? *Economic Geography*, 87, 131–156. doi:10.1007/s10683-015-0694-9

Organisation for Economic Co-operation and Development (OECD). (2005). *Oslo manual: Guidelines for collecting and interpreting innovation data* (3rd Ed.). Paris: OECD.

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. doi:10.1093/jeg/lbp036

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. doi:10.1093/jeg/lbs009

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. doi:10.1080/00343400701654186

Rogers, M. (2004). Networks, firm size and innovation. *Small Business Economics*, 22, 141–153. doi:10.1023/B:SBEJ.0000014451.99047.69

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

Scott, A. J., & Storper, M. (2003). Regions, globalization, development. *Regional Studies*, 37, 579–593. doi:10.1080/00343400332000108697a

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. doi:10.1080/0034340903365094

Sternberg, R., & Arndt, O. (2001). The firm or the region: What determines the innovation behavior of European firms? *Economic Geography*, 77, 364–382. doi:10.2307/3594106

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. doi:10.1111/j.1467-6419.2012.00723.x

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. doi:10.1016/j.respol.2008.01.001

Vogel, J. (2015). The two faces of R&D and human capital: Evidence from Western European regions. *Papers in Regional Science*, 94, 525–551. doi:10.1111/pirs.12084

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. doi:10.1093/jeg/lbs019