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“Innovation, heterogeneous firms, and the region”

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Abstract

This paper investigates the role of regional determinants on innovation performance controlling by the firm's 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 the one frequently assumed. Rather than a direct influence on firm's innovation, the regional context moderates the effect of internal determinants. In the case of product innovation the most important mechanism of interaction seems to be operating through cooperation in innovation, whereas for process innovation it seems to be through highly skilled labour.

JEL classification: D21; O31; R10; R15

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

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1. INTRODUCTION

Innovation has been shown to be a crucial determinant of the market opportunities of firms (Geroski *et al*., 1993; Hall and Mairesse, 1995; Crepon *et al*., 1998; Griffith *et al*., 2006) which plays also 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 motivated great interest in the analysis of the determinants of innovation, including the ones that are internal to the firm and those corresponding to the territory in which the firm operates. Internal factors that influence the innovation performance of the firm include its technological competences, human resources and organisational capabilities, and other features such as firm size and market concentration (e.g. Vega-Jurado *et al*., 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 also impact 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 factors that, being external to the firm, have been proposed to explain differences in the innovation behaviour of firms located in different regions (Sternberg and Arndt, 2001; Beugelsdijk, 2007; Dautel and Walther, 2013). Hot spots characterised by a high concentration of these external determinants and innovative firms have been widely analysed in the literature under different denominations (Ibrahim *et al*., 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 the mix of universities and research institutes, R&D expenditures and personnel, and a regional innovation policy are fundamental for the innovation performance of the region. In other words, the regional environment is crucial for the firm's innovation behaviour (Beugelsdijk, 2007), motivating the design of regional innovation strategies aiming at improving the environmental determinants of innovation (Love and Roper, 2001).

Most of the empirical evidence supporting the effect of the external determinants of innovation has been obtained from case studies or by exploiting aggregate regional data, frequently used to estimate the so-called regional knowledge production function. However, conclusions drawn from the former approach are difficult to generalise 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 which is relevant for 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 the firm's innovation performance should be drawn from evidence obtained by means of firm-level data rather than from the aggregate regional level. In this regard, Sternberg and Arndt (2001) is the first of a bunch of recent studies aiming at disentangling the contribution of internal and external determinants of innovation by combining firm-level with region-level data. They claim that it is the characteristics of the firms 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 put the stress on enhancing the innovation capabilities of firms in the region rather than on improving its innovation environment in general. Similar evidence has been reported by Beugelsdijk (2007) and Smit *et al*. (2015) for Dutch firms, and Vega-Jurado *et al*. (2008) for Spanish manufacturing firms.

By and large, these studies showed that internal determinants are more important for the firm's ability to innovate than are 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 counteracted the tendency to overemphasize the role of the regional context and claimed for the importance of accounting for firm heterogeneity in the internal determinants of innovation. However, other recent studies, acknowledging that firm's characteristics are important, conclude that geography also matters a lot. Love and Roper (2001) report that the region affects the efficiency with which R&D, technology transfer and networking are translated into innovation outputs in Germany, Ireland and UK. Results for firms in the regions of Flanders led Czarnitzki and Hottenrott (2009) to conclude that the availability of highly skilled labour and proximity to suppliers matter for firm's innovation, whereas the evidence reported by Srholec (2010) from firms in the Czech Republic indicates that the quality of the regional innovation system (RIS) and some social characteristics influence the likelihood to innovate. Finally, Dautel and Walther (2013) provide support for a link between agglomeration externalities and innovation output from a sample of firms located in Luxembourg, and Naz *et al*. (2014) obtain a positive association between innovation of German firms and regional R&D activity, though there is not a significant effect of the regional endowment of human capital.

An interesting feature of the empirical studies mentioned above is that they use data with a hierarchical structure. There is a first level, which corresponds to the firm micro-data, and a second level that accounts for the regional context in which the firm is located. In this context, the multilevel modelling (e.g. Snijders and Bosker, 2011; Van Oort *et al*., 2012) potentially offers a more complete perspective, as the analysis combines determinants of innovation at the firm and at the regional level (Gupta *et al*., 2007). In contrast to multi-level models, standard single-level models assume that the 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*. (2014) are the only studies that have used multi-level models to assess the contribution of the internal and regional determinants of firm's innovation. Interestingly, Srholec (2010) argues that the nested structure of the firm-level data used in this literature is straightforwardly derived from the concept of RIS, which makes the use of single-level models even more shocking.[1]

A drawback shared by almost all previous studies is that they do not consider interactions between firm characteristics and context variables. Love and Roper (2001) recognise that regional factors can depend on interactions between firms' activities and their environment. They indicate that interaction terms between the magnitudes that accounted for the level of innovative activity in the region and the firm determinants of innovation were initially included in the specifications, although they proved wholly insignificant in the estimation. Srholec (2010) is the only study that clearly takes on board interactions between the firm characteristics and the regional context variables (cross-level interactions). Results show a significant effect of the interaction between the measure of the strength of the RIS and some firm characteristics (particularly size),

[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.

and the importance of including interactions to isolate properly the effect of the regional factors on the intercept.

This paper aims at providing additional evidence on the contribution of external regional factors to the firm's innovation performance. As indicated in Beugelsdijk (2007), more empirical analyses at the regional level for the European Union and the United States are required to confirm or disprove his results for a sample of Dutch firms. A comprehensive sample of firms in the Spanish regions is used in this paper to assess the effect of regional determinants on the probability of innovating in product and in process. Some features make this study valuable. First, the share of innovative firms largely varies between regions in Spain, which makes interesting analysing whether the origin of the differences lies on disparities in the RIS, and in other socio-economic characteristics, or if they are mostly due to regional differences in the firm's internal determinants. Second, the firm-level dataset includes a rich set of firm characteristics, which allows controlling for several sources of firm heterogeneity. This prevents confounding the effect of external determinants with that of (omitted) firm characteristics. Third, a multilevel model is estimated to accommodate the hierarchical structure of the data. As mentioned above, this has been claimed to be the most appropriate specification for estimating the contribution of regional factors on firm innovation, although the number of studies using this approach is still scant. Four, the empirical model includes cross-level interaction. In fact, the main hypothesis of this paper is that the role played by regional factors is subtler than has been assumed in most of the previous literature. Rather than a direct effect on the firm innovation performance, this paper hypothesises that the regional context intertwine with internal factors related to the absorptive capacity of the firm (Cohen and Levinthal, 1990). The effect on innovation performance of the firm's absorptive capacity is, therefore, assumed to vary across regions depending on the environmental determinants. Last, differences in the contribution of the regional factors is investigated for large firms and SMEs separately, under the assumption that the latter depend more on a favourable context than large firm do.

The rest of the paper is organised as follows. The next section introduces the dataset and the main variables. The multilevel model used to obtain the estimates of the effect of the internal and external determinants is sketched in section 3, while the results for the entire sample of firms and distinguishing by size are presented and discussed in section 4. Finally, section 5 concludes. It should be mentioned that the description of the main variables under analysis and additional estimation results are provided in the supplemental material.

2. DATA AND VARIABLES

The study of the effect of the internal and external determinants of firm's innovation requires using 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, sector of activity, 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.[2] 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 controlling for unobserved firm heterogeneity in the empirical exercise in this paper. However, it can be argued that the large amount of information on firm's characteristics contained in the ICS allows controlling for most of the firm heterogeneity. Results provided in the rest of the paper correspond to the ICS wave of 2005 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 mentioning that using data for one country eliminates the risk that country-specific differences in the institutional setting contaminate the evidence on the effect of the internal and regional determinants (BEUGELSDIJK, 2007).

[2] The set of NUTS2 Spanish regions is composed by the 17 Autonomous Communities. They enjoy high political and financial autonomy, including competences in the promotion of R&D and innovation.

The definition of the measures of firm's innovation along with that of each of its internal and external determinants is provided in Table 1. 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. In turn, 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 in two groups. On the one hand, factors that proxy for the absorptive capacity of the firm, which include performing R&D activities continuously, cooperate in innovation with other agents, and employing high-skilled labour. It is noteworthy that measures of R&D intensity (R&D expenditures over sales and total employment) were initially included in this group of determinants of the firm's absorptive capacity. However, a detailed inspection of the data revealed that these measures do poorly correlate with product and process innovation. Actually, the preliminary analysis revealed that what really discriminates between innovative and non innovative firms is not the relative amount of R&D resources declared by the firm but how persistent it is in performing these activities, and if it cooperates 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 *et al.*, 2013), a clear indication was obtained supporting the link between the firm's share of highly skilled workers and innovation. The other group includes controls for several sources of firm heterogeneity that have been shown to affect innovation, such as size, activity in 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 a firm's decision to innovate takes place some time before the innovation is observed, whenever possible the variables that account for the internal factors were constructed using the information available in the ICS 2005 referred to two years before (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 1. Among the long list of candidates, this paper includes four measures that have been frequently used in similar previous studies (e.g. Sternberg and Arndt, 2001; Love and Roper, 2001; Beugelsdijk, 2007; Srholec, 2010): the region's R&D effort, proxied by its R&D expenditures over GDP; the amount of urbanization/agglomeration as measured by the share of urban population; the availability of a pool of high-skilled individuals in the region, as measured by the share of the region's population with a university degree; and per capita GDP, an all-in-one measure of the potential effect that the socio-economic context may have on firm's 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 in the Spanish regions is reported in Table 2. It is clearly observed that the share of innovative firms varies substantially between regions, as it does the measures of firm's absorptive capacity, and the ones for the internal and external determinants. 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 three 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 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). Similar 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.[3] 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 2. 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.

3. EMPIRICAL SPECIFICATION. MIXED-EFFECT LOGIT.

A mixed-effect logit specification is used to estimate the effect of the internal and external factors on firm's innovation. The term mixed-effects refers to the inclusion in the model of both fixed and random effects. In the case of this study, 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

[3] 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.

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):[4, 5]

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

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 external factors ($\gamma_{kj} R_{jr} F_{kir}$), and a random component ($u_{kr} F_{kir}$). The coefficients associated to the contextual regional factors, γ_{0j}, and to 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

[4] See Guo and Zhao (2000) for the derivation of the multilevel model for binary outcomes through a latent variable conceptualization.
[5] n_r is the number of firms in the sample for each region r, as shown in the last column of Table 2.

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 data available in the ICS 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:

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

where

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

Innov denotes any of the two observed binary measures of innovation (product and process) and *H* the logistic cumulative distribution function, $H(v) = \exp(v)/[1 + \exp(v)]$.

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 role 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.

As for the strategy followed in the empirical exercise, it can be summarised as follows:

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 for the significance of the random effects. Results correspond to columns labelled as (i) in Tables 3 and 4.
2. 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 firm's innovation, and to check if they account for the unobserved regional variability, captured by the random component. Results are in columns labelled as (ii) and (iii) respectively for the internal and external factors.
3. The mixed-effects model that includes the internal and external factors simultaneously is estimated next. In one case, no interactions between internal and external factors are considered –column labelled as (iv), whereas in another, the

interactions between the contextual variable GERD and the proxies for the firm's absorptive capacity are included –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 results revealed that all of them exert a negligible contribution in the explanation of the propensity to innovate in product and in process (the corresponding coefficients are not statistically significant).

Therefore, different specifications under the umbrella of the general mixed-effects logit model in equation (4) are estimated. However, it should be noted that the most general specification that allows for the presence of the random component in the slopes of the measures of firm's absorptive capacity are not estimated. Convergence of the estimation procedure has not been 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, estimation of a simplified version of the model, that includes just the measures of absorptive capacity and GERD as the only contextual factor, revealed that the random component of the slopes was not significant in all cases (Table A1 in the Appendix). This suggests that the interaction between the internal and external determinants account for the entire regional variability in the effect of the firm's absorptive capacity on innovation.

4. RESULTS

Full sample of firms

The estimates obtained when using product innovation as the measure of the firm's innovative output are shown in Table 3, whereas those corresponding to process innovation are in Table 4. In the case of the fixed-effect component, odd-ratios associated with each measure of absorptive capacity, internal firm controls, and external determinants are reported. For product innovation, 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 is originated in differences among firms rather than between regions. To be precise, the value of the intraclass correlation (ICC) indicates that the regional dimension only accounts for about four per cent of total variability.[6] This is a clear indication that internal determinants play a much more substantive role than the contextual factors in explaining 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. Results of the specification that includes the internal firm determinants are reported in column (ii). It is observed that the three measures of the firm's absorptive capacity exert a significant sizeable effect on product innovation. Based on these estimates, the odds to innovate in product is more than nine times higher for firms doing continuous R&D, and almost four times higher for firms that cooperate in innovation activities. Similarly, one additional percentage point in the share of high-skilled workers increases the odds of innovation in product by 1.1 per cent. As for the other internal determinants, the effect is significantly positive (odd-ratio higher than one) for the size of the firm, exporting, and being a newly created firm. Also, the probability of innovating in product largely varies across sectors as indicated by the joint significance of the corresponding dummy variables. In contrast, 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 to 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 is observed that this is due only to the contribution of the region's R&D effort (proxied by GERD). The estimate of the odd-ratio indicates that an increase of one percentage point in the R&D expenditures over the region's GDP ratio more than double the odds to innovate in product of the firms in the region.[7] The decrease in the ICC and in the variance associated to the intercept indicates that a large part of the

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[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.

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 the firm's propensity to innovate in product. Results in the last two columns in Table 3 show that it is the combination of both sets of factors that allows explaining this variability. In fact, the detailed inspection of the results in columns (iv) and (v) provides support to the major hypothesis in this study. It can be observed that the direct effect of the external factors turns out 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 the internal determinants, with the contextual factors playing a negligible role. But the results obtained in the last column of Table 3, that allow for the interaction between the measures of absorptive capacity and GERD, reveal that the role played by the regional system of innovation is subtler than the one represented by the specification that only allows for a direct effect of the contextual factors.[8] To be clear, the region's R&D effort moderates the effect of one of the elements of the firm's absorptive capacity: cooperation in innovation. The estimates indicate that cooperation is a crucial element for the success of activities aiming at innovating in product in all firms. But it is more important for firms located in regions with a weak system of innovation than for those in regions characterised by a favourable R&D environment. As a matter of example, the odds of innovating in product is almost six times higher in the firms that cooperate and locate in the region with the lowest GERD (Balearic Isl.), while it is 2.75 times higher in the region with the highest GERD (Madrid).

On the other hand, the inclusion of the internal and external factors, with the above-mentioned interactions, fully account for the unobserved regional variability, as revealed by the low value of the ICC (only 0.1% of the total remaining variability is attributable to the unexplained regional component) and the insignificance of the random component of the intercept.

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[7] It should be noted that the values of GERD range from 0.23% to 1.69% (see Table 2). Hence, a one-percentage point increase represents a substantial expansion in the R&D effort for all the Spanish regions.

[8] The specification that includes the interaction between absorptive capacity and the entire set of regional variables was also estimated. However, the corresponding test of significance of the interactions in which

Results for the analysis of the determinants of process innovation lead to similar conclusions. The estimates of the naïve specification in column (i) of Table 4 indicate that only 1.7% 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), the measures of absorptive capacity play a crucial role in explaining differences in the propensity to innovate in process. Firms doing R&D continuously have far more chances (odds are four times higher) to innovate in process than otherwise similar firms that do not. The odds are about five times in the case of firms that cooperate in innovation, whereas one percentage point increase in the share of high-skilled labour increases by 0.4 per cent the odds of being a firm that innovates in process. Meanwhile, results from the specification that just includes the context regional factors reveal that the only significant effect is that for GERD. As in the case of product innovation, the increase of one percentage point in the ratio of R&D expenditures over the region's GDP leads to more than double the odds of innovating in process. 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 4, in contrast with the evidence reported for product innovation the combination of both sets of determinants cannot fully explain 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 so despite the amount of total variability assigned to the random regional component, i.e. unexplained by the observed internal and external determinants, is 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 the firm's absorptive capacity, as well as those for size, exports and being a new firm.[9] In all cases these internal

GERD was not involved indicated that the constrained specification reported in column (v) of Table 3 was preferred (p-value of the test equals 0.12).

[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

characteristics substantially increase the odds of innovating in process. In contrast, as for product innovation, there is no significant effect on the odds of innovating in process for firms with foreign ownership, having merged, and being in an enterprise group. As for the role played by the regional factors and the interaction between GERD and absorptive capacity, the analysis of the estimates in column (v) reveals interesting differences with respect to those discussed above for product innovation. Firstly, it is observed that there are significant, though marginal, effects of GERD and human capital, which work in opposite directions. Whereas a higher R&D expenditure over GDP increases the propensity to innovate in process for firms located in the region (through a direct effect), a higher endowment of human capital, as measured by the share of tertiary educated population, slightly decreases that propensity. Secondly, there is a significant effect of the interaction between GERD and the three measures of absorptive capacity, and not just of the one corresponding to the moderating effect of the region's R&D effort on the firm's cooperation in innovation. To be more precise, the gap in the probability to innovate in process between firms doing continuous R&D and those that do not varies with GERD, being wider in regions in which the R&D environment is less favourable. The same applies to the moderating effect of GERD on cooperation. This type of activity is important when explaining innovation in process, but it seems to be crucial for firms located in regions in which the aggregate R&D effort is low. In any case, it should be taken into account that the coefficients of these two interactions are only marginally significant.

The effect that is clearly significant and has a sizeable magnitude is the one of the interaction between GERD and the share of highly skilled labour in the firm. Once again, the dimension of the regional system of innovation moderates the influence of this measure of absorptive capacity. Considering the range of the GERD indicator in the Spanish regions (see Table 2), the increase in the odds of innovating in process due to a one percentage point increase in the share of the firm's highly skilled labour varies from 1.3% in the region with the less favourable environment to a negligible 0.1% in that with the highest R&D over GDP ratio. In other words, results suggest that firms in poor environments, in term of resources that favour innovation, need to make a more

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of the corresponding test of significance of the interactions in which GERD was not involved equals 0.12, indicating that the coefficient of those interactions are not significant.

extensive use of internal human resources if they want to have real chances to innovate in process.

Overall, these results confirm the crucial role played by the absorptive capacity of the firm in the success of the innovation process, both in product and process. They also support the hypothesis that regional determinants matter, though their role is subtler than the one frequently assumed. Rather than a direct influence on firm's innovation, the regional context would be moderating the effects that exert the internal to the firm determinants. In the case of product innovation the most important mechanism of interaction seems to be that operating through cooperation in innovation, whereas the most significant for process innovation is likely to be the one of highly skilled employees.

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 are likely to vary with size. More precisely, the hypothesis in this paper is that SMEs are more sensitive to the innovative context of the region in which they are located, whereas a higher availability of internal resources in large firms made them less dependent on the characteristics of the RIS. 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 to 249 workers. 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 5.

For product innovation, estimates indicate that performing R&D continuously and cooperate in innovation are equally important for SMEs and large firms. By contrast, employment of highly skilled workers makes a difference only for SMEs. They also show a non-significant direct effect of the external factors. In the case of the interaction between GERD and the measures of absorptive capacity, the corresponding coefficients are also non-significant for large firms. For SMEs, the only interaction that seems to be relevant is the one involving cooperation. On the other hand, the inclusion of internal and external effects with the interactions allows capturing the entire regional random variability in the propensity to innovate in product, both in large firms and SMEs.

As for process innovation, the lessons that can be drawn from the estimates in the last two columns of Table 5 are somewhat different. First, because the single component of absorptive capacity that only seems to matter for process innovation of large firms is cooperation. This is in contrast with estimates for the sample of SMEs in which substantial differences caused by the three measures are observed. Actually, whereas several sources of firm heterogeneity exert a significant effect on the propensity to innovate in process for SMEs, only being active in the export market, in addition to cooperate in innovation, helps to distinguish between large firms that innovate in process from those that do not. Second, and even more important for the interest of this study, large firms and SMEs differ in the role played by external factors. Although the direct effect of the regional context seems negligible in both cases, and the same applies to the interactions for large firms, they do play a role for SMEs. To be clear, results for SMEs point to an influence of the interaction between continuous R&D and GERD, though only marginally significant, and a more clear effect of that between highly skilled labour and the indicator of R&D intensity in the region. Finally, it should be mentioned that only in the case of the large firms the inclusion of the internal and external determinants fully accounts for the random regional variability. In the case of small firms, this component is still significant although the value of the ICC indicates that, conditional to the internal and external factors, the variability explained by the regional dimension is just 0.2%.

5. CONCLUSIONS

The empirical evidence provided in this paper contributes to the literature that aims at estimating the effect of the regional determinants of innovation using firm-level data. In contrast with most previous studies, this one includes a large sample of representative firms in a set of regions which are characterised by sizeable disparity in innovation rates, accounts for firm's absorptive capacity and several other sources of firm heterogeneity, that minimize the risk of confounding the effect of (omitted) internal determinants with that of the regional context, and considers that regional determinants are likely to have a subtler effect on firm's innovation performance, by moderating the influence of the firm's absorptive capacity. It also supports that multilevel modelling is the most appropriate strategy to account for the nested structure of the firm-level data used in this literature, derived straightforwardly from the concept of RIS.

The evidence from the 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. Estimates from the multilevel model suggest a strong contribution of the firm's absorptive capacity. When controlling for the measures of absorptive capacity and the rest of internal determinants, results reveal a negligible direct effect of the RIS and the other proxies for the regional context. However, a subtler effect of the regional determinants arises when cross-level interactions are included, confirming the main hypothesis in this paper. In particular, in the case of product innovation, cooperation is important for all firms but is crucial for firms in regions with a weak RIS. For process innovation, firms in poor R&D environments need to make a more intensive use of human resources within the firm to compensate for the lack of external assets conducive to innovation.

The evidence obtained from the samples of large firms and SMEs suggests that what is driving the effect of the regional context variables in the entire sample of Spanish firms is in fact the response caused by these external factors on the innovation outcome of SMEs. Innovation in large firms seems to be independent of the context of the regions in which they locate. In other words, improvements in the RIS are likely to have neither a direct nor an indirect influence on large firms innovation. In contrast, SMEs may benefit from such improvement, although the mechanism is likely to be subtler than the one highlighted in most of the previous literature. Rather than a direct, let's say exogenous, effect on the chances to innovate, improving the regional context enhances the firm's mechanisms of absorptive capacity, which results in more frequent innovation for a fixed amount of internal resources devoted to innovation activities.

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Table 1. 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	32.4 (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 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.

Table 2. Descriptive of the main variables in the Spanish regions.

	Innovation		Absorptive Capacity			External factors				Obs.
	Product	Process	R&D cont.	Coop.	High-skilled	GERD	Urban	Human Cap.	GDPpc	
Andalusia	0.24	0.34	0.11	0.07	0.08	0.85	0.38	0.21	14.20	1099
Aragon	0.29	0.36	0.17	0.13	0.09	0.70	0.51	0.28	19.90	684
Asturias	0.26	0.32	0.12	0.12	0.09	0.67	0.45	0.24	15.90	406
Balearic Isl.	0.11	0.21	0.04	0.03	0.04	0.23	0.39	0.19	21.30	219
Canary Isl.	0.20	0.29	0.05	0.04	0.06	0.52	0.39	0.21	17.40	217
Cantabria	0.26	0.32	0.12	0.11	0.09	0.45	0.34	0.27	18.00	323
Castile Leon	0.28	0.35	0.14	0.15	0.09	0.86	0.32	0.27	17.30	647
Castile La Mancha	0.23	0.30	0.09	0.08	0.06	0.42	0.09	0.18	14.70	540
Catalonia	0.43	0.47	0.31	0.16	0.11	1.27	0.43	0.26	22.40	3118
Valencia	0.33	0.39	0.18	0.15	0.08	0.83	0.33	0.21	17.60	1796
Extremadura	0.15	0.26	0.07	0.10	0.08	0.62	0.13	0.19	12.20	219
Galicia	0.29	0.33	0.16	0.14	0.07	0.85	0.23	0.23	14.80	794
Madrid	0.36	0.37	0.26	0.16	0.12	1.69	0.75	0.33	24.60	1279
Murcia	0.26	0.31	0.12	0.09	0.07	0.68	0.46	0.22	15.80	538
Navarre	0.35	0.41	0.20	0.18	0.11	1.34	0.33	0.34	23.40	593
Basque Country	0.36	0.43	0.27	0.24	0.11	1.39	0.36	0.36	23.00	1276
La Rioja	0.26	0.36	0.13	0.12	0.09	0.63	0.49	0.26	20.60	326

Note: GDPpc in thousand €.

Table 3. Estimates for product innovation. Full sample.

Internal factors	(i)	(ii)	(iii)	(iv)	(v)
R&D cont.		9.231***		9.226***	7.900***
		(0.544)		(0.544)	(1.530)
Coop.		3.834***		3.841***	6.748***
		(0.247)		(0.247)	(1.389)
High-skilled		1.011***		1.011***	1.015***
		(0.002)		(0.002)	(0.005)
Size (log)		1.085***		1.084***	1.084***
		(0.027)		(0.027)	(0.027)
Export		1.645***		1.645***	1.639***
		(0.080)		(0.080)	(0.080)
Foreign own.		0.857		0.857	0.861
		(0.124)		(0.124)	(0.124)
New firm		26.30***		26.27***	26.31***
		(9.333)		(9.321)	(9.340)
Merge		1.057		1.053	1.048
		(0.197)		(0.196)	(0.196)
Group Nat.		0.945		0.946	0.946
		(0.064)		(0.064)	(0.064)
Group Internat.		1.137		1.137	1.140
		(0.169)		(0.169)	(0.169)
Sectors		YES***		YES***	YES***
External factors					
GERD			2.041***	1.204	1.296*
			(0.476)	(0.174)	(0.188)
Urban			0.998	1.000	0.999
			(0.005)	(0.003)	(0.003)
Human Cap.			1.010	0.978	0.976
			(0.022)	(0.014)	(0.015)
GDPpc			1.001	1.009	1.013
			(0.029)	(0.020)	(0.020)
R&D cont.*GERD					1.149
					(0.190)
Coop.*GERD					0.590***
					(0.108)
High-skilled*GERD					0.997
					(0.004)
Significance of FE coefficients (Wald tests)					
All variables				2996***	3034***
Internal factors		2963***		2930***	603.3***
External factors			30.10***	2.963	4.299
External & interactions					12.34*
Interactions					9.300**
Random Effects					
var(cons.)	0.142	0.015	0.040	0.006	0.004
LR test	300.4***	15.22***	47.94***	0.798	0.207
ICC	0.0414	0.0044	0.0122	0.0018	0.0012
Log-Lik	-8717	-6523	-8708	-6522	-6517
Observations	14,074	14,074	14,074	14,074	14,074

Notes: Odd-ratios from the mixed-effects logit estimates, and corresponding standard errors in parenthesis.. *** p<0.01, ** p<0.05, * p<0.1.

Table 4. Estimates for process innovation. Full sample.

Internal factors	(i)	(ii)	(iii)	(iv)	(v)
R&D cont.		4.120***		4.116***	5.725***
		(0.228)		(0.228)	(1.043)
Coop.		5.323***		5.327***	7.595***
		(0.342)		(0.342)	(1.582)
High-skilled		1.004***		1.004***	1.016***
		(0.001)		(0.001)	(0.004)
Size (log)		1.149***		1.149***	1.149***
		(0.026)		(0.026)	(0.026)
Export		1.471***		1.469***	1.463***
		(0.064)		(0.064)	(0.064)
Foreign own.		0.828		0.828	0.837
		(0.110)		(0.110)	(0.111)
New firm		3.256***		3.258***	3.248***
		(0.853)		(0.853)	(0.853)
Merge		1.237		1.235	1.229
		(0.207)		(0.206)	(0.206)
Group Nat.		0.936		0.937	0.933
		(0.057)		(0.057)	(0.057)
Group Internat.		1.090		1.091	1.089
		(0.149)		(0.149)	(0.148)
Sectors		YES***		YES***	YES***
External factors					
GERD			1.610***	1.081	1.270*
			(0.267)	(0.144)	(0.168)
Urban			0.996	0.998	0.998
			(0.003)	(0.003)	(0.002)
Human Cap.			1.002	0.984	0.982*
			(0.015)	(0.012)	(0.011)
GDPpc			1.017	1.019	1.024
			(0.021)	(0.017)	(0.016)
R&D cont.*GERD					0.748*
					(0.115)
Coop.*GERD					0.722*
					(0.131)
High-skilled*GERD					0.990***
					(0.004)
Significance of FE coefficients (Wald tests)					
All variables				2140***	2160***
Internal factors		2129***		2103***	534.1***
External factors			28.63***	2.133	7.160
External & interactions					21.09***
Interactions					18.53***
Random Effects					
var(cons.)	0.060	0.010	0.017	0.007	0.005
LR test	170.7***	18.27***	27.99***	5.014**	2.958**
ICC	0.0179	0.0030	0.0052	0.0020	0.0014
Log-Lik	-9269	-7801	-9261	-7800	-7791
Observations	14,074	14,074	14,074	14,074	14,074

Notes: Odd-ratios from the mixed-effects logit estimates, and corresponding standard errors in parenthesis. *** p<0.01, ** p<0.05, * p<0.1.

Table 5. Estimates for large firms and SME.

	Product Innov.		Process Innov.	
Internal factors	**Large Firms**	**SMEs**	**Large Firms**	**SMEs**
R&D cont.	6.199***	7.378***	2.573	6.044***
	(3.925)	(1.524)	(1.497)	(1.180)
Coop.	7.146***	6.148***	4.229**	7.758***
	(5.058)	(1.344)	(2.789)	(1.725)
High-skilled	1.002	1.015***	1.018	1.016***
	(0.030)	(0.005)	(0.028)	(0.005)
Size (log)	0.962	1.073**	0.855	1.141***
	(0.124)	(0.032)	(0.101)	(0.030)
Export	1.271	1.660***	1.990***	1.432***
	(0.264)	(0.084)	(0.377)	(0.065)
Foreign own.	0.755	0.916	0.904	0.824
	(0.222)	(0.152)	(0.250)	(0.125)
New firm	-	26.12***	-	3.208***
		(9.293)		(0.849)
Merge	0.572	1.185	0.976	1.246
	(0.267)	(0.240)	(0.393)	(0.229)
Group Nat.	1.314	0.927	0.918	0.915
	(0.302)	(0.066)	(0.197)	(0.059)
Group Internat.	2.165**	0.932	0.840	1.121
	(0.704)	(0.161)	(0.255)	(0.176)
Sectors	YES**	YES***	YES	YES***
External factors				
GERD	0.417	1.300	1.218	1.261
	(0.274)	(0.208)	(0.742)	(0.182)
Urban	1.000	1.000	0.995	0.999
	(0.008)	(0.003)	(0.007)	(0.003)
Human Cap.	0.977	0.978	1.005	0.982
	(0.030)	(0.015)	(0.030)	(0.012)
GDPpc	1.076	1.009	0.994	1.024
	(0.066)	(0.020)	(0.056)	(0.017)
R&D cont.*GERD	1.186	1.263	1.223	0.731*
	(0.596)	(0.226)	(0.569)	(0.121)
Coop.*GERD	0.532	0.655**	0.839	0.750
	(0.295)	(0.130)	(0.436)	(0.148)
High-skilled*GERD	1.000	0.997	0.988	0.990**
	(0.021)	(0.004)	(0.019)	(0.004)
Significance of FE coefficients (Wald tests)				
All variables	252.4***	2632***	168.1***	1856***
Internal factors	57.58***	517.7***	43.64***	450.3***
External factors	3.666	3.635	0.593	5.702
External & interactions	8.771	9.435	1.266	17.67**
Interactions	1.309	6.158	0.597	15.76***
Random Effects				
var(constant)	0.000	0.007	0.000	0.007
chi2	0.000	1.104	0.000	5.267**
ICC	0.000	0.0022	0.000	0.00216
Log-Lik	-459.0	-6037	-515.7	-7256
Observations	958	13,114	958	13,114

Notes: Odd-ratios from the mixed-effects logit estimates, and corresponding standard errors in parenthesis. New firm was excluded during the estimation procedure as only two large firms in the sample were created in the period and both were innovative firms. *** p<0.01, ** p<0.05, * p<0.1.

APPENDIX

Table A1. Estimates for a restricted specification with random slopes.

	Product Innovation		Process Innovation	
Internal factors				
R&D cont.	9.626***	9.601***	6.600***	6.768***
	(1.819)	(1.814)	(1.183)	(1.375)
Coop.	7.640***	7.777***	8.613***	8.533***
	(1.544)	(1.685)	(1.769)	(1.751)
High-skilled	1.016***	1.016***	1.016***	1.016***
	(0.005)	(0.005)	(0.004)	(0.004)
External factors				
GERD	1.323**	1.324**	1.333***	1.338***
	(0.159)	(0.158)	(0.127)	(0.123)
R&D cont.*GERD	1.158	1.163	0.724**	0.697**
	(0.187)	(0.189)	(0.110)	(0.125)
Coop.*GERD	0.574***	0.560***	0.692**	0.702**
	(0.103)	(0.111)	(0.124)	(0.126)
High-skilled*GERD	0.997	0.997	0.989***	0.989***
	(0.004)	(0.004)	(0.004)	(0.004)
Constant	0.140***	0.140***	0.243***	0.243***
	(0.017)	(0.017)	(0.023)	(0.023)
Wald Joint signif.	2820.8***	2695.2***	1988.0***	1557.8***
Random Effects				
var(constant)	0.018**	0.017**	0.010**	0.008**
var(R&D cont.)		0.000		0.013
var(Coop.)		0.008		0.000
var(High-skilled)		0.000		0.000
LR test	25.35***	25.6***	21.7***	23.4***
LR sign. var(slopes)		0.200		1.600
Log-Lik	-6699,0	-6698,9	-7920,3	-7919,5
Observations	14074	14074	14074	14074

Notes: Odd-ratios from the mixed-effects logit estimates, with the corresponding standard errors in parenthesis. *LR test* is the result of a likelihood ratio test of the significance of the random components in the intercept or in the intercept and slopes. *LR sign. var(slopes)* is a likelihood ratio test of the significance of the random component in the slopes. *** p<0.01, ** p<0.05, * p<0.1.

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