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Regional variation of academic spinoffs formation

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Abstract Using a self-collected longitudinal dataset that comprehends the population of academic spinoffs created in Portugal from 1995 until 2007 we investigate to what extent these firms are geographically clustered and the determinants of their geographical distribution at the time of their formation. We focus on university and agglomeration economies-related mechanisms at the municipality level. Our results show that overall academic spinoffs do not exhibit a tendency to cluster, nevertheless some local clusters do exist. Additionally, our findings show that the presence of university incubators and/or university research parks is the most relevant university-related mechanism, whereas regarding agglomeration economies all seem to be important to explain academic spinoffs distribution across municipalities.

Keywords Academic spinoffs · Agglomeration economies · Panel count data · Spatial analysis

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1 Introduction

Economists have long established the importance of the set-up of new firms to economic growth (Schumpeter 1934; Aghion et al. 2009). Over recent years special attention has been given to the role played by the so-called academic spinoffs, i.e., start-ups that take to the market technology and knowledge generated by research institutions (Poyago-Theotoky et al. 2002; Hall et al. 2003; Shane 2004; Link and Scott 2005). Academic spinoffs are of particular interest because of their ability to create wealth. First, academic spinoffs are a vehicle to bring new scientific knowledge to industry, which is a key source of firmś innovative capability and thereby of economic growth (Nelson 1986; Jaffe 1989; Mazzoleni and Nelson 2007). Second, academic spinoffs may contribute to regional economic development by creating new and highly skilled jobs and generating knowledge spillovers (Audretsch and Feldman 2004; Asterbo and Bazzazian 2011).

It has been well documented that academic spinoffs set-up process is different from the set-up of other start-ups or corporate spinoffs for at least two reasons. First, academic spinoffs need access to key resources, namely technical knowledge and physical assets, such as R&D laboratories, which are crucial for their development (Mustar et al. 2006; Wright et al. 2012; Fernández-Alles et al. 2015). Second, academic entrepreneurs frequently lack business competences, which they need to compensate for by seeking the support from infrastructures such as incubators and science parks that are provided by parent institutions (Shane 2004; Heirman and Clarysse 2004; Lockett and Wright 2005).

For these reasons, previous studies have found that academic spinoffs tend to be clustered around the parent institution (e.g. Egeln et al. 2004; Shane 2004; Asterbo and Bazzazian 2011; Heblich and Slavtchev 2013; Fernández-Alles et al. 2015). In addition, the proximity to other resources may also influence the decision of locating in the same region of the parent institution, namely social ties (Heblich and Slavtchev 2013; Casper 2013). But, the spinoff may also choose to locate in a region distinct from its origin. This happens when it feels the need to engage in technological cooperation with other knowledge sources, and/or when it needs to access resources that are scarce in its origin region, such as highly qualified labor or supplier networks (Egeln et al. 2004).

Studies on the determinants of academic spinoffs location and geographical distribution (e.g. Acosta et al. 2011; Bonaccorsi et al. 2013; Fritsch and Aamoucke 2013; Calcagnini et al. 2016) emphasize the knowledge spillover hypothesis according to which firms co-locate in order to benefit from knowledge externalities (Audretsch and Stephan 1996; Acs et al. 2009). Yet, their findings are not consistent regarding the mechanisms through which knowledge spills over. This can be due to differences in the contexts in which the spinoffs emerge, such as country or regional context. So far, only a few contributions have investigated the influence of other mechanisms beyond those university-related in order to explain differences on academic spinoffs formation and distribution across regions. For instance, Fini et al. (2011) analyzed the extent to which university-level support mechanisms and local-context support mechanisms complement or substitute for each other in fostering the creation of academic spinoffs. They found that university-related mechanisms complement the legislative support offered to high-tech entrepreneurship whereas they have a substitution effect with regard to the amount of regional social capital, regional financial development and regional public R&D expenses as well as the level of innovative performance in the region.

In this paper we add to this emerging line of research by incorporating economic geography principles (e.g. Guimarães et al. 2000; Ellison et al. 2010) to the investigation of academic spinoffs formation and clustering across regions. By incorporating these principles into the analysis of academic spinoffs formation and location we add the spatial context to the analysis and expect to contribute to the understanding of the relative importance of different mechanisms underlying these phenomena.

For this purpose we investigate the role of agglomeration externalities in addition to university-related mechanisms in determining academic spinoffs location. The first group of variables contains university-related mechanisms as suggested by previous studies (total number of higher education and research labs located in the region, the quality of these institutions, their scientific knowledge base and the presence of business incubators). The second group contains traditional location variables that capture agglomeration externalities. We employ a self-collected database that represents the population of Portuguese academic spinoffs. The data analysis is performed over the 1995–2007, at the municipality-level. This is the smallest territorial and administrative division in Portugal and for this reason has been used in much of previous studies on Portuguese firmś location (e.g. Figueiredo et al. 2002).

Our focus is on regional differences and we assume that academic spinoffs share common genetic characteristics at their formation stage (Colombo and Piva 2012). Our paper is in line with Acosta et al. (2011) and Fini et al. (2011), but we explicitly test for the presence of spatial-autocorrelation in the entry of academic spinoffs and the extent to which these firms tend to be clustered in geographic space. While previous studies have considered the role of agglomeration economies on the location of innovative start-ups in general, they have considered them as control variables in (e.g. Acosta et al. 2011; Baptista and Mendonça 2010; Bonaccorsi et al. 2013). Moreover, they do not set academic spinoffs apart from other knowledge-based start-ups. Yet, considering these firmś peculiarities, such as their lack of business development capacities, need of highly qualified human capital and research resources, it can be argued that this distinction should be made (Druilhe and Garnsey 2004).

The paper is organized as follows. Section 2 discusses the mechanisms at the local level that may influence the formation of academic spinoffs. Section 3 presents the empirical model, data and econometric approach. Section 4 presents the results and Sect. 5 the conclusions.

2 Academic spinoffs location at entry

It has been observed that the number and characteristics of the universities in a region leads to an increase in the number of new firms, highlighting the role of universities as anchors of regional development (Audretsch et al. 2005; Woodward et al. 2006). Different arguments have been advanced in order to explain the clustering of new or innovative start-ups near universities. The most common one in the literature is the access to knowledge spillovers. In particular, the spatial proximity to the university facilitates the flow of tacit knowledge (Audretsch and Stephan 1996).

According to the knowledge spillover theory of entrepreneurship (Audretsch and Stephan 1996; Acs et al. 2009) new business in general, and highly innovative start-ups in particular, are manifestations of knowledge spillover from extant knowledge sources. Therefore, the number and types of new business are shaped considerably by the regional knowledge base, and the emergence of innovative start-ups can be especially expected in regions with significant amounts of knowledge, private or public.

Several papers have tested this theory by investigating the role of universities or research institutions on new business formation and/or innovative start-ups (e.g. Acosta et al. 2011; Baptista and Mendonça 2010; Bonaccorsi et al. 2013; Fritsch and Aamouke 2013; Calcagnini et al. 2016) and on academic spinoffs (Casper 2013; Heblich and Slavtchev 2013) at the regional level. Overwhelmingly, this evidence corroborates the positive effect of universities or higher education institutions on the number of these firms on the region. However, evidence is not consistent regarding the particular mechanism through which knowledge spills over in the case of new business formation and/or innovative start-ups in general. For instance, Fritsch and Aamoucke (2013) found that it is the presence and size of universities that matters to explain the emergence of start-ups whereas Di Gregorio and Shane (2003) and van Looy et al. (2011) found out that it is the institutioń s quality. Still others have found that graduates (Acosta et al. 2011) or the nature of scientific knowledge (Audretsch et al. 2004; Fritsch and Aamoucke 2013) are more important than the mere presence or number of universities in the region.

In the academic spinoffs case, existing evidence suggests that the mere local availability of a university may not per se guarantee access to knowledge and resources; social ties are additionally required (Casper 2013; Heblich and Slavtchev 2013;). Furthermore, the authors find that only the parent university influences academic entrepreneurś decision to stay in the region while other universities play no role. The importance of social ties implies that academic knowledge and resources are not necessarily local public good (Heblich and Slavtchev 2013).

These findings suggest a less important role to the knowledge spillover theory in the case of academic start-ups than it has been suggested. In fact, being in the vicinity of a university may also provide important cost advantages to the spinoff firm, because by keeping a formal relation with their parent university, spinoffs can minimize investment in fixed capital as they can make use of the parent's infrastructures (Poyago-Theotoky et al. 2002; Hall et al. 2003; Shane 2004; Link and Scott 2005). In addition, having access to the services provided by universitieś incubators and/or science parks can prove to be critical to the spinoffs start-up and evolution (e.g. Fernández-Alles et al. 2015).

The business development capabilities of incubators or science parks make it possible to support spinoffs in the early stages, both in terms of opportunity recognition and in defining the suitable business model, thus minimizing the frequent lack of business competences of academic entrepreneurs (Di Gregorio and Shane 2003; Heirman and Clarysse 2004; Lockett and Wright 2005; O'Shea et al. 2005). The incubator supports spinoffś development, not only in terms of strategic management and business orientation and of access to knowledge necessary for completing the technologies or products, but also in what concerns access to physical facilities, particularly laboratories and administrative staff (Colombo and Delmastro 2002; Lofsten and Lindelof 2005; Wright et al. 2007).

Besides the knowledge spillover hypothesis as put forward by theory of entrepreneurship, the clustering of academic spinoffs can be also explained by the agglomeration economies theory. The agglomeration economies theory advances that there are benefits from co-location or co-agglomeration. These benefits ultimately reflect gains that occur when proximity reduces transport costs (Ellison et al. 2010). In order to understand the role of agglomeration economies one has to distinguish between externalities that arise from the co-location of producers active in the same industry (known as localization economies) and those that extend across industries (urbanization economies).

The localization economies originate from Marshall (1920) who emphasized three different types of transport costs, the costs of moving goods, people, and ideas, which can be reduced by industrial agglomeration. These economies are associated with the benefits of intra-industry externalities and imply that a high density of high-technology firms can attract new companies to that knowledge intensive region, allowing them access to knowledge spillovers (Armington and Acs 2002; Friedman and Silberman 2003; Lach and Schankerman 2008). Urbanization economies relate to diversity and the access to a wide range of market opportunities, thus these economies are associated with inter-industry spillovers (Figueiredo et al. 2002). Hence, urban areas can be particularly favourable to the set-up of new firms, given the high population density and the relative ease of access to customers and suppliers (Stam 2010; Buenstorf and Geissler 2011).

In addition to knowledge spillovers, agglomeration economies allow firms to benefit from a specialized labor market. In the academic spinoffs case, human capital is a key resource not only in the set-up phase but also for their evolution (e.g. Fernández-Alles et al. 2015). Human capital is a determinant of firḿs innovation capability because it produces in-house knowledge and allows for firms to profit from the knowledge produced by others. This idea, initially proposed by Cohen and Levinthal (1989), refers to the importance of absorptive capacity of firms in order to use the pool of new knowledge that is produced by other firms. Regions that have a high level of employees with higher educational levels show higher levels of start-up activity (Armington and Acs 2002; Figueiredo et al. 2002; Baptista and Mendonça 2010). In the specific case of high-technology firms, access to specialized and qualified labor is an essential resource, so its presence directly influences location decisions (Audretsch et al. 2005; Piva et al. 2011; Kim et al. 2012; Woodward et al. 2006).

However, it has been noted that not all of the observable clustering is necessarily the result of agglomeration economies (Figueiredo et al. 2002; Buenstorf and Geissler 2011). In fact, most evidence on clustering and firm performance find little evidence for the Marshallian hypothesis that co-location brings localization economies. Other contributions have argued that clustering may be instead the result of heritage, where new entrants predominantly locate close to their geographic "roots". Thus, entrepreneurs may decide to locate the firm in the region where they reside and where have built social networks that allow access to resources needed for creating the company, particularly so in the spinoffs case (Sorenson and Audia 2000; Figueiredo et al. 2002; Sousa et al. 2011).

In the spatial product life approach firms clustering follows from a productś life cycle (Thompson 1968), where product standardization leads to scale economies and increasing market concentration. In this view, firms start by localizing in core regions, such as metropolitan areas where capital, talent, early users and supporting institutions are more abundant and then relocate to peripheral regions as product gets standardized and cost competition takes over product competition. In the more recent industry life cycle approach (Klepper 2007) clusters can emerge from a single successful firm and subsequent spinoffs. As such, in this view localization economies do not necessarily play any role in the formation of clusters over time. Rather, clusters emerge from a series of spinoff firms born from selected firms (see also Frenken et al. (2015) for a critical survey).

Concerning the spatial product life cycle, existing evidence corroborates the main hypothesis in that firms in emerging innovative industries profit most from being located in large diversified cities, while firms in routinized industries profit more from being in smaller specialized cities. Thus, localization economies increase with the maturity of industries, while benefits from variety tend to decline when industries become more mature (Frenken et al. 2015). However, this evidence is not consistent with the industry life cycle view and evidence. Specifically, the industry life cycle studies find that localization economies have no effect on clustering and survival of firms as these two events are more the result of the random location of exceptional entrepreneurs. Yet, since more diversified urbanized regions will have higher likelihood of having more industries related to the new industry, new industries can be expected to emerge in such diversified areas rather than in specialized areas, in line with the product life cycle theory (Frenken et al. 2015).

3 Empirical model, data and econometric approach

3.1 Empirical model

Our aim is to investigate the regional distribution of academic spinoffs formation by focusing on a set of factors that vary across regions, operationalized as municipalities. The reduced form of our model is specified as:

$$\text{SPINOFF}_{it} = f(\mathbf{U}_{it}, \mathbf{R}_{it},) \tag{1}$$

where SPINOFF_{jt} denotes the number of academic spinoffs that are founded in municipality i at time period t, $\mathbf{U}_{\text{it}}$ is a vector of university-related variables and $\mathbf{R}_{it}$ is a vector of agglomeration economies-related variables.

3.2 Data collection

For this study we followed the literature definition of an academic spinoff (Heirman and Clarysse 2004; Lockett and Wright 2005; Mustar et al. 2006) and considered firms created by universitieś faculty members or graduate students, who developed a technology as part of their activity in that institution. In order to identify this population we draw on information from publicly available sources (annual reports and websites), obtained directly from firms, universities, technology transfer offices (TTOs) and incubators. Whenever necessary, the data were complemented or validated through direct contacts. Each spinoff firm was assigned to a municipality. Portugal mainland is divided into 308 municipalities, which is the smallest administrative division of Portuguese regions.

Given that the focus of our analysis is on the region in which the firm is located, all additional data were also collected at the municipality level. Data on universities and research organizations were collected from the Ministry of Science and Higher Education (MCTES) databases and from the *Webometrics Ranking of World Universities*. Data on population density were collected from the Portuguese National Institute of Statistics (INE). Finally, data regarding the regionś human capital, high technology firms and industry specialization were collected from the *Quadros de Pessoal* database and at the municipality level. The *Quadros de Pessoal* database results from information gathered yearly by the Portuguese Ministry of Social Security and Labor, on the basis of mandatory information submitted by firms. Whereas the first Portuguese academic spinoff was created in 1979 (to the best of our knowledge), data on Portuguese universities are available only since 1995 onwards. Hence, to construct our panel data we consider spinoffs that have been launched since 1995. Data collect from the *Quadros de Pessoal* database was only available until 2007. During the period between 1995 and 2007 we identified 261 new academic spinoffs that were located across 45 municipalities. Therefore, our data comprise a panel of 45 municipalities for the period 1995–2007.

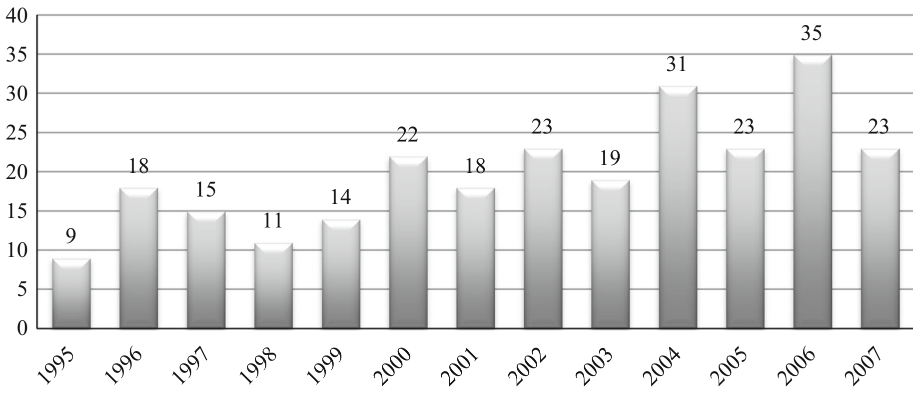


Fig. 1 Portuguese academic spinoffs by founding year, 1995–2007

3.3 Dependent variable

Our dependent variable $SPINOFF_{it}$ is the number of new academic spinoffs in municipality i at time t. By observing the number of spinoffs by founding year, it is noticeable an increase since 2004 (Fig. 1), which follows the European trend and reflects the adoption by several European countries (including Portugal) of regulatory frameworks to promote the entrepreneurial mission of universities (Clarysse et al. 2011; Matias and Fontes 2013).

The empirical distribution of spinoffs entry shows some interesting features (Table 1). First, we observe a high preponderance of zeros, corresponding to the modal value and to 76 % of the cases. The maximum observed value in spinoffs in the pair municipality-year is 7 and it was a one-time event. Whereas the median value is 3.5 spinoffs, the mean value of spinoffs formation is indeed very low, only 0.45. Second, the variance (1.066) exceeds the mean (0.433) suggesting a careful choice of the econometric approach.

An inspection of spinoffs entry variability between and within municipalities (over time) shows that there are both cross-municipality variability and over time variability and that they are of similar importance. Overall, there appears to be a significant degree of variability across municipalities and over time, i.e., the dispersion of academic spinoffs across municipalities is quite uneven (Table 2).[1]

Figure 2 shows the geographic distribution of academic spinoffs in 1995 and in 2007. In 1995 there were four clusters located nearby the municipalities of Lisbon, Porto, Braga and Coimbra. By 2007, an additional cluster appeared located near Aveiro. The figure clearly shows that all clusters are located in the main metropolitan areas, where the main Portuguese Universities are located. This clustering is consistent with the product life cycle hypothesis, according to which, new firms launching new products start locating in core regions, namely metropolitan and urban areas.

Table 3 shows a more detailed picture of this distribution. Four municipalities alone account for nearly half (49 %) of the total number of spinoffs establishments; this percentage increases to 70 % if we take into account the top eight municipalities. Lisbon

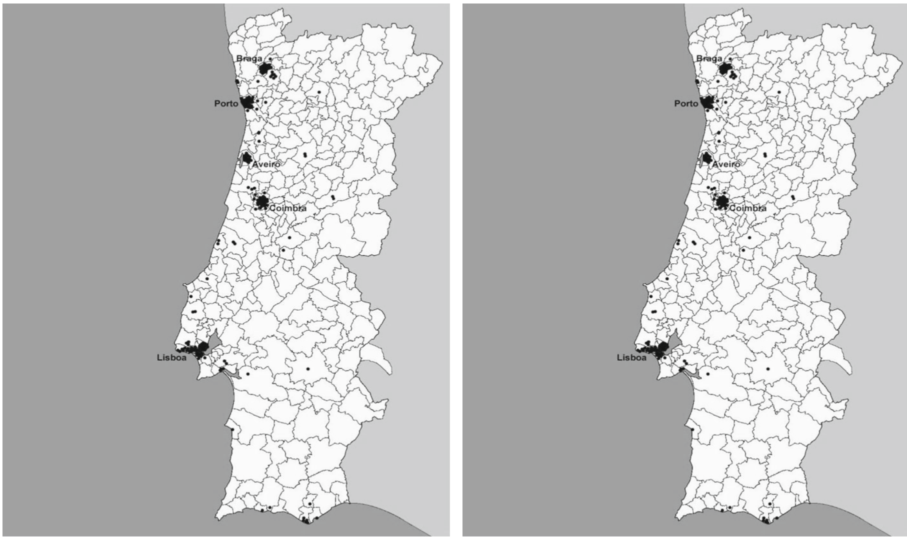
[1] If we consider the transition probabilities from 1 year to the next for the entry of spinoffs we observe that the zero outcome has a high probability (84.3 %) of remaining zero, but when the number of spinoffs entry is four or more in a given municipality, then the probability of having four or more spinoffs in that municipality in the next year is as high as 53.3 %. For simplicity we do not present these results, but they are available upon request to the authors. .

Table 1 Frequency distribution of spinoffs entry

	Count	Frequency
	0	444
	1	83
	2	28
	3	15
	4	5
	5	4
	6	5
	7	1
Mean	0.446	
SD	1.066	

Table 2 Variability of spinoffs entry across municipalities and over time

Variable	Variation		
	Overall	Between	Within
Spin-offs entry	1.033	0.729	0.739
Observations	N = 585	n = 45	T = 13



Note: Total number of academic spin-offs in 1995. Note: Total number of academic spin-offs in 2007

Fig. 2 Geographic distribution of Portuguese academic spinoff firms, 1995 and 2007. **a** *Note*: Total number of academic spin-offs in 1995; **b** *Note*: Total number of academic spin-offs in 2007

alone, accounts for nearly 17 % of all spinoffs, contrasting with 37 municipalities that have <10 spinoff firms (Table 3).

Table 4 presents the top eight municipalities with spinoff firms along with the mean values of the empirical variables that enter in our model (the descriptive statistics and correlations coefficients are presented in Table 5). Overall, the mean values of the

Table 3 Distribution of academic spinoffs across municipalities

Spin-offs (nbr)	Municipalities (nbr)	Spin-offs (nbr)	Spin-offs (%)
1 < 10	37[a]	77	29.5
10 < 20	4	57	21.8
20 < 40	3	83	31.8
>40	1	44	16.9
Total	45	261	100

[a] 22 municipalities have 1 spin-off firm

empirical variables of these municipalities are higher than the sample means, particularly with respect to the mean values of the institutional context variables. However, with respect to the other characteristics of the region, we observe that only the top four municipalities with spinoff establishments (Lisbon, Coimbra, Porto and Oeiras) exhibit higher mean values than the sample mean throughout the cases, and these municipalities have approximately twice of human capital and knowledge intensive firms when compared to the remaining top four municipalities (Braga, Aveiro, Maia and Matosinhos). When we look at the data by metropolitan area, we observe a higher incidence of spinoffs in the largest metropolitan areas, Lisbon and Porto, which is consistent with the product life cycle approach of new firms and clusters formation. This clustering also suggests the presence of spatial correlation in spinoffs formation in these municipalities.

3.4 Independent variables

In our vector of university-related mechanisms we include the following variables. *Institutions*, which is the number of Higher-Education and research institutions in the municipality, *Technology Base*, which *is* a dummy variable that equals 1 if there are universities with a science and engineering disciplinary base in the municipality, and *Reputation*, which is a dummy variable that equals 1 if there is at least one university located in the region among the Top 500 in the *Webometrics Ranking of World Universities*, and measures the quality of the scientific research that is done locally. Finally, we include *Incubator*, which is a dummy variable that equals 1 if there are business incubators or science parks in the municipality.

In the agglomeration economies vector we include *Human Capital*, which is measured by the ratio of the number of employees with higher education to the total number of employees in the municipality and accounts for the regiońs absorptive capability and qualified workforce. *Localization*, which is measured by ratio of the number of firms in high-technology industries by the total number of firms per municipality and it measures the agglomeration externalities or spillovers derived from proximity to other high-tech firms. *Urbanization*, which is measured by total population per square meter and is a proxy for municipality's industrial diversity and attractiveness to the set-up of new firms, accessibility and amenities.

Table 5 displays the summary statistics and correlations of the variables included in our study. A potential problem in our data is the high correlation among indicators for the universities and for the regional characteristics. We tested for multicollinearity among variables and found that the VIF (variance inflation factors) for the university-related and

Table 4 Top eight Portuguese municipalities with academic spinoffs

Metropolitan area/urban area	Municipality	Spin-offs	Institutions	Reputation	Technology-base	Incubator	Human capital	Localization	Urbanization
Lisbon	Lisbon	44	35.462	1	1	1	0.162	0.263	6615.385
	Oeiras	21	3.923	0	1	1	0.158	0.257	3577.308
Porto	Porto	26	15	1	1	1	0.151	0.235	6166.538
	Maia	13	1	0	1	1	0.085	0.130	1459.154
	Matosinhos	13	3	0	1	0	0.083	0.165	2638.308
Coimbra	Coimbra	36	5.692	1	1	1	0.103	0.205	447.846
Braga	Braga	17	2	1	1	1	0.065	0.140	893.769
Aveiro	Aveiro	14	3	1	1	1	0.103	0.182	365.462
Sample		261	2.275	0.133	0.533	0.311	0.069	0.136	951.935

Spin-offs is the total number of academic spin-offs that were set-up in the municipality over the 1995–2007 period; the values of all the other variables are their mean values

Table 5 Descriptive statistics, correlations and collinearity diagnostics

Variable	Descriptive statistics				Collinearity diagnostics							
	Min	Max	Mean	SD	1	2	3	4	5	6	7	VIF
Institutions	0	38	2.275	5.63	1							2.31
Reputation	0	1	0.133	0.34	0.617	1						2.45
Technology base	0	1	0.533	0.50	0.354	0.367	1					3.31
Incubator	0	1	0.311	0.46	0.383	0.584	0.532	1				2.70
Human capital	−5.040	−1.394	−2.839	0.596	0.414	0.355	0.252	0.345	1			18.19
Localization	−3.353	−1.171	−2.059	0.361	0.492	0.458	0.392	0.453	0.821	1		6.22
Urbanization	2.197	8.911	5.896	1.496	0.468	0.380	0.350	0.220	0.392	0.443	1	13.28
Mean VIF												6.92

Variables values in log as they enter in the regression business incubator variables are not a concern but the other region-specific variables exhibit high VIF values, particularly between the variables *Human Capital* and *Urbanization* (see Table 5).

3.5 Econometric approach

The preponderance of zeros, the small values and the discrete nature of our dependent variable (see Table 1) suggest that we could improve the linear model with a specification that accounts for these characteristics (Cameron and Trivedi 1998). The starting point for count data regression is the Poisson model (Hausman et al. 1984). The Poisson distribution assumes that the mean and the variance of the process are equal; however this equidispersion assumption is violated in the case of our data given that the variance exceeds the mean (Table 1). Among the reasons that may lead to the violation of this assumption is a high frequency of zeros (Cameron and Trivedi 1998), which is present in our data.

The negative binomial model (NB) provides a solution for the unobserved heterogeneity by incorporating an unobserved specific effect α. The NB model is more general than the Poisson model because it accommodates overdispersion and it reduces to the Poisson model as $\alpha \rightarrow 0$. Considering longitudinal count data regression models, Cameron and Trivedi (1998) define that NB models are standard count models, with the addition of an individual specific term reflecting individual heterogeneity.

We first run Poisson regression models and then compared them with negative binomial models. The likelihood-ratio test on the hypothesis that the overdispersion parameter alpha is equal to 0 always showed that alpha is significantly different from zero therefore we re-estimated all the models using the negative binomial model. For simplicity, we only present the negative binomial estimates. Assuming that unobserved heterogeneity is randomly distributed across regions we rely on a random effects model (Hausman et al. 1984). In fact, the high variability in the number of spinoffs created across regions excludes a fixed effects model and we employ a random effects model.

A potential problem when dealing with spatial data is that data could be spatially correlated, as suggested by data in Fig. 2 and Table 4. If neighboring localities are subject to correlated shocks, then it is likely that spinoffs location in one region is correlated to spinoffs entry in its neighbor. Therefore we tested for the presence of spatial interdependence in the geographical distribution of academic spinoffs by employing the Moran's I index of spatial autocorrelation (Pfeiffer et al. 2008). This index expresses the overall degree of similarity between spatially close municipalities with respect to the spinoffś entry. The Moran's I test of spatial autocorrelation was not statistically significant, therefore allowing us to proceed with the estimation of our empirical model. Since global indices of spatial autocorrelation are not intended so much for identifying specific clusters, we also constructed the local counterpart of the Moran's I index.

Finally, given the high VIF values of agglomeration externalities variables (Table 5), we proceed as follows. In a first step, we estimated a baseline model without the indicators for agglomeration externalities, that is, we started with the university-related indicators and the business incubator variable. In a second step, we add only one of these indicators at a time to this model. Our measure for the impact of these indicators is the change in the AIC (Akaike information criterion) (see Greene 2008) compared to the baseline model. A decrease in the AIC value due to the inclusion of an additional variable indicates a better fit of the model in terms reducing the remaining ''unexplained'' variance. An increase in the remaining variance leads to a higher AIC value. As robustness checks we then replicated the regressions by diving the sample as follows. First, we excluded from data the municipalities that are were identified as inlands in the spatial contiguity matrix. Second, we excluded the municipalities that tested positive for local spatial interdependence.

4 Results

Table 6 presents the summary statistics of the spatial matrix. The minimum distance between two municipalities is 5.8 km and the maximum distance is 477 km. There are seven islands, that is, municipalities that do not share a common border, one municipality that has five links, that is, it shares a border with five municipalities, and the average number of links is 1.6 indicating geographic proximity among observed municipalities.

Table 7 presents the Moran's I tests for both global and local spatial interdependence in academic spinoffs formation. On one hand, the test for global spatial interdependence shows that there is no general tendency for these firms to cluster, that is, overall the set-up of academic spinoffs in one municipality is not correlated with its neighbours. This result is particularly interesting because although academic spinoffs are geographically concentrated this proximity does not seem to be motivated by spillovers arising from other academic spinoffs. Therefore, this result seems to be more consistent with the view that firmś clustering is the result of heritage, where entrants predominantly locate near their geographic roots as suggested by Figueiredo et al. (2002) or near their parents (Klepper 2007) than the result of localization economies as advanced by Marshall (1920). On the other hand, the test of local spatial interdependence reveals the presence of some clusters in the data, that is, some municipalities in which academic spinoffs are correlated with their neighbors (see Table 7), in which case can be seen as evidence supporting the Marshalĺs hypothesis or the existence of knowledge spillovers as advanced by Acs et al. (2009) but only among few locations. Regarding the latter one can point out that these clusters are located in the Northern and Centre regions of the country but they are not close to the largest metropolitan areas of Lisbon and Porto, as one could expect.

Given these results, the clustering of academic spinoffs cannot be explained by spatial proximity to other spinoffs in neighboring municipalities. Even so, there could still be some agglomeration economies associated with benefits arising from the access to a pool of skilled labour, or from the access to spillovers arising from other start-ups or local amenities. Thus, Table 8 presents the negative binomial estimates of the prevalence of spinoffs entry in each municipality regarding both the university- and agglomeration economies effects. Column (1) shows the estimates of the baseline model in which only university-related mechanisms are included in the regression and time dummies. From column (2) through column (4) we add the agglomeration economies variables to the regression separately. This exercise allows us to see how each of these variables relates to the dependent variable and their contribution to the fitness of the model in addition to the

Table 6 Summary statistics of the distance and spatial matrix of portuguese municipalities with academic spinoffs

				Min.	Max.	Mean
Distance (km)				5.8	477	78.5
Links (nbr)				0	5	1.6
Links count	0	1	2	3	5	4
Links frequency	7	17	12	6	1	2

Table 7 Moran's I test of spatial autocorrelation of academic spinoffs in portuguese municipalities, 1995–2007

Global index		Local index				
Moran's I	*p*-value	Location			Moran's I	*p*-value
		NUTS2	Metropolitan/urban area	Municipality		
0.003	0.434	North	Braga	Guimarães	0.238	0.056
			Porto	Póvoa de Varzim	0.404	0.003
				VN Famalicao	0.187	0.098
		Centre	Aveiro	Ílhavo	−0.559	0.042
			Coimbra	Coimbra	−0.331	0.034
				Condeixa-a-Nova	−0.242	0.095
		South	Faro	Faro	−0.687	0.020

p value of 1-tail test

university-related mechanisms. Column (5) presents the full model and in column (6) and we also include dummies for the NUTS 2 regions.

As illustrated in column (1) all the variables are statistically significant and have a positive effect on the number of spinoffs entry. Thus, among the university-related mechanisms the most relevant effect is *Incubator*, the indicator for the presence of incubating infrastructures in the municipality, followed by *Reputation*, indicator for institutional quality, then the *Technology Base*, the predominant scientific area of knowledge, and lastly by the total number of institutions. In all, these results are consistent with previous evidence (e.g. Poyago-Theotoky et al. 2002; Hall et al. 2003; Shane 2004; Link and Scott 2005; Heirman and Clarysse 2004; Lockett and Wright 2005; Fernández-Alles et al. 2015) that has underlined the key role played by incubating infrastructures in the set-up of academic spinoffs. Also, these results are consistent with evidence that has found more relevant both the institutional quality (Di Gregorio and Shane 2003; van Looy et al. 2011) and the scientific are of knowledge (Audretsch et al. 2004; Fritsch and Aamoucke 2013), than the mere presence or number of universities in the region.

Given the high VIF values among the agglomeration externalities (Table 5), we add these variables to the model separately. The following results can be pointed out. First, all the agglomeration economies variables are statistically significant. Second, in terms of their relative importance, *Human Capital* seems to be the most relevant; it has the largest coefficient and it is the model with the best fit in terms o AIC. This result is consistent with Fernández-Alles et al. (2015) who recently have identified human capital as a key resource to academic spinoffs set-up phase, and also with other contributions that have argued the same (e.g. Link and Scott 2005; Heirman and Clarysse 2004; Wright et al. 2012). Regarding the localization and urbanization externalities, the estimates suggest that intra-industry externalities are more important than inter-industry externalities to explain the incidence of spinoffs in a given municipality, even so, both types of externalities emerge as highly statistically significant. Third, as we add the agglomeration externalities variables to the model only the variables *Incubator* and *Reputation* remain statistically significant across models. In fact, the total number of institutions variable, *Institutions*, is no longer

Table 8 Negative binomial estimates of regression coefficients along with standard errors

Variable	Estimates (1)	S.e.	Estimates (2)	S.e.	Estimates (3)	S.e.	Estimates (4)	S.e.	Estimates (5)	S.e.	Estimates (6)	S.e.
Institutions	0.037*	0.021	0.001	0.017	0.024	0.026	0.007	0.019	−0.020	0.019	−0.008	0.018
Reputation	0.731*	0.401	0.711**	0.334	0.928**	0.446	0.721*	0.348	0.789**	0.333	0.536*	0.315
Technology base	0.527*	0.318	0.423	0.292	0.598*	0.337	0.258	0.307	0.282	0.298	0.233	0.284
Incubator	1.106***	0.331	0.729**	0.308	1.281***	0.362	1.170***	0.305	0.969***	0.323	1.074***	0.304
Human capital	–		1.374***	0.309	–		–		1.083***	0.317	1.693***	0.381
Localization	–		–		0.898***	0.339	–		0.415	0.345	5.094**	2.572
Urbanization	–		–		–		0.329***	0.096	0.235**	0.102	0.017	0.155
Year dummies	Yes		Yes		Yes		Yes		Yes		Yes	
NUTS 2 dummies	No		No		No		No		No		Yes	
Intercept	0.145	1.018	4.846***	1.385	1.184	1.196	−1.184	0.834	3.639**	1.883	54.576	2.706
Log-likelihood	−373.346		−363.318		−372.825		−367.703		−360.425		−354.982	
Wald test for goodness-of-fit	99.26***		141.61***		96.89***		126.72***		151.52		176.53***	
AIC	782.692		764.636		783.651		773.4797		762.851		763.699	
No. obs.	540		540		540		540		540		540	

Dependent variable is the number of academic spin-offs in municipality-year; panel data random effects estimates; variables are in log and lagged by 1 year

*, **, *** means that coefficients are statistically significant at 10, 5 and 1 % significance level, respectively

Table 9 Negative binomial estimates of regression coefficients along with standard errors on subsample without spatially correlated municipalities

Variable	Estimates (1)	S.e.	Estimates (2)	S.e.	Estimates (3)	S.e.	Estimates (4)	S.e.	Estimates (5)	S.e.	Estimates (6)	S.e.
Institutions	0.039*	0.023	−0.001	0.018	0.031	0.025	0.007	0.020	−0.018	0.020	−0.010	0.017
Reputation	0.656	0.421	0.850**	0.338	0.444*	0.465	0.682*	0.367	0.868***	0.342	0.674**	0.323
Technology base	0.579*	0.330	0.404	0.298	0.583*	0.334	0.286	0.318	0.260	0.307	0.158	0.288
Incubator	1.128**	0.350	0.596*	0.318	1.252***	0.375	1.185***	0.320	0.860***	0.356	1.055***	0.337
Human capital	–		1.496***	0.338	–		–		1.147***	0.375	1.665***	0.403
Localization	–		–		0.434	0.404	–		0.338	0.336	0.854**	0.153
Urbanization	–		–		–		0.327***	0.098	0.213**	0.108	0.020	0.153
Year dummies	Yes		Yes		Yes		Yes		Yes		Yes	
NUTS 2 dummies	No		No		No		No		No		Yes	
Intercept	1.259	2.578	6.869**	3.806	2.768	4.556	−0.803	2.319	5.277	4.399	17.305	638.095
Log-likelihood	−350.371		−341.219		−349.775		−355.170		−339.166		−333.109	
Wald test for goodness-of-fit	93.54***		140.36***		91.07***		121.11***		147.40***		181.28***	
AIC	736.741		720.439		737.551		728.341		720.332		716.219	
nbr obs.	504		504		504		504		504		504	

Dependent variable is the number of academic spin-offs in municipality-year; panel data random effects estimates; variables are in log and lagged by 1 year

*, **, *** means that coefficients are statistically significant at 10, 5 and 1 % significance level, respectively

Table 10 Negative binomial estimates of regression coefficients along with standard errors on subsample without islands

Variable	Estimates (1)	S.e.	Estimates (2)	S.e.	Estimates (3)	S.e.	Estimates (4)	S.e.	Estimates (5)	S.e.	Estimates (6)	S.e.
Institutions	0.034**	0.016	0.005	0.015	0.029	0.018	0.017	0.018	−0.006	0.019	−0.001	0.018
Reputation	0.290	0.348	0.336	0.306	0.356	0.371	0.385	0.347	0.435	0.335	0.353	0.332
Technology base	0.668**	0.303	0.553**	0.286	0.667**	0.307	0.440	0.320	0.463	0.312	0.407	0.306
Incubator	1.436***	0.313	1.042***	0.304	1.497***	0.307	1.407***	0.313	1.130***	0.328	1.272***	0.313
Human capital	–	–	1.183***	0.297	–	–	–	–	1.104***	0.315	1.663***	0.382
Localization	–	–	–	–	0.241**	0.363	–	–	0.025	0.349	0.705**	0.367
Urbanization	–	–	–	–	–	–	0.204**	0.107	0.084	0.116	−0.124	0.159
Year dummies	Yes		Yes		Yes		Yes		Yes		Yes	
NUTS 2 dummies	No		No		No		No		No		Yes	
Intercept	−0.085	0.927	4.106	0.910	0.581	1.166	−1.196**	1.121	4.048	1.862	7.785***	2.833
Log-likelihood	−335.936		−327.372		−335.708		−334.069		−326.936		−321.836	
Wald test for goodness-of-fit	127.27***		158.96***		123.37***		130.82***		152.83***		176.07***	
AIC	707.873		692.656		709.417		706.139		695.87		691.672	
No. obs.	456		456		456		456		456		456	

Dependent variable is the number of academic spin-offs in municipality-year; panel data random effects estimates; variables are in log and lagged by 1 year

*, **, *** means that coefficients are statistically significant at 10, 5 and 1 % significance level, respectively

significant. Likewise, *Technology Base*, indicator for the scientific area of knowledge, is only significant once, with the *Localization* variable.

Lastly, column (5) and column (6) present the estimates with all variables. Essentially, these estimates corroborate the estimates presented in the previous columns. That is, once we add the agglomeration economies into the model, the university-related variables that seem to be most relevant are *Incubator* and *Reputation*, whereas with respect to the agglomeration economies the most important is the pool of human capital available in the municipality. Regarding the localization and urbanization economies, results are also interesting in that localization economies seem to be more relevant than urbanization economies, once we control for regional differences at the NUTS 2 level. When we take into account the regional dummies (NUTS 2 dummies), the variable *Urbanization* (measured by population density), is no longer significant (see Guimarães et al. (2000) for a similar effect). So, as we control for these differences plus the size differences across regions as measured by *Urbanization*, the spillovers arising from other knowledge intensive firms (*Localization*) seem to influence more the prevalence of academic spinoffs in a given municipality therefore corroborating Marshalĺs hypothesis. In brief, the prevalence in academic spinoffs formation across municipalities can be explained by the presence of business incubator services and high-quality research local skilled labour force, and knowledge spillovers associated with other high-tech firms located in the municipality.

As robustness checks, we excluded from the data the municipalities that tested positive for local spatial interdependence (Table 9) and the islands (Table 10). Regarding the former, the first noticeable result is that estimates are consistent with those presented in Table 8; the single difference relates the baseline model in which the variable *Reputation* is not significant (see column (1) in Table 9).

However, when the islands are removed from the data *Reputation* that is no longer statistically significant (see Table 10). In our data the islands are municipalities that are located inland, distant from major urban centers and without any reputed University; as these municipalities are removed from the data we are left with the more populated, urban areas where the more reputed universities are located. Hence, the estimates indicate that presence of at least one top quality university in the region is not a differentiator factor to explain academic spinoffs set-up. A similar explanation could be given to the result found in the estimates of the baseline model presented in column (1) of Table 9. Nevertheless, the difference across sub-samples in the *Reputation* estimates is itself an interesting finding as it suggests that although the quality of universities has a positive effect on academic spinoffs formation, its effect it is bounded in space.

5 Conclusions

This paper contributes to the understanding of the role of university-related and local externalities-related mechanisms in explaining regional variation in academic spinoffs formation. Specifically, it analyzes to what extent these firms are geographically clustered and the determinants of their geographical distribution. Previous evidence has emphasized university-related mechanisms, and in particular the spillover hypothesis, in order to explain the incidence of spinoffs formation. However, this evidence does not provide consistent results regarding the mechanism through which knowledge spills.

Furthermore, as firmś entry is determined by both firḿs own characteristics and the environment in which operates, there could be other mechanisms other than knowledge spillovers and university-related relevant to explain the geographic distribution of academic spinoffs. In this paper we extend recent studies that explore the role of the surrounding context in which these firms set-up and operate (Fini et al. 2011) and bring into the analysis the role played by agglomeration economies, besides the university-related mechanisms that have been considered in previous studies. Hence, we seek to understand if the principles that explain the economic geography of firms (Guimarães et al. 2000; Ellison et al. 2010) also apply to academic spinoffs geographic distribution. In this paper we focus on regional differences as our data is at the municipality level, and not at the firm level. Specifically, we observe the number of academic spinoffs that set-up each year-municipality for the 1995–2007 period.

Our results show some interesting findings. First, as found in previous studies academic spinoffs are highly geographically concentrated and in major metropolitan areas (Egeln et al. 2004; Fritsch and Aamoucke 2013). We see this finding consistent with the product life cycle approach (Thompson 1968) in that innovative firms at birth tend to locate in core regions. Second, despite the observed clustering academic spinoffs are not spatially interdependent, except in a few cases. In other words, the number of spinoff entries in a given municipality is not influenced by the entries of its neighbors. This evidence indicates that the clustering across neighboring municipalities is not driven by spillovers associated with other spinoffs located in neighboring regions or municipalities, except in few cases.

So, the clustering of academic spinoffs *across* municipalities is more consistent with Sorenson and Audia (2000) and Figueiredo et al. (2002) argument in that clustering may be instead the result of heritage, where new entrants predominantly locate close to their geographic "roots" and social ties, and with Klepper's (2007) view in that clusters can emerge from a single successful parent and is independent of localization economies, than with the knowledge spillover hypothesis (Acs et al. 2009).

Third, estimates show that both university and agglomeration economies effects are important to explain academic spinoffs prevalence across municipalities, but they suggest that the latter may have a more important role than the former. In particular, we find that the most relevant university-related mechanism to explain the number of spinoff entries in each municipality is the presence of incubators inn line with Colombo and Delmastro 2002; Wright et al. 2012; Fernández-Alles et al. 2015), which corroborates the argument that these firms have a lack of capabilities with respect to market knowledge and firm management and thus look for support in these areas (e.g. Link and Scott 2005; Heirman and Clarysse 2004; Wright et al. 2012; Fini et al. 2011; Fernández-Alles et al. 2015). Furthermore, the lack of supporting evidence regarding the university-related mechanisms, suggests that social ties and preference to locate in the parent́s vicinity are instead the mechanisms underlying Portuguese academic spinoffs clustering, consistent with Fontes (2005), Sousa et al. (2011), Casper (2013), Heblich and Slavtchev (2013).

Fourth, regarding agglomeration economies, access to qualified human capital seems to be the most important externality, to academic spinoffs, arising from co-agglomeration, which is in line with previous contributions (Woodward et al. 2006; Colombo and Piva 2012; Fernández-Alles et al. 2015). Fifth, whereas previous studies on firm location and agglomeration have found supporting evidence for either localization economies (Armington and Acs 2002; Friedman and Silberman 2003; Lach and Schankerman 2008) or urbanization economies (Figueiredo et al. 2002; Stam 2010; Buenstorf and Geissler 2011), we found that both types of agglomeration economies economies seem to play a role to explain academic spinoffs geographic distribution, though our findings suggest that the former seems to more relevant than the latter. That is, spillovers arising from co-location with other high-tech firms seem to be more important than access to general amenities present in urban areas or more densely populated regions. This result is at odds with Buenstorf and Geissler (2011) who conclude that the science-based industry's geography was shaped by the urbanization economies rather than by localization economies), but in all our findings are consistent with Abramovsky et al. (2007) who found that agglomeration effects more important than university quality.

Our findings corroborate the view that research-based or academic spinoffs are distinct from other knowledge-based start-ups (e.g. Druilhe and Garnsey 2004; Casper 2013; Fernández-Alles et al. 2015) therefore should receive support accordingly. Particularly, central and local governments should design policies aiming to promote the set-up of business incubators and/or their development, as these supporting infrastructures seem to play a key role in the process of academic spinoffs entry.

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