

The role of knowledge spillovers on the University Spin-Offs innovation

ABSTRACT: University Spin-Offs (USOs) are active involved in the knowledge spillover process and full integrated in the regional innovation systems. Drawing on the Knowledge Spillover Theory of Entrepreneurship and using a multilevel approach of analysis, we explore whether the region's knowledge spillover and the firm's absorptive capacity jointly determine the innovative performance of USOs. At regional level technological spillovers, production spillovers and human capital-oriented spillovers has been considered. The results from a cross-national panel sample of 531 and 952 Spanish and Italian USOs, over the period 2005-2013 and located in 36 administrative regions, show that only the production spillovers has a significant positive effect on the USO's innovative activity. Firm-specific characteristics are important for explaining USOs' innovation. More specifically, firm age has a negative effect, while firm size seems to have a positive effect. Additionally, USOs active in high-tech sectors seems perform better in their innovation activity.

KEYWORDS: university spin-offs; innovation; knowledge spillovers; multilevel analysis; university technology

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1. INTRODUCTION

University spin-offs (USOs) are a fruitful mechanism for transferring skills, research outcomes and knowledge/technologies developed in academia to industry and society in general (Dorner et al., 2017), generating knowledge spillovers (Audretsch et al. 2005; Wennberg et al. 2011). Due to their university background, USOs are viewed as effective actors at the forefront of technological expansion and innovation (Clarysse et al., 2011; Wright et al., 2007a; Soetanto & Jack, 2016; Rodríguez-Gulías et al., 2016).

Nevertheless, mainly due to lack of resources, uncertainty in the R&D process, market acceptance and inadequate entrepreneurial familiarity and expertise, it is acknowledged that USOs face several difficulties in pursuing their innovative purposes (Gredel et al., 2012; van Geenhuizen & Soetanto, 2009). In the last years, a growing number of studies have endeavoured to determine the critical factors that drive the innovation performance of these ventures (Prencipe, 2016; Corsi & Prencipe, 2016; Soetanto, & Jack, 2016; Abbate & Cesaroni, 2016; Rodríguez-Gulías et al., 2016, 2017). Recently, some scholars have focused on location factors (i.e. the characteristics and the agents' interactions of the regional context in which USOs operate) by adopting a multilevel approach (Sternberg, 2014; Rodríguez-Gulías et al., 2016, 2017; Corsi & Prencipe, 2016).

In this regard, it was stressed the central function of the geographical dimension and proximity in understanding firms' level of innovation (Gittelman, 2007). Without a doubt, regions have been acknowledged as chief elements for creation and exchange of knowledge at firm level (Florida, 1995; Audretsch & Feldman, 2004). From this point of view, the Knowledge Spillover Theory of Entrepreneurship (KSTE) is suitable to explain the regional innovation system (Acs et al., 2013; Plummer & Acs, 2014). Given that investments in university knowledge is closely related to those of regions, USOs may potentially benefit from the region's knowledge spillovers, enabling their innovation performance (Guerini & Rossi-Lamastra, 2014).

Nevertheless, literature has partially explored the relational dynamics among regions and innovation activity of USOs (Rodríguez-Gulías et al., 2016; Corsi & Prencipe, 2016). In particular, little evidence exists up to now about the role of knowledge spillovers of regional context in affecting the innovation output of USOs. Further, a growing and significant body of literature is calling for applying an 'interactionist approach' (i.e. by means of hierarchical or multilevel modelling) to the study of firm innovation (Boshuizen et al., 2009; van Oort et al., 2012; Rodríguez-Gulías et al., 2016; Corsi et al., 2017).

This paper aims to fill these gaps in the USOs literature by analysing whether the regional knowledge spillovers jointly with the firms' characteristics determine the innovative activity of USOs. Using a panel dataset of 531 and 952 Spanish and Italian USOs, respectively, over the period 2005-2013 and located in 36 administrative regions, multilevel analysis is applied. Three variables have been considered to measure the knowledge spillovers in terms of technological spillovers, production spillovers and human capital spillovers of regions.

This paper contributes to the literature on regional determinants of innovation dynamics in academic entrepreneurship in several ways. First, since USOs stem from universities to commercialize knowledge and technologies, they may take advantage from regional knowledge spillovers to a greater extent than other ventures. This is fundamental to better understand the dynamic flow of knowledge spillover, both with regard to its magnitude and direction, in the regional innovation system; hence, the study builds upon the KSTE literature, which remains still limited in aspects such as the strategic use of knowledge spillovers to enable smarter business decisions (Ferreira et al., 2017). Second, the use of a multilevel approach helps to detach the effects of the regional and the firm levels in predicting the innovation activity of USOs. This allows a better understanding of the innovation drivers from both levels at the same time, as well as it makes the empirical analysis of cross-level interaction effects possible. Third, since the creation and development of USOs have frequently been linked to public plans at national and regional levels, knowing what elements affect the USOs' innovation result in better design more effective regional supporting policies.

The remainder of the paper is organised as follows: Section 2 introduces the literature review and the research hypotheses; in Section 3, the data are described and the model specifications used for the empirical analysis are discussed; Section 4 give the results, and, finally, Section 5 summarises the main results and provides the implications for literature and practice.

2. LITERATURE REVIEW: REGIONAL AND FIRM CONTEXT

The KSTE postulates that new knowledge is a key source of productivity, innovation and economic development (Acs & Audretsch, 1990; Audretsch et al., 2014; Cappelli et al., 2014), by favouring external economic agents from tapping into the knowledge created by others (Sarkar, 2017). Knowledge is generated by incumbent companies and research centres (Utterback, 1994); in turn, knowledge spills over to knowledge-based firms, such as USOs, that are chiefly capable to absorb such knowledge and combine it with internal generated knowledge (Audretsch et al., 2004, 2005; Arvanitis et al., 2016). Furthermore, the KSTE holds geographic features of knowledge: once generated knowledge, spillover is not only spatial (i.e. interfirm knowledge spillovers) endorsing clustering between companies in related economic sectors (Feldman, 1994; Jaffe et al., 1993; Jaffe, 1989; Hayter, 2016), but also 'aspatial' (i.e. either intra-firm or interregional) (Tavassoli et al., 2017).. These arguments are related to the development of the so-called 'incubator region' (Schoonhoven & Eisenhardt, 1989), also known as innovation 'ecosystem' (Clarysse et al., 2014; Bahrami & Evans, 2000).

Literature has also revealed that technology and knowledge-based firms, such as USOs, might take advantage from regional knowledge capacity and further elements related to spatial externalities (Guerini & Rossi-Lamastra 2014). In this regard, whereas Corsi & Prencipe (2016) find that the regional context plays a minor role in enabling the innovation activity of USOs, Rodríguez-Gulías et al. (2016) conclude that the former is critical in explaining the USOs' innovative outputs.,

In spite of this evidence, few studies have adopted an 'interactionist approach' that allows explaining how regional knowledge capacity may affect differently the innovative activity of firms. This paper aims to fill this gap by analysing the way in which regional knowledge spillovers influence the innovative activity of USOs. This question can be empirically investigated by applying multilevel modelling, whose basic hypothesis is that contextual effects

may not be the same for all types of firms, and firm-specific characteristics are essential 'controls' to disentangle the effect of the contextual variables (Raspe and Van Oort, 2009). Thus in carrying out our analysis, we connect the factors determining the innovative activity of USOs at two different contexts (or levels) of analysis; regional context (Sub-section 2.1) and firm context (Sub-section 2.2).

2.1. Regional context

In general, the entrepreneurial configuration of a region might be critical in inspiring the innovation dynamics of USOs, since the formal and informal inter-organizational relations strengthen the natural flows of new ideas (Fernandes et al., 2013; Fini et al., 2009; Fini et al., 2011). It is noteworthy that the concentration of technology clusters in the local context of USOs enables their formation and their development (O'Shea et al., 2007). The same forces might have a significant effect also in terms of innovative activity and performance.

More in detail, the relationship between knowledge spillovers and innovation activity is examined in most previous research in the framework of the spatial knowledge economy, which has explicitly focused on externalities stemming from knowledge (Raspe & Van Oort, 2009). More specifically, technological, production, and human capital spillovers are considered central and with the most significant effects on firm' innovation (Feldman & Audretsch, 1999; Glaeser et al., 1992).

Regarding the technological spillovers, the regional knowledge infrastructure represents a critical component in the knowledge/technology spillover, encouraging innovative investments (Beugelsdijk, 2007). The regional knowledge infrastructure is a mix of R&D personnel and expenditures, for which the entrepreneurial context may take advantage (Fini et al., 2011; Audretsch & Feldman, 2004; Corsi & Prencipe, 2016; Raspe & Van Oort, 2009). This view is in accordance with the arguments in favour of a close relationship between regional R&D activity and firms' innovative performance (Audretsch, 2003). Further, research is a learning process, and regional R&D activities, hence, may not only rise firms' innovation, but also the human capital of personnel. Often, the R&D capital of companies is mainly embodied in the personnel.

Concerning the production spillovers, the literature typically uses the patent activity as an indicator of the region's knowledge spillovers (Audretsch & Keilbach, 2008), finding a positive relationship with firms' innovation output in regional context (Jaffe, 1986; Peri, 2005; Bloom et al., 2013). In a recent study, Arvanitis et al. (2016), using a patent-based measure of knowledge spillovers, find that knowledge spillovers have a positive and substantial impact on innovation performance. Additionally, regional patent activity may actually act as input for other companies due to the imitative conduct of competitors (Raspe & Van Oort, 2009), improving the extent of the knowledge spillover in the region. In accordance with these arguments, it could be argued that USOs may benefit from the production spillovers of the region in which are located.

In terms of human capital spillovers, the formation and improvement of human capital in the regional context is considered an essential basis of knowledge spillover for technology-based firms, such as USOs (Audretsch & Feldman, 2004). Since well-educated human capital has numerous likelihoods to absorb and apply knowledge, it constitutes a strategic and systematic element of the regional knowledge economy (Raspe & Van Oort, 2008). Although Florida (2005) warns that the classical association between education and innovation productivity within the same region may no longer hold (due to the mobility of individuals with superior skills and education across regions and countries), the regional human capital is still critical for USOs. Indeed, the academic background of USOs leads them to retain and absorb the best-skilled and talented human capital in the regional context (Rodríguez-Gulías et al., 2017).

Drawing on the KSTE, we propose the next hypothesis:

Hypothesis 1: The regional knowledge spillovers, together with firm-specific characteristics, determine the USOs' innovative activity.

2.2. Firm context

The effect of localized knowledge spillovers is not equal among firms or, in other words, not all firms benefit from the knowledge externalities in the same extent. This is intensely and positively associated to the absorptive capability of the firm (Segarra-Blasco & Arauzo-Carod, 2008; Ramadani et al., 2017), which frequently comprises skills and resources that are asymmetrically spread among the firms of the regional context (Acs et al., 2009). Hence, it is crucial to perform the analysis of the knowledge spillovers effects taking into account the firm level.

At firm level, firms' age has been observed to have a negative effect on the knowledge absorptive capacity, suggesting that the impact of localized knowledge externalities on firm growth and innovation tends to reduce as the firm evolves over its life cycle (Audretsch & Dohse, 2007; Raspe & Van Oort, 2008). Indeed, following the knowledge-based theory of the firm (Grant, 1996) the recurrent lack of in-house resources leads young ventures to rely on external sources of knowledge (Cohen et al., 2002), while matures companies are more apt to reduce external relations over the time, negatively affecting the diversity and productivity of knowledge exchange (Audretsch & Dohse, 2007). Moreover, the empirical evidence has often showed that young firms more successfully cope with knowledge filters than mature firms (Feser and Proeger, 2017).

Further, literature claims that firm size is a central element of firms' knowledge absorptive capacity. Usually, small firms have scarcer assets to exploit inter-organizational knowledge and to develop exchange with research centres (Fontana et al., 2006; Laursen & Salter, 2004). In contrast, Aldrich & Yang (2014) argue that the working environments in small firms allow the personnel to develop the crucial knowledge and expertise required in the entrepreneurship process (Hyytinen & Maliranta, 2008; Parker, 2009). Hence, small firms embody a background in which knowledge spillovers through learning effects to personnel are common (Gast et al., 2016). Moreover, Sarkar (2017) shows how small firms can also benefit from the new knowledge of the industry leader, who intentionally spills it over with the purpose of keeping customers' quality perception of the industry.

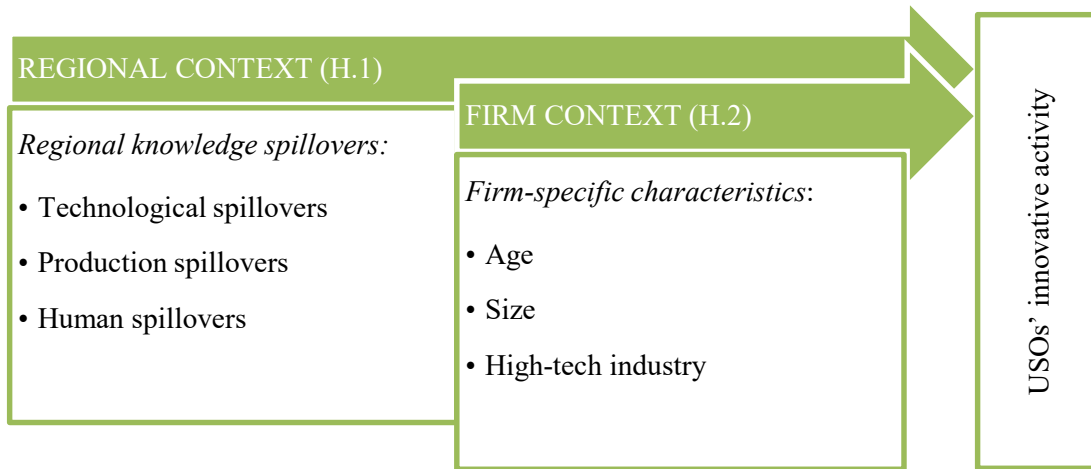
Additionally, the industry in which a firm operates may have a significant influence in its absorptive capacity. In general, technological knowledge spills over and complements R&D mainly in high-technology industries (Bernstein & Nadiri, 1988; Fischer et al., 2006). Additionally, high-tech firms usually have well-developed inter-firms collaboration networks (Hagedoorn et al., 2006), which contribute to capture external knowledge spillover, also when this take the tacit and organizationally embedded form (Kogut, 1988; Grant & Baden-Fuller, 2004; Operti & Carnabuci, 2014). Moreover, operating in high-tech industries can mitigate the effect of size in the firm's absorptive capacity (Ramadani et al., 2017).

Drawing on previous arguments, we propose the next hypothesis:

Hypothesis 2: The firm-specific characteristics, together with the regional spillovers, determine the USOs' innovative activity.

By applying a multilevel approach we test simultaneously the effect of regional knowledge spillovers and firm-specific characteristics on the USOs' innovative activity. Figure 1 summarizes our conceptual model and hypotheses.

Figure 1. Conceptual model



3. METHODOLOGY

3.1. The sample

For the purpose of the study, a sample was constructed from the aggregation of two primary databases: one for Spanish USOs and one for the Italian ones. The final sample consisted of 1,112 USOs that are located in 22 regions¹ and observed over the period 2005-2013. More in detail, 401 of these USOs are established in 6 Spanish regions and the other 711 USOs in 16 Italian regions².

3.2. Dependent variable

Patents are a widely used indicator of firms' innovation capability and efforts in innovation process (Dahlstrand, 1997; Lee & Lee, 2013). Similarly, the literature on USOs has mostly employed patenting as a proxy for the innovative activity (for more detail, see Rodríguez-Gulías et al., 2016). Hence, we constructed a dependent variable (PAT) that takes the value 1 if the USO had had any patent activity in the year, and 0 otherwise. Patent activity involved both patent applications and patents granted. The patent data has been compiled from ESPACENET for both Spanish and Italian USOs.

About 23% of USOs (253 firms) presented patent activity in at least one year between 2005 and 2013. The number of USOs with patent activity is displayed in Figure 2.

¹ In this work regions have been defined following NUTS-2 2013 classification of Eurostat, being equivalent to the Spanish administrative units "Comunidades Autónomas" and the Italian administrative units "Regioni". For more detail see: <http://ec.europa.eu/eurostat/web/nuts/national-structures-eu>

² The region with higher number of USOs in the sample is Catalonia (11.15%), followed by Piedmont (8.09%) and Emilia-Romagna (7.82%). It is noteworthy that 8 regions have hosted around 60% of the USOs in the sample.

Figure 2. Number of USOs with patent activity (2005-2013)

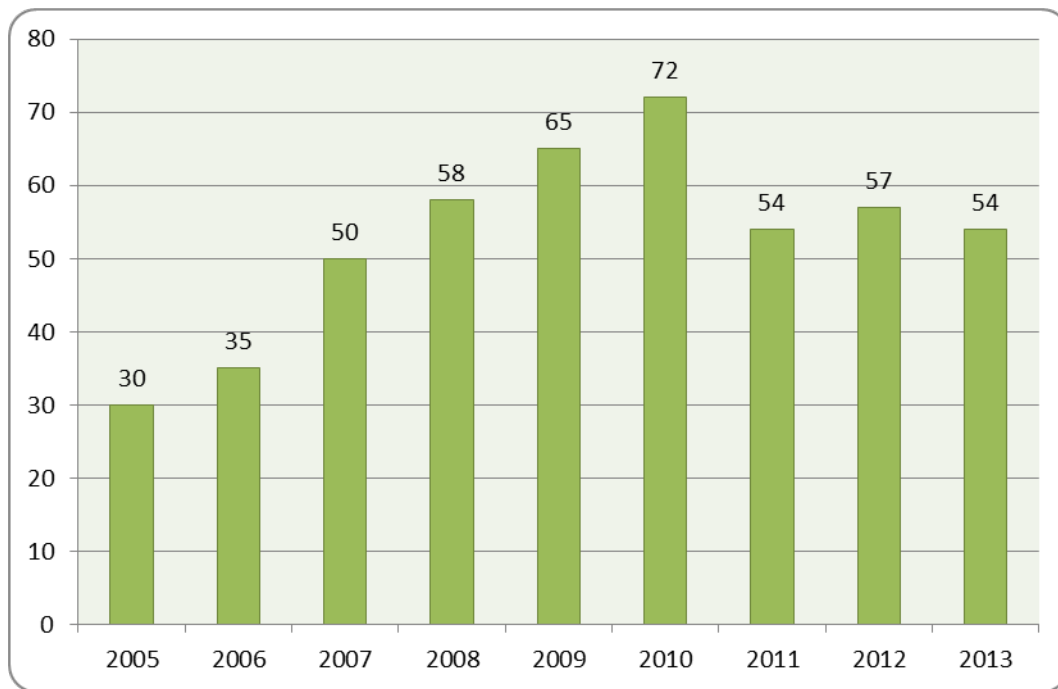
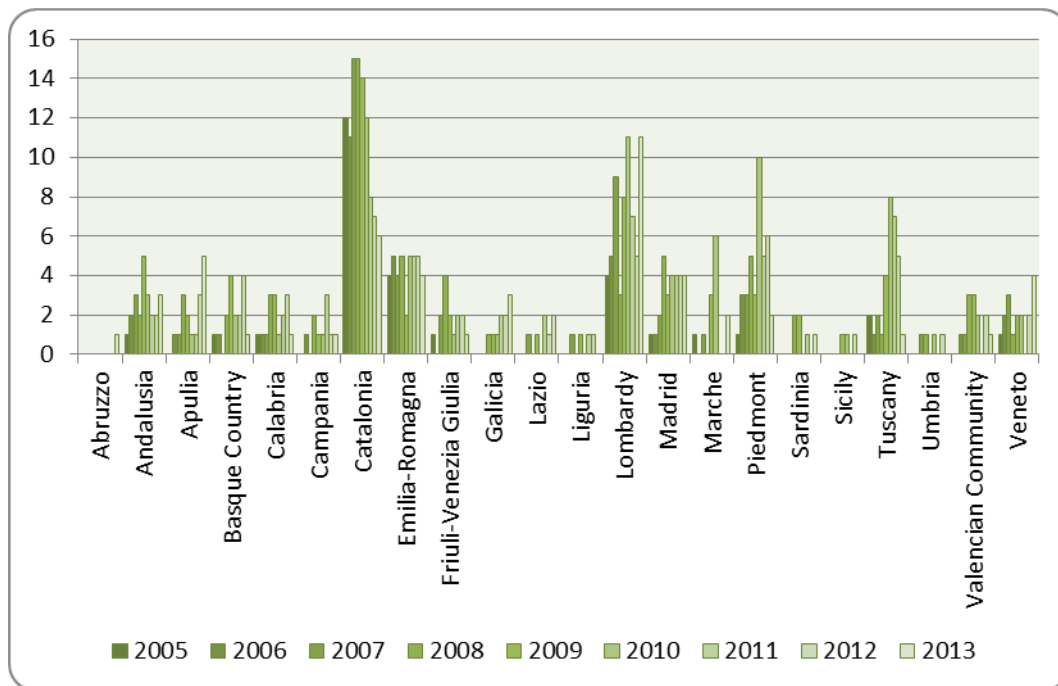


Figure 3 shows the number of USOs with yearly patent activity grouped into regions. In general, the trends in patent activity differ across regions.

Figure 3. Number of USOs with patent activity by region (2005-2013)



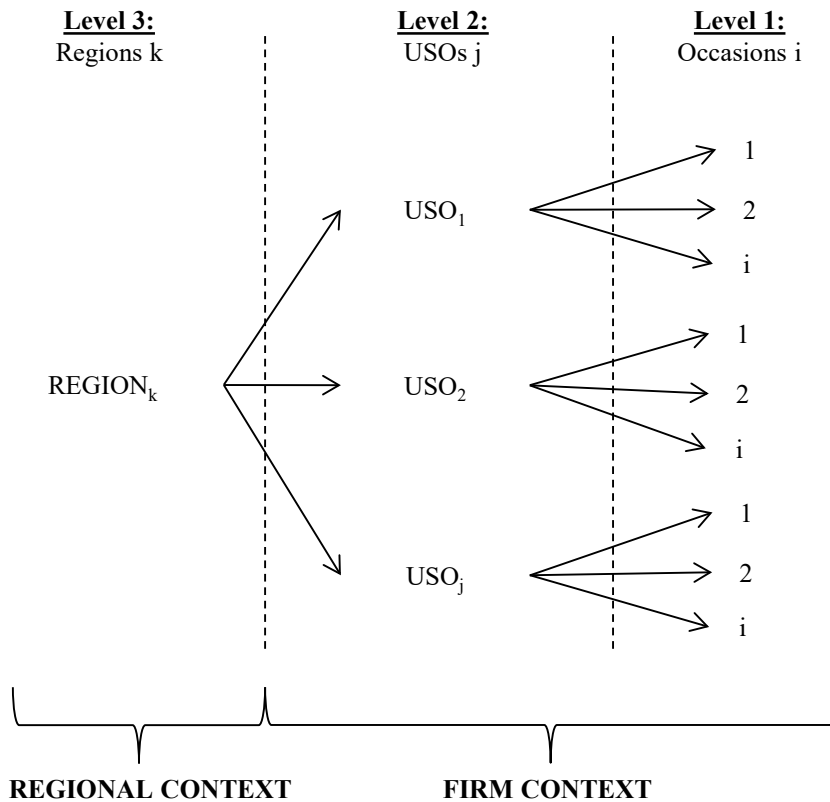
3.3. Independent variables: firm and regional contexts

As we mentioned, we worked with data referred to two contexts (firm and regional contexts) and three levels (Figure 4). At the firm context, we differentiated two levels. The first level involves firm characteristics that change along the time (the occasion level or level 1 variables), whereas the second level includes firm characteristics that remain constant over the period analysed (the cluster level or level 2 variables). Thus, the variables included at level 1

(occasions) were two: the natural logarithm of the firm age (LN_AGE) and the natural logarithm of the total assets (LN_TA), as proxies for the firm's experience and the firm size, respectively. At level 2 (cluster or firm level), we used a dummy variable (HIGH_TECH) which equals 1 for firms in high-tech industries according to the Eurostat classification³, and 0 otherwise. It was used as a proxy of the effects of firms' industries. The firm level data were compiled from SABI for Spanish and Aida BdV for Italian USOs. Both databases are provided by Bureau Van Dijk.

At the regional context, we included a set of variables that vary across regions and years, but not between companies in the same region (the supercluster level or level 3 variables). First, the total R&D personnel (in full-time equivalent, FTE) over total employment (RD_P) was used in measuring the potential technological spillovers. Second, the patent applications to the EPO (European Patent Office) by priority year per million inhabitants (PAT_EPO) were employed as measure of the production spillovers. Third, the natural logarithm of the number of persons with tertiary education (EDU_TER) was used as a proxy for the human capital spillovers⁴. All of the regional context variables have been collected from Eurostat database.

Figure 4. Structure of data



3.4. Model Specification

In order to explore the effects of knowledge spillovers at both firm and regional contexts, we applied a hierarchical linear model or multilevel modelling that enables to simultaneously use

³ Eurostat uses the aggregation of the manufacturing industry according to technological intensity and based on the NACE Rev.2 at the two-digit level.

⁴ It is noteworthy that even when RD_P and EDU_TER variables are mainly based on human capital, we proxy the technological spillovers with RD_P. The underlying rationale for this choice is that the core business of USOs lies in tangible and intangible goods in which tacit knowledge embedded in available human capital is more relevant than surrounding physical infrastructure.

explanatory variables at these two levels (Snijders & Bosker, 1999). This is due to the structure of the dataset, with occasion observations i (level 1) for each USO j (level 2) located in each region k (level 3). Furthermore, we adopted a logistic model as the dependent variable (PAT) is a dummy, and we assumed fixed slopes (Rabe-Hesketh & Skrondal, 2012) since the number of observations is low in some regions. As a result, we defined the following three-level logistic random intercept models written as a latent response models:

Model 1 (with firm variables):

$$PAT^*_{ijk} = \beta_0 + \beta_1 LN_AGE_{ijk} + \beta_2 LN_TA_{ijk} + \beta_3 HIGH_TECH_{jk} + v_k + u_j + e^*_{ijk}$$

Models 2A, 2B and 2C (with firm variables and one by one regional variables):

$$PAT^*_{ijk} = \beta_0 + \beta_1 LN_AGE_{ijk} + \beta_2 LN_TA_{ijk} + \beta_3 HIGH_TECH_{jk} + \beta_4 RD_P_{ik} + v_k + u_j + e^*_{ijk}$$

$$PAT^*_{ijk} = \beta_0 + \beta_1 LN_AGE_{ijk} + \beta_2 LN_TA_{ijk} + \beta_3 HIGH_TECH_{jk} + \beta_4 PAT_EPO_{ik} + v_k + u_j + e^*_{ijk}$$

$$PAT^*_{ijk} = \beta_0 + \beta_1 LN_AGE_{ijk} + \beta_2 LN_TA_{ijk} + \beta_3 HIGH_TECH_{jk} + \beta_4 EDU_TER_{ik} + v_k + u_j + e^*_{ijk}$$

Models 3 (with firm variables and a set of regional variables):

$$PAT^*_{ijk} = \beta_0 + \beta_1 LN_AGE_{ijk} + \beta_2 LN_TA_{ijk} + \beta_3 HIGH_TECH_{jk} + \beta_4 RD_P_{ik} + \beta_5 PAT_EPO_{ik} + \beta_6 EDU_TER_{ik} + v_k + u_j + e^*_{ijk}$$

where PAT^*_{ijk} is the observed patent activity for occasion i in USO j in region k , β_0 is the overall mean of PAT^*_{ijk} (across all groups), v_k is the region random effect (level 3), u_j is the firm random effect (level 2), and e^*_{ij} is the occasion residual (level 1) with mean zero and variance $\sigma^2 e^*$ (assuming a logistic distribution of σ^2) (Bellman et al., 2013; Leckie, 2013; Steel, 2009).

In addition, a likelihood ratio test (LR) has been performed to test whether the regional context, together with firm-specific characteristics, determines the innovative activity of USOs (the proposed hypothesis). The LR test compares the proposed three-level models (Models 1, 2 and 3) with the simpler two-level models (occasions-firms without supercluster level models), for the purpose of testing the null hypotheses that there are no supercluster level effects ($H_0: \sigma^2_v = 0$) (Leckie, 2013; Rabe-Hesketh & Skrondal, 2012)⁵:

$$LR = -2 \ln L_1 - (-2 \log L_2)$$

where L_1 are the likelihood values of the two-level models and L_2 are the likelihood values of the three-level models, while \ln represents the natural logarithm.

4. RESULTS

Table 1 displays the descriptive statistics of the independent variables.

⁵ Additionally, we test the adequacy of the multilevel analysis by comparing the three-level models with the single level logistic regression also performing a LR test.

Table 1. Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
AGE ¹	7,252	5.49	3.26	1.00	16.00
TA ¹²	6,675	863.98	4,612.53	1.01	182,833.00
HIGH_TECH	7,235	0.58	0.49	0.00	1.00
RD_P	6,965	1.09	0.34	0.31	2.07
PAT_EPO	6,282	75.77	54.94	4.38	217.36
EDU_TER ¹³	7,252	690.90	503.15	71.50	1,902.90

Notes: ¹Variables are not in logs. ²Variable is in thousands of euros. ³Variable is in thousands of persons.

The mean age of the USOs in the sample is around five and a half years and their average total assets are under 864 thousand of euros. Nearly 58% of the USOs operate in high-tech industries. Concerning the regional level, on average, about 1.09% of total employment is occupied by R&D personnel, the mean number of annual European patent applications is over 75 per million inhabitants, and around 691 thousand of persons have higher education.

Table 2 exhibits the estimated coefficients of the proposed models and, also, the results of the LR tests. The Model 1 includes a random intercept and the explanatory variables at the occasion (level 1) and firm levels (level 2). The Models 2A, 2B and 2C add one by one the regional level explanatory variables (level 3). The Model 3 adds to Model 1 all the regional variables together.

Table 2. Three-level logistic random intercept model

	Model 1	Model 2A	Model 2B	Model 2C	Model 3
CONSTANT	-6.382*** (0.359)	-6.312*** (0.454)	-6.816*** (0.421)	-6.376*** (0.946)	-7.046*** (0.990)
FIXED EFFECTS					
<u>Level 1 and 2 variables (occasion and firm level)</u>					
LN_AGE	-0.806*** (0.120)	-0.821*** (0.125)	-0.787*** (0.130)	-0.806*** (0.120)	-0.802*** (0.135)
LN_AT	0.598*** (0.059)	0.617*** (0.061)	0.599*** (0.063)	0.598*** (0.061)	0.618*** (0.066)
HIGH_TECH	0.717*** (0.193)	0.715*** (0.194)	0.737*** (0.201)	0.717*** (0.193)	0.740*** (0.203)
<u>Level 3 variable (regional level)</u>					
RD_P		-0.131 (0.331)			-0.272 (0.391)
PAT_EPO			0.005* (0.002)		0.006* (0.002)
EDU_TER				-0.001 (0.153)	0.066 (0.170)
RADOM EFFECTS					
σ^2_v	0.14131	0.1515399	0.0751669	0.1413186	0.0789517
σ^2_u	2.710862	2.710173	2.816818	2.710834	2.802512
N° observations (Occasions–Level 1)	6,662	6,527	5,779	6,662	5,644
N° clusters (USOs – Level 2)	1,110	1,110	1,109	1,110	1,109
N° superclusters (Regions – Level 3)	22	22	22	22	22
Log likelihood	-1,331.9037	-1,304.8727	-1,173.8664	-1,331.9036	-1,146.7134
LR TEST (n-level to 1-level model)^a					
X ²	260.88	249.71	209.25	260.58	198.65
p-value	0.0000	0.0000	0.0000	0.0000	0.0000
LR TEST (3-level to 2-level model)					
X ²	5.6	5.98	1.74	5.54	1.79
p-value	0.0180	0.0145	0.1870	0.0186	0.1808
p-value (divide by 2) ^b	0.0090	0.0073	0.0935	0.0093	0.0904

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

^a The LR test results (n-level to 1-level model) are significant (with $p < 0.01$) in all models. Hence, a multilevel approach is significantly more appropriate than the single-level one when analysing the regional effect on the Spanish and Italian USOs' innovation performance. ^b As suggested by Rabe-Hesketh & Skrondal (2012), the p -value is divided by two for testing one variance when another uncorrelated random effect is in the model.

In all the estimated models, except for those that include the variable PAT_EPO (Model 2B and Model 3), the LR test which compares 3-level to 2-level models rejects the null hypothesis that there are no supercluster effects ($H_0: \sigma^2_v = 0$). These results suggest that the regional context partly determines the USOs' innovative performance. Particularly, in Models 1, 2A and 2C the regional Variance Partition Coefficients (VPC) are around 2.30-2.46%. These figures indicate the proportion of the total residual variance in the propensity of USOs to patenting due to

differences across regions. Although these percentages are small, as we mentioned, LR test turned out to be significant, suggesting that USOs located in the same region are more alike than others from different regions in terms of innovation activity. Then, it makes sense investigating the USOs' innovative performance under an interactionist approach using multilevel modelling.

In models that include the variable PAT_EPO (Model 2B and Model 3), the LR test does not reject the null hypothesis. Therefore, these three-level models are no preferred to their two-level occasions-within-USOs counterparts, even after dividing their p -value by two. By including the variable PAT_EPO, we have explained so much of the region level variation σ^2_v away that the little variation which remains is no longer significantly different from zero differences between regions (Leckie, 2013). Taking together, the above-mentioned findings lead us to conclude that the regional production spillovers have a positive effect on USOs' innovative performance, supporting the *Hypothesis 1*. This evidence is partly consistent with the findings obtained by Arvanitis et al. (2016) and Rodríguez-Gulías et al. (2016). It also supports the arguments of that knowledge spillovers, proxied by production spillovers, occur between agents that have geographical proximity to each other (Tavassoli et al., 2017). In contrast, in the case of the region's technological spillovers (RD_P) and human capital spillovers (EDU_TER) no effect is found. This result could be partly explained by the fact that the selected regional variables do not capture appropriately the knowledge spillovers from which USOs can be benefiting.

At firm context, firm age (LN_AGE) shows a negative effect on the USOs' innovation activity, supporting the argument that young firms tend to benefit from knowledge spillovers to a greater extent than older firms (Cohen et al., 2002; Audretsch & Dohse, 2007), partly because the former overcome more successfully knowledge filters than the latter (Feser and Proeger, 2017). Conversely, firm size (LN_TA) has a positive effect on the probability of patenting. The estimated coefficients support the arguments that bigger firms have an advantage in innovation activities due to their higher resources and linkages to exploit external knowledge (Fontana et al., 2006; Laursen & Salter, 2004). Also the variable for firms in high-tech industries (HIGH_TECH) presents a positive sign, supporting the argument that being a high-tech firm positively affects innovation activity (Bernstein & Nadiri, 1988; Fischer et al., 2006). Previous results support the *Hypothesis 2* referred to the firm-specific characteristics that, together with the regional context, influence the USOs' innovation. In so doing, these findings reveal that the effect of localized knowledge spillovers differs across the region's firms depending on companies' characteristics.

5. CONCLUSIONS AND IMPLICATIONS

In the last years, the attention paid to USOs as a valuable mechanism for transferring technology and effectively contribute to the knowledge economy has increased. Scholars generally remark the critical role of knowledge spillover emerging in the regional context as an essential input of firms' innovation activities. USOs, backed by their research-based nature and linkages to universities, are active involved in the knowledge spillover process and fully integrated in the regional innovation system, benefiting from the knowledge dissemination in the local context. Moreover, firm characteristics are also important to define the USOs' ability to absorb regional knowledge and incorporate it in their innovation process. Hence, both regional and firm contexts should be jointly considered to assess the innovative activity of USOs in order to better understand their contribution to knowledge economy. Few studies have adopted such 'interactionist approach' in addressing this issue. Drawing on the KSTE, this paper explores whether the region's knowledge spillovers and firm's absorptive capacity jointly determine the innovative activity of USOs.

The regional effect was measured in terms of technological spillovers, production spillovers, and human capital oriented spillovers. The results from a cross-national panel sample of 531 and 952 Spanish and Italian USOs show that USOs located in the same region are more alike

than others from different regions in terms of innovation activity. Additionally, this innovation activity is positively affected by the regional production spillover, suggesting that regional patent activity works as an important R&D input for the firms operating in the same context. Hence, USOs may be able to absorb the technological/knowledge input deriving from the regional spillover englobed in patents stocks to develop and catalyse new innovation.

Nevertheless, the other two elements of regional spillover analysed, technological spillovers and human capital oriented spillovers, do not seem to affect the innovation activity of USOs, downsizing the overall effect of regional context. The reasons behind this evidence could be partly related to the capability of the selected regional variables to capture properly the regional knowledge spillovers used by USOs to leverage their innovative efforts. Although the total R&D personnel and number of persons with tertiary education represent good proxies of technological spillovers and human capital-oriented spillovers, respectively, the difficulty to identify appropriate and valuable measures to capture the heterogeneous and mainly 'tacit' nature of the knowledge spillover effect is a critical issue in this type of study (Kaiser, 2002; Breschi & Lissoni, 2001; Liao, 2015).

At firm level analyses, the findings show that firm age has a negative effect on the USOs' innovation activity, supporting the argument of the knowledge-based theory of the firm that stresses that young firms lacking of critical internal resources need to tap into external knowledge flows to a greater extent than mature firms. In contrast, firm size has a positive effect on the USOs' innovation activity, highlighting that bigger firms can better reach a good level of knowledge absorptive capacity compared to their smaller counterparts; their availability of superior resources and inter-organizational relationships prove critical to fully exploit external knowledge. Additionally, USOs active in high-tech sectors seems perform better in their innovation activity, confirming the advantage of high-technology based firms to capture the knowledge spillover from the regional context and traduce it in effective and successful innovation. Overall, the empirical results also acknowledge that the firm-level characteristics are pivotal in assessing the knowledge absorptive capacity of USOs, which, in turn, affects their innovation activity.

These findings also have some important policy implications. Particularly, given that the region's patent activity has a significant effect on the USOs' innovation, future strategies aimed at fostering innovation in academic entrepreneurship should improve the protection of intellectual rights and innovative ideas. In this regard, it is important that patent applications rely on a large base of regional actors (e.g., industry, governmental agencies, or public research organizations, among others). Indeed, only in this case the knowledge spillover could be fully exploited by all the actors involved, including USOs, at regional level. Indeed, contexts with strong protection of property rights endorse venture capital and private equity investment (La Porta et al., 2002; Lerner & Schoar, 2005), which, in turn, can effectively promote the USOs' innovative activity, since venture capital are reputed to be the most tailored investors for the growth and innovation of technology and knowledge-based firms.

Further, the effect of knowledge spillovers on the USOs' innovation cannot be attributed solely to one specific geographical scale. In order to gain insights into this issue, it is needed assessing the effect of potential knowledge spillovers stemming from other levels of analysis, such as university level.

As any research, this study presents some limitations. Although the panel data methodology helps in capturing the quantitative effects of regional and firm level variations, complementary in-depth qualitative analysis of the differences in the innovation processes performed by USOs in different countries is also necessary. Further, we only considered USOs' innovation in terms of patent activity, which can underestimate the innovative activity of USOs, since not all innovation are patented (Cantner & Goethner 2011). Hence, future research may benefit from considering additional indicators of the USOs' innovation, such those related to the innovation input (i.e. R&D intensity), and innovative outputs (e.g. product, process and organizational

innovation). Further research on the topic could extend the proposed conceptual model by adding other spillover mechanisms labour mobility flows and inter-organizational R&D alliances. This approach would lead to a better understanding about the prominence of different mechanisms of knowledge spillovers at the different geographical scales in which they arise. A systematic view of the mechanisms of knowledge spillovers may have central consequences for regional and innovation program alike.

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