The effect of regional resources on innovation: A firm-centered approach

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Abstract:

The current environment of high competitiveness has made innovative firms, especially job-creating ones, central to regional economic growth. Most of previous studies have not considered the interactions between internal and regional factors, and has focused on product innovation performance. This paper aims to fill both gaps in the literature on the regional determinants of firm innovation. Assuming a firm-centered approach, the main goal of the paper is to analyse whether the regional resources determine firm innovation either in a direct way or by shaping the effect of the firm's internal. resources. We used multilevel modelling and panel data methodology in a sample of 2,141 Spanish manufacturing firms over the period 2008 to 2014. More specifically, we assume fixed slopes and estimate a three-level logistic random intercept models (observations: level 1; firms: level 2; regions: level 3). Our results show that the internal factors are the cornerstone of firm innovation. Nevertheless, there is also a 'regional effect' in the firms' propensity to innovate. Particularly, the effect of the region's resources in explaining the differences across firms in product innovation is more substantive than in process innovation. In this last case, regional factors play a subtler role by shaping the effect of its internal drivers Policy-makers should be conscious of the need of keeping a bottom–up approach (or a firm-centered approach) when designing regional innovation policies. In this respect, policies aimed at promoting the size, export activities and R&D intensity of firms could be effective to increase the number of firms that can benefit from the exploitation of the region's resources.

Keywords: external resources; regional resources; product innovation; process innovation; multilevel; absorptive capacity; interaction effects

1. INTRODUCTION

The current environment of high competitiveness has made innovative firms, especially job-creating ones, central to regional economic growth. In this respect, one of the main concerns of the European governments is the limited number of leading innovators in Europe compared to the US (Coad et al., 2016; Veugelers and Cincera, 2010) or China. As a result, promoting firms 'innovation has become a cornerstone of the policies geared towards boosting the sustained growth prospects of a territory (European Commission, 2014).

Responding to this claim, many studies have analysed the drivers of firms' ability to innovate in more detail. Broadly speaking, these innovation drivers could be classified into the factors that are external to the firm, usually referred to the region in which the firm is located, and those that are internal to the firm (López-Bazo and Motellón, 2018; Sternberg and Arndt, 2001), mostly associated with its absorptive capacity. In this respect, whereas solid evidence on the substantive effect of internal drivers exists, still-inconclusive evidence regarding the contribution of the external or regional factors has been found (López-Bazo and Motellón, 2018). This could be partially due to the need of acknowledging the existence of heterogeneous firms within the same region, which implies using data with a hierarchical structure, as well as the fact that firm innovation and environment are inherently dynamic. Addressing these issues requires including the role of the regional factors in firm-centered models by applying multilevel analysis (Beugelsdijk, 2007: Rodríguez-Gulías et al., 2016) and panel data methodology. An additional explanation for such ambiguous result is that most of previous studies have not considered the interactions between internal and regional factors, overlooking that the latter may shape the firms' internal resources associated with innovation (López-Bazo and Motellón, 2018). Moreover, while the bulk of the literature on the effect of external resources exploitation has focused on product innovation performance, the number of studies regarding process innovation is still limited (Niehaves and Plattfaut, 2011).

This paper aims to fill the abovementioned gaps in the literature on the regional determinants of firm innovation. Using a sample of 2,141 Spanish manufacturing firms over the period 2008 to 2014 we explore the effect of regional and internal resources on product and process innovation in a firm-centered approach. To this end, multilevel modelling and panel data methodology are applied and interactions between regional and firm characteristics are tested. In so doing, we not only extend the recent body of the literature that calls for the need of accommodating the hierarchical structure of the data through multilevel models when analyzing firms' innovative outputs (Autio et al., 2014; Beugelsdijk, 2007; López-Bazo and Motellón, 2018; Rodríguez-Gulías et al., 2016), but we also provide a better understanding of the links between internal and external determinants of firm innovation in countries like Spain whose SMEs traditionally show low levels of innovative activities compared to the European Union. Thus, in 2014 the innovative firms represented the 36.4% and 49.1% of the Spanish firms and EU firms, respectively (Eurostat, 2018). In addition, during the recent economic downturn, public and private resources supporting innovative activities have decreased to the point that the R&D effort of the Spanish firms is about half of the firms' average R&D effort of the UE firms (COTEC, 2017). In such resource-constrained environment, understanding the effect of regional factors on firm innovation can help design more efficient policies aimed at promoting innovative firms.

This paper contributes to the literature in several ways. First, the use of the multilevel analysis with interactions terms allows detaching the effects of the external (regional) and internal determinants on firm innovation. In this respect, this paper responds to the claim of reconciling the micro-level and the regional-level of analysis gaining insights into how regional context shapes the absorptive capacity of the firms (Autio et al., 2014; Beugelsdijk, 2007; Rodriguez-Gulías et al., 2016). Second, the longitudinal nature of the dataset (2008-2014) is incorporated to the analysis through a three-level multilevel model. Given that firms' innovation activities are inherently a dynamic process, exploiting the longitudinal dimension of data implies something more than overcoming an econometric drawback. Moreover, the sample period (2008-2014) is relevant to know the effect or regional resources on firms' innovative activities in environments affected by a severe economic downturn. Third, it extends the literature on the effect of external resources exploitation on the firms' process innovation, which it is still rather limited (Niehaves and Plattfaut, 2011). In fact, the results reveal that the role of external resources in shaping internal determinants differs across product innovation and process innovation. Fourth, the use of a rich set of firm characteristics reduces the perils of confounding the influence of regional innovation determinants with that of the omitted firm –level variables (López-Bazo and Motellón, 2018). Finally, the aforementioned characteristics of the Spanish environment over the sample period make it an interesting context for such an analysis.

The remainder of the paper is organised as follows: Section 2 summarizes the literature review and introduces the positioning of the paper. Section 3 describes the data and the model specifications used in the empirical analysis. Section 4 discusses the econometric results, and, finally, Section 5 concludes and provides the implications for literature and practice.

2. REVIEW OF REGIONAL DETERMINANTS OF FIRMS' INNOVATION FROM A FIRM-CENTERED APPROACH

After the pioneering paper of Cohen and Levinthal (1990), it is acknowledged that innovative activities at a firm level allow enhancing the firm's absorptive capacity and, consequently, its chance to exploit knowledge generated outside the firm. Under this assumption, innovative firms located in environments with a high level of external knowledge will have greater opportunities of obtaining advantages of this outside knowledge resources. To this end, absorptive capacity has been considered the interface between the firm level and the contextual (i.e. regional or local) level, becoming a crucial factor in understanding how the environment and individual firms interact (Pinch et al., 2003). Drawing on the concept of absorptive capacity, most of studies defend a relationship of complementarity between the internal and external determinants of innovative performance (Vega-Jurado et al., 2008).

Both internal and external drivers of firm innovation have been extensively researched. Regarding the former, a consensus exists to accept firms' characteristics such as R&D intensity, firm size, firm age, ownership structure or past performance as internal determinants of firms' ability to innovate (see Becheikh et al., 2006). In contrast, the evidence concerning the external drivers is less conclusive highlighting a variety of factors, such as the availability of highly skilled workers, R&D infrastructures or networks with universities and research centers, at a regional level. Broadly speaking, previous factors try to capture certain spatially bounded knowledge circumstances. Indeed, literature on geography of innovation has given rise to the emergence of different denominations to refer to these circumstances: namely clusters (Porter, 1998), industrial (Bergman and Jeser, 1999) and technological clusters (Saxenian, 1994; Markusen, 1996), industrial districts (Scott and Storper, 2003), learning regions (Florida, 1995), innovation milieus (Maillat, 1995). regional innovation systems (Cooke, 2001) or even creative cities (Lee and Rodríguez-Pose, 2014) among others. Broadly speaking, such denominations rely on the assumption that the 'proximity' exposes firms to involuntary knowledge spillovers that happen quickly, cheaply, and, to some extent, automatically through the interactions with other close actors.

Stemming from this dissociation, López-Bazo and Motellón (2018) implicitly classify the studies that jointly address the external and internal drivers of firms' innovation performance into two groups; those ones that show that internal determinants are more relevant to explain the firm's innovative output than the external factors, and those ones that, acknowledging the importance of internal factors, give external factors a key role in shaping the firm's ability to innovate. Following this classification, Table 1 summarizes the main results regarding the external (regional) determinants of firm innovation obtained by a recent number of studies that could be classified within the group that emphasizes the role of regional factors in a firm-centered model.

Table 1 Regional determinants of firm innovation in firm-centered studies

	Nber. of firms/Country/ Period	Model	Dependent variable	Results		
				Technological resources	Production spillovers	Human capital resources
Love and Roper (2001)[3]	Manuf. in UK (1,700), Germany (1,300) and Republic of Ireland (500) (1991-1994)	Tobit model	Innovation intensity (nber. of product innovations/ employee). / Innovation success (% sales attributable to new and improved products)	Industry innovation intensity and regional innovation intensity (+) for innovation intensive and success in Germany		
Czarnitzki and Hottenrott (2009) [3]	Manuf. and selected business services: 1,265/ Belgium/ Flemish Region (2002–2004)	Tobit and IV Tobit model	% of sales due to new products		Firms' network of suppliers in the region (+)	Regional employment in a firm's industry; skilled labour supply (+)
Srholec (2010) [4]	Industry and market services: 3,801/ Czech Republic (1999-2001)	Logit multilevel	(0,1) Product or process innovations	Advanced innovation systems (+)		Long-term unemployment and crime (-)
Batsakis (2012)	R&D subsidiaries: 173 in 25 host countries (1989)	Cross-classified multilevel	Nber. of patents	GDP Per Capita ( )	Publications in Scientific and Technical Journals ( ) Patents and Utility Models ( )	
Wang and Lin (2012)[3]	ICT: 908 China (2006 - 2007)	Logit model	(0,1) for patent, invention patent, and invention products	R&D expenditure / GDP( )	Nber. of certificate patents (+) for invention patent	Presence of supportive universities (+) for invention patent
Zuluaga (2012)	6,670 Colombia (2003-2004)	Poisson multilevel	Nber. of product innovations adjusted by objective	GDP Per Capita (-) Exports (+) Spillovers Neighbouring Regions (-)		Qualified Employees (+)
Bellman et al. (2013) [1,2]	Manuf: ± 4,100 Germany (2007-2009)	Logit multilevel / random-effects model	(0,1) for 4 types of innovation: process, radical, incremental, and imitation	Research and Technology Centers or Parks ( )		Unemployment Rate (-) for process / radical innovation Qualified Employees (+) for process / radical innovation
Naz et al. (2015) [1]	6,129 Germany (1998–2009)	Multilevel model / random intercept model	(0,1) innovation activities (new products and services or process innovations)	R&D employment (+) (engineers, chemists, physicists, mathematicians, technicians, other specialized technical staff, as well as natural scientist)		% of high-skilled workers (university degree) in total employment (+)
López-Bazo and Motellón (2018) [2, 4]	Manuf: 14,074 Spain (2005)	Mixed-effect (fixed and random effects) logit specification	(0,1) product/process innovation	R&D expenditures / GDP (+) for product / process innovation		Population with tertiary education (-) for process innovation
Rodríguez-Gulías et al. (2018) [1]	University spin-offs in Spain (401), Italy (711) (2005-2013)	Logit multilevel	(0,1) Patents	R&D personnel / total employment ( )	Patent applications to the European Patent Office by priority year / Million inhabitants (+)	Nat. log. of the nber. of persons with tertiary education ( )
Tojeiro-Rivero and Moreno (2019) [1]	Manuf: 4,010 Spain (2000-2012)	Multilevel	Nber. of product innovations	R&D expenditures (+) Public R&D expenditures ( ) Private R&D expenditures (+)	Regional stock of patents / knowledge-intensive regions (+)	

Notes: (+/ - /) denote a positive/negative/not significant effect on firm innovation. Manuf. denotes manufacturing sector. [1] denotes that multilevel modelling has been used in the analysis; [2] indicates that process innovation has been analysed separately from product innovation; [3] indicates that standard single-level models have been applied, which implies that observations are considered as independent; [4] indicates that interactions between regional variables and firm characteristics have been included.

2.1. Regional determinants of firm innovation

As can be observed in Table 1, a stream of the literature on the geography of innovation has focused on exploring the externalities stemming from knowledge (Raspe and Van Oort, 2009). In this respect, the most widely researched externalities have been those related to technological, production and human capital resources of the region (Feldman and Audretsch, 1999; Glaeser et al., 1992).

Within the region's technological resources available to firms, the literature has mostly paid attention to the role of R&D infrastructure in promoting firms' innovative outputs (Beugelsdijk, 2007). These region's resources have usually been defined as a mix of research and development (R&D) expenditures and workers. The underlying argument is that the region's R&D can, in turn, acts as input for firms' innovative activities (Raspe and Van Oort, 2009), which would benefit from the outputs obtained by regional expenditure in R&D, as well as from the availability of skilled R&D workers (Corsi and Prencipe, 2015; Powers and McDougall, 2005). Thus, Love and Roper (2001) and Tojeiro-Rivero and Moreno (2019) have found a positive relationship between R&D activities at the region level and firms' product innovation. Similar results are obtained by López-Bazo and Motellón (2018) for firms' process innovation.

Regarding the second group of regional resources, commonly known as production spillovers, it has been traditionally associated with innovative performance. Innovative outputs differ from R&D expenditure or employment (i.e. inputs). In this respect, it is acknowledged that external innovation can work as a catalyst for the innovative activities of other firms (e.g. suppliers, customers or simply imitators) (Czarnitzki and Hottenrott, 2009). Czarnitzki and Hottenrott (2009) and Tojeiro-Rivero and Moreno (2019) provide empirical evidence of this positive effect of production spillovers on firms' product innovation.

The studies have also emphasized the region's human capital as an external knowledge source. The underlying argument is that highly skilled workers have great opportunities to absorb, use and exchange knowledge (Raspe and Van Oort, 2008). Thus, Czarnitzki and Hottenrott (2009) and Zuluaga (2012) have found that the higher the percentage of highly skilled workers of the region, the higher the firms' probability to innovate in product. A positive relationship is also found by Bellmann et al. (2013) referred to process innovation, whereas López-Bazo and Motellón (2018) obtain the opposite association between both variables.

2.2. Internal determinants of firm innovation

The firms' ability to exploit external knowledge (i.e. absorptive capacity) could be considered a cornerstone for successful innovative firms (Srholec, 2010), since the literature on knowledge spillovers has showed that the extent to what a firm can benefit from localized knowledge externalities relies on this absorptive capacity. Nevertheless, this ability to capitalize on external knowledge requires a set of resources and capabilities that is unevenly distributed in the firms' population (Acs et al., 2009).

Thus, R&D activities have been consistently associated with the ability for innovation by firms (Teixeira and Correia, 2020). Artz et al. (2010) conclude that firms with high capacity to support R&D expenditures are more likely to benefit from increasing returns to scale to spread costs and re-allocate these saved costs to develop more R&D projects that could lead to innovative outputs. In this vein, it is also acknowledged that performing R&D activities provides the firm an increasing capability to absorb external knowledge (Cohen and Levinthal, 1990). In other words, firms reliant on the production of knowledge through their own R&D activities would benefit from environmental factors to a greater extent that those firms lacking R&D activities, pushing the former to innovate.

Whether firm size matters in innovation has been, however, subject to contention. Broadly speaking, the argument behind the relationship between firm size and innovation is that the firms that rely more on external knowledge sources develop a greater absorptive capacity; while the small firms do it 'by need', the large ones do it 'by opportunity'. Thus, large firms have more resources which can help them access knowledge from external sources and engage in collaboration with research centers (Fontana et al., 2006; Laursen and Salter, 2004). Additionally, their employees show a broader professional background, including fields of study such as science and engineering (Laursen and Salter, 2004), which facilitate large firms to get involved in R&D activities (Barbosa and Eiriz, 2009; Chen et al., 2012). In contrast, as small firms have fewer internal resources, they rely more on external knowledge sources than their larger counterparts.

One of the most recursive topics in the literature on innovation is the role of industry, particularly of those industries that are more active at the technological frontier. According to Raspe and Van Oort (2009), firms in certain industries benefit more from innovative environment. More specifically, the dependence of high-tech industries on scientific innovations make their firms more prone to collaborate with research centers and universities that create and transfer new knowledge, helping them innovate (Fontana et al., 2006). Consequently, it is expected that these firms rely more on external knowledge sources than their counterparts in other industries.

Research in firm innovation has also considered the importance of belonging to corporate groups in firms' innovative performance, yielding inconclusive results. Corporate affiliates have access to innovative resources from the group at a lower cost as well as additional talent, being more reliant on the corporate's internal resources of knowledge. However, Mohnen and Houreau (2003) find that group affiliated firms are more likely to collaborate with partners as research centers and universities. This kind of partnerships with innovative agents positively influences on firms' innovative performance (Hausman, 2005) and increases the firm's absorptive capacity. The same argument could be extended to the independent firms, but in this case the collaboration would be driven, again, 'by need'. The lack of corporate internal resources makes them rely on external networks to access knowledge resources and innovate, enabling their absorptive capacity.

There is also a wide body of the literature that focuses on the relationship between export and innovative activities (Di Cintio et al., 2017). In this vein, particular emphasis has been devoted to the direction of causality between both activities obtaining controversial results. The learning-by-exporting hypothesis posits that export activities enables firms' domestic innovation after entry since exporters have to be competitive in international markets (Bellman et al., 2013). In so doing, exporters attain new capabilities and knowledge (Lu and Beamish, 2006) to be exploited through innovative activities (Du and Temouri, 2011). Additionally, exporters maintain links with clients, suppliers or investors other than domestic ones, which may act as sources of 'incremental' tacit knowledge (Forero-Pineda et al., 2010) compared to those firms that only interact with domestic agents.

After reviewing the studies considering regional determinants of innovation in firm-centered models, it appears that the most recent ones have already taken into account the hierarchical structure of data by applying multilevel modelling. However, to the best of our knowledge, only Bellman et al. (2013), Naz et al. (2015), Rodríguez-Gulías et al. (2018) and Tojeiro-Rivero and Moreno (2019) use panel data methodology. Applying such methodology not only allows exploiting longitudinal data, but also considering the dynamic nature of both firm innovative activities and environment. In other words, it is something more than overcoming an econometric drawback, as firms use their capabilities to adapt and survive in a dynamic context (D'Agostino and Moreno, 2019) through inherently dynamic strategies such as innovating.

A second drawback mostly shared by the previous studies is that they have overlooked the interactions between firm characteristics and regional variables. Only Schrolec (2010) and López-Bazo and Motellón (2018) address this issue. Whereas the former work considers a limited number of internal determinants, the latter put the emphasis on the interactions between the internal determinants and only one regional variable referred to the region's R&D effort.

Finally, whereas the literature on the effect of external resources exploitation mostly focuses on product innovation, empirical research concerning process innovation is sparse (Niehaves and Plattfaut, 2011). Only Bellman et al. (2013) and López-Bazo and Motellón (2018) explore this issue by considering separately product and process innovation.

This paper aims to tackle the abovementioned issues: (1) whether regional and internal resources affect firm innovation by considering the hierarchical structure and dynamic nature of the data (i.e. applying multilevel panel data methodology); (2) whether regional factors shape the effect of firms' internal resources linked to innovations (i.e. the interaction effects), and (3), whether such effects depend on the firm's innovative output (i.e. product and process innovation). In so doing, this paper fits with the recent stream of the literature that claims the need of jointly analysing the effect of external (regional) and internal determinants of firms' innovative output. To avoid the dissociation between the level of study and the level relevant for the process of innovation (López-Bazo and Motellón, 2018; Autio et al., 2014), it is necessary to use firm-centered models that also include regional factors and take into account the hierarchical structure and the dynamic nature of data, as well as the interactions effects between regional and internal determinants of firm innovation.

3. METHODOLOGY

This section describes the sample and the variables, as well as the strategy of estimation and the specification of the econometric models used in the multivariate analysis.

3.1 The data and sample

The source of information is the ESEE (*Encuesta sobre Estrategias Empresariales*, or Survey on Business Strategies), a representative annual survey of Spanish manufacturing firms sponsored by the Ministry of Industry and the SEPI Foundation. ESEE database is formed by a random sample for small companies with more than 10 and fewer than 200 employees and an exhaustive sample for large firms with more than 200 employees. ESEE is an unbalanced panel because some companies cease providing information and new companies enter the survey in order to preserve representativeness. Data information in ESEE includes: accounting data, technological activities (R&D activities, patents or innovation) and foreign trade (exports and imports).

The initial sample consisted of 2,686 Spanish manufacturing firms observed during the period 2008–2014. Once those companies with two or less observations were eliminated to fulfil the requirements of the multilevel analysis (Snijders and Bosker, 1999), a final sample of 2,141 companies was used in this study.

To complete de data of ESEE, at the regional level we compiled data for each Spanish region from three sources: the database of the Spanish National Statistics Institute (INE), the Spanish Patent and Trademark Office (OEPM), and the Web of Science (WOS).

3.2 Definition and measurements of the variables

Following the Oslo Manual (OECD, 2018), a product innovation is: "a new or improved good or service that differs significantly from the firm's previous goods or services and that has been introduced on the market". Hence, it was created a dependent variable (INNOPROD) for each year that takes the value 1 if the firm had any product innovation in this year, and 0 otherwise.

Similarly, a business process innovation is: "a new or improved business process for one or more business function that differs significantly from the firm´s previous business processes and that has been brought into use in the firm" (OECD, 2018). Thus, it was constructed a dependent variable (INNOPROC) for each year that takes the value 1 if the firm had any business process innovation in this year, and 0 otherwise.

More than 36% of firms observed during the period 2008-2014 had at least one year with any product innovation. Year by year, the percentage of firms with product innovation decreased from 25% in 2008 to 20% in 2014 (Figure 1). About 61% of the sample firms presented process innovation in at least one year of de study (2008-2014). By year, the percentage of observed firms with process innovation was around 50% (Figure 2).

Figure 1 Number of firms with product innovation by year.

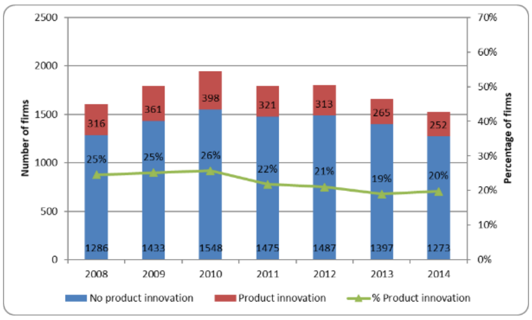
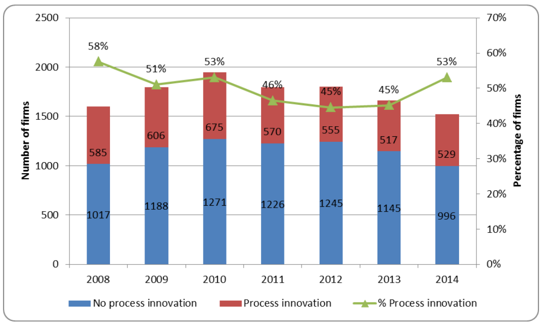


Figure 2 Number of firms with process innovation by year.



The independent variables were referred to the internal and external determinants of firms' ability to innovate highlighted by the literature. The former was related to the firm's absorptive capacity, whereas the latter were referred to the regional context characteristics (Table 2).

Accordingly, five explanatory variables were included as internal factors at the firm level. The first two variables were the natural logarithm of the number of employees (LNEMP) and the percentage of sales dedicated to R&D (RD_SALES) as proxies of the firm size and the firm R&D intensity, respectively. The other three variables are three dummies that take the value 1 for companies that export (EXPORT), for firms integrated in a group of firms (GROUP) or for firms in high-medium technology sectors according to the Eurostat classification[1] (HIGHTECH), and 0 otherwise.

At the regional or external level, a set of 6 explanatory variables that vary across regions and years, but not between firms was included. The first two tried to collect the region's technological resources and these were the percentage of Gross Domestic Product (GDP) dedicated to R&D (RD_GDP) and the percentage of workers in R&D (NRDE_TE). The next three were the percentage of innovative firms (NIF_TF), the natural logarithm of the number of academic documents published in Web of Science (WOS) over the number of professors at the region's universities (LNWOS_PDI), and the natural logarithm of the number of patent applications per 100 thousand inhabitants (LNPAT_100TH) as proxies of the region production spillovers. Finally, the percentage of adult population (age 16+) with higher education tried to reflect the human capital resources available in each region (P_POPHE).

[1] Eurostat uses the aggregation of the manufacturing industry according to technological intensity and based on the NACE Rev.2 at the two-digit level.

Table 2 Definitions of dependent and independent variables

Group	Factor	Variable	Measures	Source
Dependent	Product innovation	INNOPROD	1 for companies that had any product innovation and 0 otherwise	ESEE
	Process innovation	INNOPROC	1 for companies that had any process innovation and 0 otherwise	ESEE
Internal factors	Size	LNEMP	Natural logarithm of the number of employees	ESEE
	R&D intensity	RD_SALES	R&D expenditures/Sales (%)	ESEE
	Internationalization	EXPORT	1 for companies that export and 0 otherwise	ESEE
	Group of firms	GROUP	1 for the firms integrated in a group of firms and 0 otherwise	ESEE
	Industry	HIGHTECH	1 for the firms in high-medium technology sectors and 0 otherwise	ESEE
External (regional) factors	Technological resources	RD_GDP	R&D expenditures / GDP (%)	INE
		NRDE_TE	Number of R&D employees / Total employed persons (%)	INE
	Production spillovers	NIF_TF	Number of innovative firms / Total firms (%)	INE
		LNWOS_PDI	Natural logarithm of the number of WOS (Web of Science) publications / Number of professors at the region's universities	WOS and INE
		LNPAT_100TH	Natural logarithm of the number of patent applications per 100 thousand inhabitants	OEPM
	Human capital resources	P_POPHE	Percentage of adult population (age 16+) with higher education (%)	INE

Table 3 displays the descriptive statistics of the independent variables for internal and regional determinants of firms' innovation.

Table 3 Descriptive statistics of internal and external factors

	Variable	Obs	Mean	Std. Dev.	Min	Max
INTERNAL FACTORS	EMP[a]	12,125	197.54	681.29	1	13091
	RD_SALES	12,087	0.82	2.64	0	62.33
	EXPORT	12,125	0.68	0.47	0	1
	GROUP	12,117	0.36	0.48	0	1
	HIGHTECH	12,125	0.35	0.48	0	1
EXTERNAL FACTORS	RD_GDP	119	1.11	0.49	0.32	2.23
	NIF_TF	119	0.75	0.32	0.26	1.70
	NRDE_TE	119	1.03	0.46	0.34	2.07
	WOS_PDI [a]	119	0.51	0.15	0.25	0.91
	PAT_100TH [a]	119	7.02	4.16	1.46	19.53
	P_POPHE	119	24.69	5.18	16.57	38.47

[a] Variables are not in logs.

The mean number of employees is near to 198 and the average percentage of sales dedicated to R&D expenditures is about 0.82%. In mean terms, 68% of firms sell in foreign markets and 36% are integrated in a group of firms. Only 35% of them operate in high-medium technology industries. Regarding the regional level, on average, 1.11% of GDP is dedicated to R&D expenditures and 1.03% of workers are R&D employees. About 0.75% of the firms are innovative, the mean number of academic documents published in WOS per university professor is 0.51 and the mean number of patent applications per 100 thousand inhabitants is 7.02. The mean percentage of adult population with higher education is 24.69%. A deeper description of the regional variables under analysis showing their annual values over the period 2008-2014 in each region is reported in figures A.1 to A.5 of Annex A.

Finally, Table 4 shows the correlation matrix of the independent continuous variables. All the variables, internal and external factors, are positively correlated.

Table 4 Correlation matrix

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1)	LNEMP	1							
(2)	RD_SALES	0.1714*	1						
(3)	RD_GDP	0.0985*	0.0987*	1					
(4)	NRDE_TE	0.0921*	0.1048*	0.9536*	1				
(5)	NIF_TF	0.1193*	0.0559*	0.5995*	0.5213*	1			
(6)	LNWOS_PDI	0.0181*	0.0207*	0.1407*	0.2642*	-0.2556*	1		
(7)	LNPAT_100TH	0.0744*	0.0759*	0.7138*	0.7592*	0.5991*	0.1829*	1	
(8)	P_POPHE	0.0669*	0.1021*	0.7917*	0.8642*	0.3449*	0.2756*	0.5889*	1

Notes: Table shows the Pearson correlation coefficients for the continuous variables considered in the empirical analysis. *, **, *** denote significance at the 5%, 1%, and 0.1% levels.

3.3 Strategy of estimation and model specification

In order to analyse the effect of external (regional) and internal factors on the probability of having product or process innovation we used a three-level multilevel model since the dataset involves observations (level 1) for firms (level 2) nested in regions (level 3). Additionally, given that the dependent variables (INNOPROD and INNOPROC) are dummies, we assume a logistic model. More specifically, we assume fixed slopes and estimate a three-level logistic random intercept models which can be written as a latent response:

Model 1 (empty model without variables):

$$INNO^*_{ijk} = \beta_0 + v_k + u_j + e^*_{ijk}$$

Model 2 (with internal factors):

$$INNO^*_{ijk} = \beta_0 + \beta_1 LNEMP_{ijk} + \beta_2 RD\_SALES_{ijk} + \beta_3 EXPORT_{ijk} + \beta_4 GROUP_{ijk} + \beta_5 HIGHTECH_{ijk} + v_k + u_j + e^*_{ijk}$$

Model 3.1 to 3.6 (with internal and regional factors):

$$INNO^*_{ijk} = \beta_0 + \beta_1 LNEMP_{ijk} + \beta_2 RD\_SALES_{ijk} + \beta_3 EXPORT_{ijk} + \beta_4 GROUP_{ijk} + \beta_5 HIGHTECH_{ijk} + \beta_6 REGION_{jk} + v_k + u_j + e^*_{ijk}$$

where $INNO^*_{ijk}$ is the observed product or process innovation for occasion *i* in the firm *j* in the region *k*, β_0 is the overall mean of $INNO^*_{ijk}$ (across all groups), v_k is the region random effect (level 3 random effect), u_j is the firm random effect (level 2 random effect), and e^*_{ijk} is the occasion residual (level 1 residual) with mean zero and variance $\sigma^2 e^*$ (assuming a logistic distribution of σ^2) (Bellmann et al., 2013; Leckie, 2013; Steele, 2009). In turn, $REGION_{jk}$ refers to the 6 regional variables (RD_GDP_{jk}, $NRDE\_TE_{jk}$, NIF_TF_{jk}, $LNWOS\_PDI_{jk}$, $LNPAT\_100TH_{jk}$, P_POPHE_{jk}) alternatively introduced in the specifications.

Model 1 is the empty model with a random intercept and no explanatory variables. Model 2 adds the internal factors; those are the firms' characteristics related to absorptive capacity. Model 3 is defined with six alternative specifications, including external factors (third-level variables) one at a time, in order to elude possible multicollinearity problems in view of the correlation matrix (Table 4).

To know the proportion of the total residual variance that is due to regional level, the region variance partition coefficient (VPC) is reported in all estimated models.

$$VPC = \frac{\alpha_v^2}{\alpha_v^2 + \alpha_u^2 + \alpha_{e*}^2}$$

Where α_{e*}^2 is 3.29 for a logit model. Since the standard logistic distribution has a variance of $\pi^2/3 = 3.29$ this can be taken as the occasion or level 1 variance (Snijders and Bosker, 1999).

In order to test the significance of the region effects, that is the null hypothesis that there are no supercluster level effects (H_0: $\sigma^2_v = 0$), the previous three-level occasions-firms-regions models are compared with the simpler two-level occasions-firms models (without supercluster level) by a likelihood ratio test (LR) (Leckie, 2013; Rabe-Hesketh and Skrondal, 2012).

$LR = -2\, lnL_1 - (-2\log L_2)$

Where L_1 is the likelihood value of the two-level model and L_2 is the likelihood value of the three-level model, whereas *ln* denotes to the natural logarithm.

Finally, models that interact regional and firms level variables are also estimated to analyse the simultaneous effect of external and internal drivers of firms' innovation performance.[2]

4. EMPIRICAL RESULTS

Multivariate analyses were conducted in three stages. Firstly, given the hierarchical structure and dynamic nature of the data multilevel logit models are estimated to test the importance of the external determinants of innovation in firm-centered models (issue 1). In the second stage, regional factors are interacted with firm variables to explore whether the former shape the effect of the latter on firm innovation (issue 2). Thirdly, we repeated the analyses of the first stage by using an alternative measure of the regional variables to check the robustness of the results. All the estimations are separately made for product and process innovation (issue 3), allowing a comparative analysis across the two main types of firms' innovative outputs.

4.1 The effect of regional and internal resources: a multilevel panel data analysis

Table 5 and Table 6 display the estimates for product innovation (INNOPROD) and process innovation (INNOPROC), respectively.

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

Table 5 Three-level logistic random intercept model: estimates for product innovation

	Model 1	**Model 2**	**Model 3.1**	**Model 3.2**	**Model 3.3**	**Model 3.4**	**Model 3.5**	**Model 3.6**
CONSTANT	-3.568***	-7.585***	-10.126***	-7.939***	-8.299***	-8.428***	-9.441***	-5.204***
	(0.231)	(0.333)	(0.676)	(0.445)	(0.360)	(0.389)	(0.589)	(0.727)
FIXED EFFECTS								
Internal factors								
LNEMP		0.840***	0.828***	0.842***	0.803***	0.814***	0.828***	0.826***
		(0.067)	(0.068)	(0.067)	(0.067)	(0.068)	(0.068)	(0.068)
RD_SALES		0.274***	0.271***	0.273***	0.272***	0.274***	0.270***	0.276***
		(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)
EXPORT		0.854***	0.854***	0.839***	0.904***	0.923***	0.833***	0.907***
		(0.160)	(0.162)	(0.160)	(0.160)	(0.161)	(0.161)	(0.162)
GROUP		-0.035	-0.004	-0.040	0.008	0.003	-0.024	0.007
		(0.136)	(0.138)	(0.136)	(0.137)	(0.137)	(0.137)	(0.138)
HIGHTECH		0.094	0.062	0.081	0.088	0.113	0.074	0.120
		(0.154)	(0.157)	(0.155)	(0.155)	(0.156)	(0.156)	(0.157)
External factors								
RD_GDP			2.087***					
			(0.457)					
NRDE_TE				0.321				
				(0.258)				
NIF_TF					1.039***			
					(0.180)			
LNWOS_PDI						-1.159***		
						(0.229)		
LNPAT_100TH							1.005***	
							(0.244)	
P_POPHE								-0.099***
								(0.027)
RANDOM EFFECTS								
σ^2_v	0.518	0.133	0.780	0.133	0.120	0.253	0.160	0.404
σ^2_u	9.120	6.608	6.828	6.609	6.688	6.703	6.712	6.739
LR TEST (3-level to 1-level model)								
χ^2	3011.01	1947.55	1973.48	1945.89	1958.45	1974.08	1945.75	1960.37
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
LR TEST (3-level to 2-level model)								
χ^2	42.16	11.55	28.72	11.48	10.47	25.25	6.01	16.95
p-value	0.0000	0.0007	0.0000	0.0007	0.0012	0.0000	0.0143	0.0000
p-value (divide by 2)	0.0000	0.0004	0.0000	0.0004	0.0006	0.0000	0.0072	0.0000
Nº observations	11798	11753	11753	11753	11753	11753	11753	11753
Nº superclusters (Regions)	17	17	17	17	17	17	17	17
Nº clusters (Firms)	2090	2089	2089	2089	2089	2089	2089	2089
Log likelihood	-4086.75	-3783.67	-3766.90	-3782.87	-3766.83	-3770.32	-3776.21	-3773.92
VPC	4.01%	1.33%	7.16%	1.33%	1.19%	2.47%	1.57%	3.87%

Notes: Standard errors in brackets; *, **, *** denote significance at the 5, 1, and 0.1% levels.

Table 6 Three-level logistic random intercept model: estimates for process innovation

	Model 1	Model 2	Model 3.1	Model 3.2	Model 3.3	Model 3.4	Model 3.5	Model 3.6
CONSTANT	-1.443***	-5.214***	-5.686***	-5.174***	-5.757***	-5.876***	-5.858***	-4.638***
	(0.133)	(0.213)	(0.283)	(0.277)	(0.238)	(0.261)	(0.326)	(0.397)
FIXED EFFECTS								
Internal factors								
LNEMP		0.836***	0.832***	0.836***	0.816***	0.820***	0.834***	0.834***
		(0.051)	(0.051)	(0.051)	(0.051)	(0.052)	(0.051)	(0.051)
RD_SALES		0.123***	0.122***	0.124***	0.122***	0.123***	0.122***	0.124***
		(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)
EXPORT		0.564***	0.552***	0.566***	0.582***	0.607***	0.547***	0.580***
		(0.112)	(0.112)	(0.112)	(0.113)	(0.114)	(0.112)	(0.113)
GROUP		0.128	0.129	0.128	0.145	0.151	0.130	0.138
		(0.107)	-0.107	(0.107)	(0.108)	(0.108)	(0.107)	(0.108)
HIGHTECH		-0.095	(0.129)	-0.093	-0.115	-0.090	-0.112	-0.079
		(0.116)	-0.117	(0.117)	(0.117)	(0.118)	(0.117)	(0.117)
External factors			0.397**					
RD_GDP			(0.153)					
				-0.037				
NRDE_TE				(0.162)				
					0.778***			
NIF_TF					(0.138)			
						-0.942***		
LNWOS_PDI						(0.180)		
							0.347**	
LNPAT_100TH							(0.130)	
								-0.023
P_POPHE								(0.014)
RANDOM EFFECTS								
σ^2_v	0.176	0.016	0.018	0.018	0.017	0.081	0.016	0.028
σ^2_u	5.927	4.352	4.395	4.353	4.464	4.469	4.386	4.382
LR TEST (3-level to 1-level model)								
χ^2	3139.91	2048.86	2053.57	2048.03	2072.97	2077.72	2052.89	2052.31
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
LR TEST (3-level to 2-level model)								
χ^2	25.92	1.62	1.05	1.62	1.22	13.05	1.26	2.46
p-value	0.0000	0.2034	0.3057	0.2037	0.2695	0.0003	0.2610	0.1169
p-value (divide by 2)	0.0000	0.1017	0.1529	0.1019	0.1348	0.0002	0.1305	0.0585
Nº observations	11798	11753	11753	11753	11753	11753	11753	11753
Nº superclusters (Regions)	17	17	17	17	17	17	17	17
Nº clusters (Firms)	2090	2089	2089	2089	2089	2089	2089	2089
Log likelihood	-5918.91	-5579.80	-5575.62	-5579.77	-5563.49	-5565.25	-5576.08	-5577.97
VPC	1.87%	0.21%	0.23%	0.23%	0.22%	1.04%	0.20%	0.36%

Notes: Standard errors in brackets; *, **, *** denote significance at the 5, 1, and 0.1% levels.

Model 1 (i.e. the empty model) only includes a random intercept and no explanatory variables. The corresponding LR test, which compares three-level region-firm-occasion model with the simplest two-level firm-occasion model, rejects the null hypothesis that there are no regional supercluster effects (H_0: σ^2_v=0). These results suggest that the regional dimension partly determines the firms´ product and process innovation. In other words, firms located in the same region are more homogenous than others located in different regions in terms of product and process innovation performance. Nevertheless, the variance partition coefficient (VPC), calculated as 0.518/(0.518+9.120+3.29)=0.0401 for product innovation and as 0.176/(0.176+5.927+3.29)=0.0187 for process innovation, shows that only 4.01% and 1.87% of the residual variation in the propensity to have product and process innovation respectively are attributable to the region's unobserved characteristics. Similar conclusions are found by López-Bazo and Motellón (2018).

The estimates of the models which include the internal factors (Model 2) are reported in the second columns of Table 5 and Table 6. They show that three out the five internal factors positively affect product and process innovation. Thus, the probability of innovating increases with firm size (LNEMP). Similar effect was found by Bellmann et al. (2013) for German firms, by López-Bazo and Motellón (2018) for Spanish companies in a simpler two-level model, and by

Zuluaga (2012) in the case of Colombian firms' product innovation. Similarly, R&D intensity (RD_SALES) significantly increases the probability of firms' product and process innovation performance. Exporting firms (EXPORT) have also more chances of innovating in product and process than firms only selling in the domestic market. This result is consistent with those by Bellmann et al. (2013) and López-Bazo and Motellón (2018). However, belonging to a group of firms and operating in high-medium technology fail to be significant for the estimated models.

Adding internal factors to the estimation (Models 2 versus Models 1) reduces the supercluster variance, that is, the variance associated with the regional dimension (σ^2_v), and the VPC, but it is still significant in product innovation while is no longer significant in process innovation. These findings, together with the VPC of Models 1, suggest that external factors play a lesser substantive role in explaining the differences across firms in process innovation than in product innovation.

The models including the internal and external factors simultaneously are showed in the remaining columns (Model 3.1 to 3.6) of Table 5 and Table 6. The estimations in Table 5 show that, despite having included regional variables, the variance associated with the regional dimension (σ^2_v) is still significant in product innovation in all estimated models. However, for process innovation, only in Model 3.4, which combines internal factors and scientific production (LNWOS_PDI), the supercluster variance is still significant, as showed in Table 6. Again, it appears that external determinants are more relevant to explain the differences across firms in product innovation than in process innovation.

Regarding the external technological resources, the estimations show that the region's R&D financial effort (RD_GDP) positively affects firm innovation, while the percentage of workers in R&D (NRDE_TE) fails to be significant. In other words, it seems that firms' innovation performance can be benefitting from the regional expenditure in R&D, but not from the region's skilled R&D workers. While these findings are consistent with those obtained by López-Bazo and Motellón (2018), they differ from the evidence found by Naz et al. (2015), who established a positive relationship between regional R&D workers and innovative performance measured as product or process innovation. This difference could be partly explained by the use of an aggregate measure of firm innovation without differentiating into product and process innovation, which lead us to insist on the need of separately analysing both innovative outputs.

In the case of the regional innovation (or the production spillovers), the estimates show that both the percentage of innovative firms (NIF_TF) and the number of patent applications (LNPAT_100TH) positively influence firm innovation. However, when the regional production spillover is approximated as the number of academic documents published (LNWOS_PDI) the effect is the opposite.[3] The studies that separately analyse process innovation (Bellman et al., 2013; López-Bazo and Motellón, 2018) did not consider the role of the region's production spillovers. Consequently, previous findings cannot be compared with those of the studies in Table 1 in the case of process innovation. Meanwhile, the few papers that associate such external resources with product innovation found a positive effect of the region's patent activity (Rodríguez-Gulías et al., 2018: Tojeiro-Rivero and Moreno, 2019) and no significant evidence for the region's publishing activity (Batsakis, 2012). In our opinion, there are several potential explanations for the negative relationship between the number of academic papers in the region and firm innovation. Thus, a substantive part of these papers could be basic research, which is often associated with low appropriability regardless the level of firms' absorptive capacity. A second potential explanation is that when the academic research may result in outputs with economic value, the authors avoid publishing it and focus on patenting or trade secret protection.

[3] Other different measures of the regional production spillovers through scientific publishing were used. In particular, we used the natural logarithm of the number of WOS (Web of Science) publications per 100 thousand inhabitants, the natural logarithm of the number of SCOPUS publications per 100 thousand inhabitants, and the natural logarithm of the number of SCOPUS publications over the number of professors at the region's universities. These alternative measures yield similar results to those presented in Table 5 and Table 6. These models are not reported for space reasons. They can be obtained from the authors if required.

Finally, regarding the human capital resources, the percentage of adult population with higher education in the region (P_POPHE) has a negative effect on product innovation and no significant effect on process innovation. Then, the higher capacity to absorb and use information that is assumed in regions with high levels of highly skilled workers seems not have any effect on firms' process innovation and decrease product innovation. Our results are in line with those obtained by López-Bazo and Motellón (2018), who also found a negative significant effect for Spanish manufacturing firms. In contrast, Zuluaga (2012) found the opposite effect in the case of Colombian firms, as well as Bellmann et al. (2013) and Naz et al. (2015) in the German ones. A potential explanation for this counterintuitive result may rely on the specific characteristics of the Spanish labour market. Thus, regardless the population level of education, it is characterized by higher unemployment rates compared to other European countries. Moreover, during the period of analysis the unemployment rates significantly increased. In 2014 they were about 16% for the population with higher education and reached 40% for those aged 20-24 years (INE, 2014). In other words, for a region having high shares of population with higher education is not synonymous with these skilled population is working, maybe it is unemployed, or working in jobs for which it is overqualified.

4.2 The role of the regional resources in shaping the effect of internal resources: the interaction effects

As mentioned, models which include cross-interactions between the internal and external factors were also estimated. Table 7 reports the results of such specifications for the direct effects of the regional and firm variables (in the shaded rows and columns, respectively), as well as for the interaction terms. Regarding the direct effects, overall, the regional and internal determinants of firm innovation hold the effects described in the previous sub-section. Only in a small number of occasions they are no longer significant, but the sign remains the same.

Table 7 Three-level logistic random intercept model: cross-interaction effects

INNOPROD			EXTERNAL FACTORS					
			RD_GDP	NRDE_TE	NIF_TF	LNWOS_PDI	LNPAT_100TH	P_POPHE
DIRECT EFFECTS			(+)	( )	(+)	(-)/( )	(+)	(-)/( )
INTERNAL FACTORS	LNEMP	(+)	( )	( )	( )	( )	( )	( )
	RD_SALES	(+)/( )	( )	( )	( )	( )	( )	( )
	EXPORT	(+)/( )	( )	( )	( )	( )	( )	( )
	GROUP	( )	( )	( )	( )	( )	( )	( )
	HIGHTECH	( )	( )	( )	( )	( )	( )	( )
INNOPROC			**EXTERNAL FACTORS**					
			RD_GDP	NRDE_TE	NIF_TF	LNWOS_PDI	LNPAT_100TH	P_POPHE
DIRECT EFFECTS			(+)	( )	(+)	(-)	(+)/( )	(-)/( )
INTERNAL FACTORS	LNEMP	(+)	(-)	( )	( )	( )	( )	( )
	RD_SALES	(+)/( )	( )	( )	( )	(+)	( )	( )
	EXPORT	(+)/( )	( )	( )	(-)	(+)	( )	( )
	GROUP	(+)/( )	(-)	( )	( )	( )	( )	( )
	HIGHTECH	( )	( )	( )	( )	( )	( )	( )

Notes: (+/ - /) denote a positive/negative/not significant effect on firm innovation.

Regarding the interaction effects, the findings presented in Table 7 reveal that regional variables play a subtle role in shaping the internal determinant of process innovation. More specifically, the significant interactions between the region's R&D financial effort and firm size and belonging to a corporate group indicate that such firm characteristics are even more relevant in regions exhibiting a low R&D financial effort. López-Bazo and Motellon (2018) found a similar effect of the region's R&D effort through three firm characteristics mainly referred to innovation activities, namely R&D intensity, cooperating in innovation with other agents and the firm's share of highly skilled workers.

Similarly, export activities increase process innovation in all firms, but this effect is even more important in the regions with a low share of innovative firms. In turn, firms exhibiting high R&D intensity or export activities are more likely to have process innovation in those regions with a high level of scientific publishing, even though the impact of such variable on process innovation is negative.

In contrast, no interaction term between regional and firm-level variables has become significant in the case of product innovation. It appears that regional determinants of product innovation only have a direct impact, without shaping the role of the internal resources of firms.

4.3 Comparative analysis by types of regions: robustness check

Previous findings on how the region's resources shape the absorptive capacity of Spanish manufacturing firms are difficult to generalise to other economically-comparable countries where policy competences are more centralised. In addition, Smart Specialisation strategies and related European regional development funds (ERDF) provide EU regions in general, and Spanish regions in particular, with instruments and resources to set up their own R&D regional strategies, creating more variety. In such a context, a comparative analysis, still firm-centered, by types of regions might help in identifying differences across regions. To this end, an analysis by 'clusters' of regions was conducted as robustness check of previous results.[4]

Thus, regions were clustered based on EU Cohesion Policy eligibility 2007-2013, which takes into account the regional GDP per capita (in comparation with the EU average) and establishes three types of regions: Convergence objective (Regions type 1), 'Phasing out' assistance (Regions type 2), and Competitiveness and Employment objective (Regions type 3). [5]

The limited number of clusters discouraged using multilevel modelling by adding a fourth level referred to the type of region (level 4: the type of region). In spite of this fact, mixed effects logistic models were also estimated including, one by one, the type of region measured as a dummy variable[6]. In so doing, the original three levels of analysis (region-firm-occasion) were maintained. The obtained estimates confirmed previous findings related to the effect of the region. First, none of the dummy variables referred to the kind of region was significant in any of the estimated models, for both product and process innovation. Second, it seems again that external determinants were more relevant to explain the differences across firms in product innovation than in process innovation since the VPC was higher in product innovation models than in process innovation ones. Third, firm innovation was mostly explained by the firm's characteristics referred to absorptive capacity.

Then, we adopted an alternative estimation strategy based on similar ideas to identify differences across regions. More specifically, we estimated panel data logistic models by dividing the global sample in three subsamples (Table 8).

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

[5] For details see: https://ec.europa.eu/regional_policy/es/policy/how/is-my-region-covered/2007-2013/

[6] Those models are not reported for space reasons. They can be obtained from the authors if required.

Table 8 Panel data logistic models by clusters of regions: estimates for product and process innovation

	PRODUCT INNOVATION			PROCESS INNOVATION		
Regions	**Type 1**	**Type 2**	**Type 3**	**Type 1**	**Type 2**	**Type 3**
CONSTANT	-7.879***	-7.188***	-7.835***	-5.417***	-4.244***	-5.239***
	(0.724)	(1.786)	(0.386)	(0.499)	(0.848)	(0.261)
LNEMP	0.731***	0.679	0.826***	0.792***	0.592**	0.835***
	(0.152)	(0.359)	(0.077)	(0.120)	(0.198)	(0.059)
RD_SALES	0.204***	0.421***	0.279***	0.072*	0.473***	0.127***
	(0.042)	(0.124)	(0.024)	(0.031)	(0.110)	(0.019)
EXPORT	0.553	2.153*	1.130***	0.690**	0.083	0.644***
	(0.315)	(0.959)	(0.194)	(0.238)	(0.456)	(0.135)
GROUP	0.412	0.310	-0.106	0.348	0.575	0.094
	(0.330)	(0.928)	(0.153)	(0.269)	(0.514)	(0.122)
HIGHTECH	0.516	-0.839	0.035	0.051	-0.620	-0.096
	(0.360)	(1.017)	(0.172)	(0.282)	(0.508)	(0.133)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Nº superclusters (Regions)	4	2	11	4	2	11
Nº clusters (Firms)	477	111	1501	477	111	1501
Nº observations	2683	616	8454	2683	616	8454
Log likelihood	-756.69138	-158.6649	-2828.2523	-1180.6226	-271.86121	-4083.5759
Wald X^2	92.11***	30.23**	384.14***	128.38***	43***	421.34***
σ^2_u	6.881	12.813	6.468	5.409	3.330	4.376
rho	0,677	0,796	0,663	0,62	0,50	0,57
LR test of rho=0	364.49***	118.18***	1476.38***	507.6***	64.88***	1500***

Notes: Standard errors in brackets; *, **, *** denote significance at the 5, 1, and 0.1% levels.

The results of the panel data logistic models by subsample (i.e. type of region) appear to indicate that the effect of some internal determinants of firm innovation differ across the types of region. Thus, only one out the three internal determinants of firm innovation which showed a significant effect on firm product and process innovation in the previous estimations (Table 5 and Table 6) holds its positive effect. Particularly, the positive influence of R&D intensity (RD_SALES) on innovative performance does not differ across the kinds of regions.

Concerning the firm size (LNEMP), its effect on product innovation is no longer significant in 'Phasing out' assistance regions (type 2), while it remains positive and significant in two other groups or regions (type 1 and type 3) and on process innovation in all regions (type 1, type 2 and type 3).

Finally, the effect of export activities (EXPORT) is not significant on product innovation in firms from Convergence objective regions (type 1) and on process innovation in firms from 'Phasing out' assistance regions (type 2), but it is still significant in all other cases.

5. CONCLUSIONS AND IMPLICATIONS

In the last two decades, the concern of the governments for the scarcity of innovative job-creating firms in the EU, compared to other environments, has given rise to regional policies aimed at increasing the firms' ability to innovate. While the literature on the geography of innovation has put the emphasis on acting at a regional level, a recent stream of the literature on firms' innovative performance calls for the joint consideration of both external and internal drivers of innovation, by including the former in models where the firms' absorptive capacity acts as the main catalyst of the innovation process (i.e. firm-centered models). Hence, both external and internal drivers should be jointly considered to assess the firms' ability innovative. Few studies have adopted such approach, particularly when the innovative performance is referred to process innovation.

Using a sample of 2,141 Spanish manufacturing firms over the period 2008 to 2014, we explore the effect of external (regional) and internal factor on firm innovation taking into account the hierarchical structure of the data through multilevel models. The evidence indicates that the internal factors play a much more substantive role than the regional determinants in explaining firm innovation. However, there is also regional variability (or a 'regional effect') in the firms' propensity to innovate. More specifically, the effect of the region's resources in explaining the differences across firms in product innovation is more substantive than in process innovation. Taking together, both previous findings lead to recommend the inclusion of external factors in future research, although incorporating them in firms-centered models, given that it is the firms' absorptive capacity what determines firm innovation rather than external factors. Moreover, the findings also indicate that whereas the regional factors have a direct effect on product innovation, they play a subtler role in process innovation, shaping the effect of its internal drivers. In other words, the importance of the internal drivers of process innovation becomes to some extent dependent on the environmental characteristics. Particularly, in those regions where the context could be considered less conducive to innovation, the internal resources of firms are even more important in enabling process innovation. t

Given that the results confirm that the effect of internal determinants is much more substantive than those of external factors, policy-makers should be conscious of the need of keeping a bottom–up approach (or a firm-centered approach) when designing regional innovation policies. In this respect, policies aimed at promoting the size, export activities and R&D intensity of firms could be effective to increase the number of firms that can benefit from the exploitation of the region's resources.

Additionally, this paper has paid especial attention to the influence of the most extensively researched groups of regional drivers of firms' innovative performance, namely technological, production, and human capital resources. Regarding the region's technological resources, while the R&D financial effort increases the firms' ability to innovate, no effect of the percentage of R&D workers is found. As regional R&D expenditures improve firms' innovative performance, regional governments should increase R&D financial effort, severely affected by the cuts of public budgets caused by the economic downturn. They also should improve the fiscal incentives to facilitate the R&D investment of private sector.

Concerning the influence of the region's production spillovers, while the percentage of innovative firms and the patent applications positively influence firm innovation, the opposite effect is found for academic documents published. These findings suggest that the contact with other innovative firms in region, which maybe work as customers, suppliers or competitors, can enable firms' ability to innovate in process. Then, an important policy implication is to favour the networking between the region's firms, putting them in touch especially with those innovative ones. Similarly, given that the region's patent activity increases firm innovation, actions aimed at reaching more visibility of the region's patent stock should be implemented to. This kind of actions may catalyse new innovation, and even new business.

In contrast, the region's human capital resources do not seem to affect firm innovation. The reasons behind this finding could be partly related to the situation of the Spanish labour market during the sample period (2008-2014), with high unemployment rates even for highly skilled people.

Finally, this study presents some limitations. Although the firm location has been implicitly taken into through multilevel modelling, it also could be considered a firm-level variable. In this respect, future research could benefit from including more specific measures of such variable at firm-level such as urban or rural location. In addition, even though the context of the analysis (Spanish economy in 2008-2014) provides an interesting environment to address the topic of firms' process innovation, additional evidence from other economies and/or periods would be helpful to confirm the obtained evidence.

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ANNEX A

Figure A.1 Percentage of innovative firms (NIF_TF) in each region by year

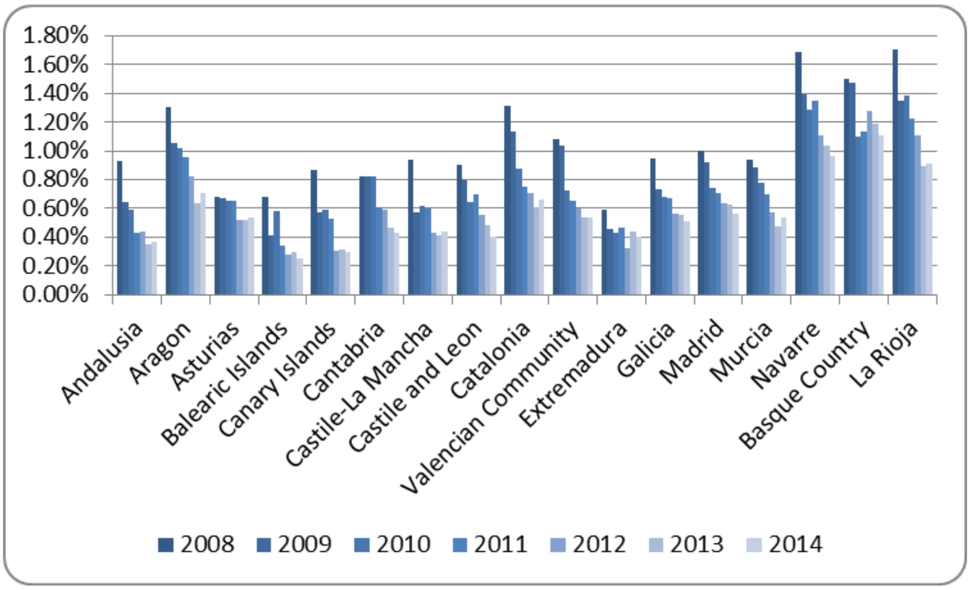

Figure A.2 Percentage of GDP dedicated to R&D (RD_GDP) in each region by year

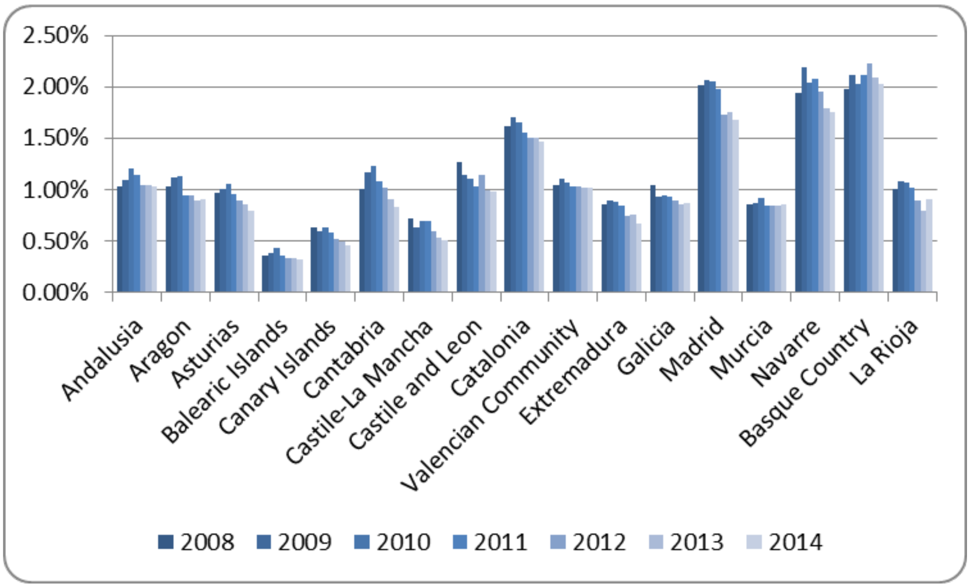

Figure A.3 Percentage of workers in R&D (NRDE_TE) in each region by year

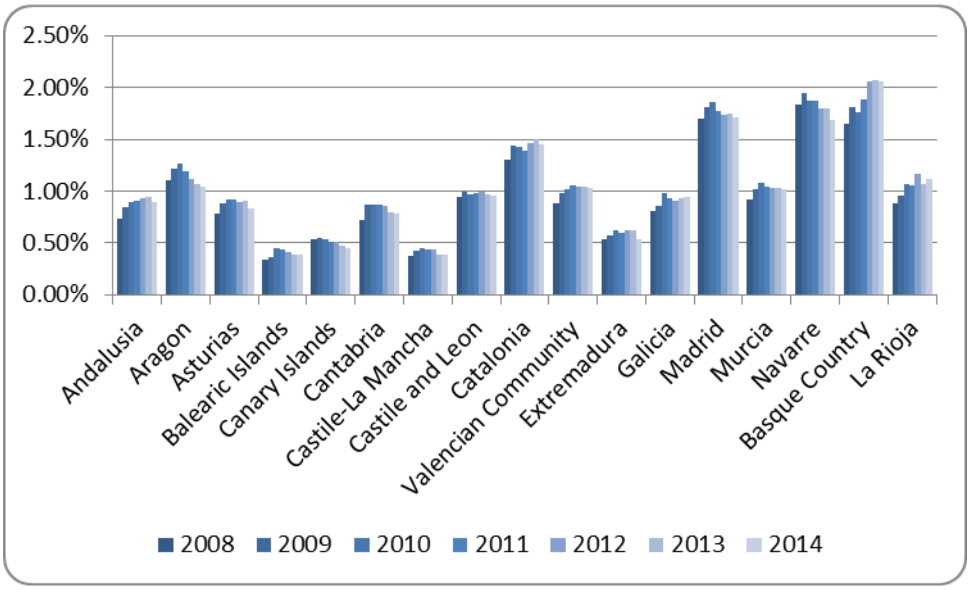

Figure A.4 Number of academic documents published in WOS per university professor (LNWOS_PDI) in each region by year

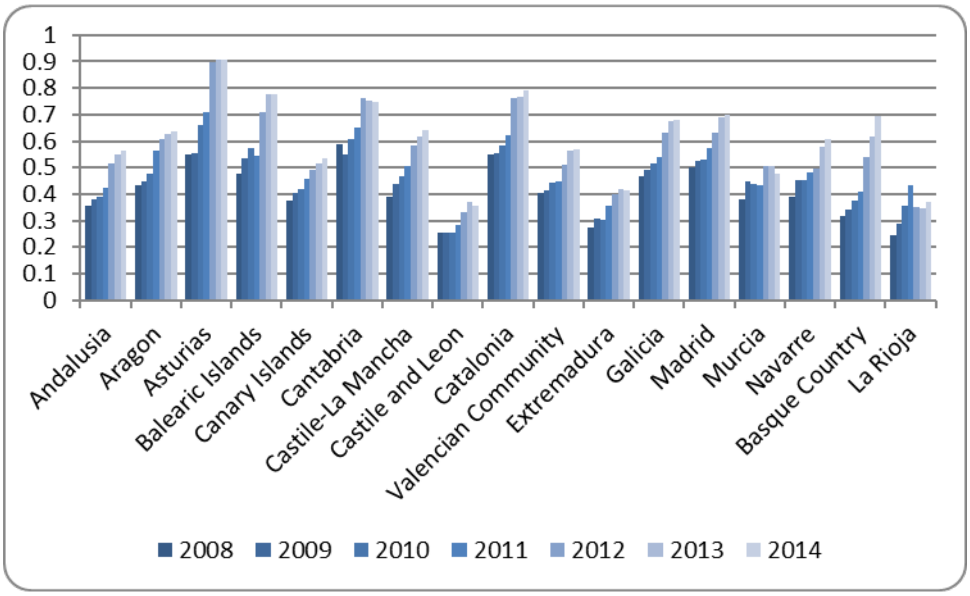

Figure A.5 Number of patent applications per 100 thousand inhabitants (LNPAT_100TH) in each region by year

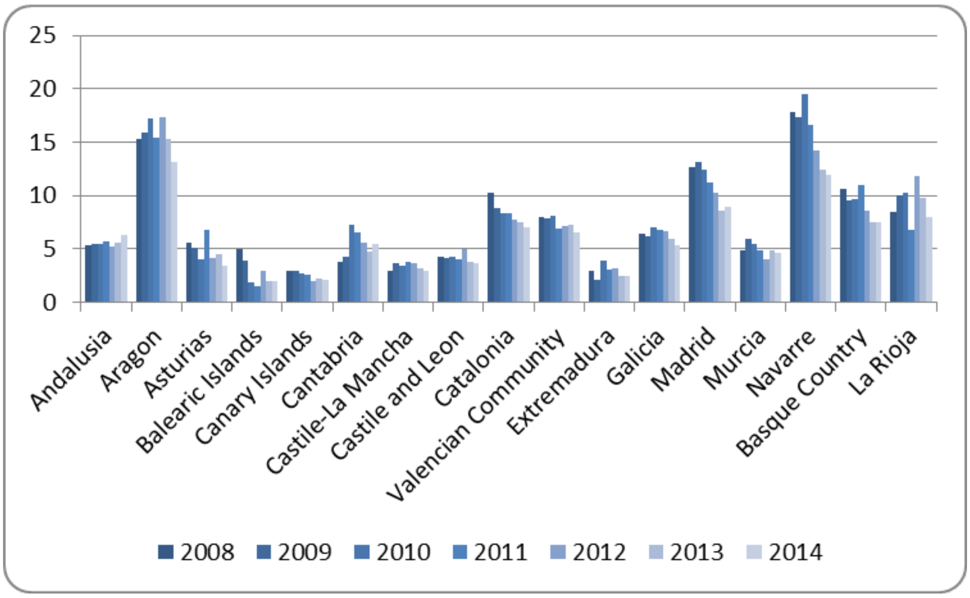

Figure A.6 Percentage of adult population with higher education (P_POPHE) in each region by year