Entry by research-based spin-offs: the determinants of regional variation

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Abstract

Reflecting the increasing number of research based spin-offs (RBSOs) created since the nineties, previous studies focus their analysis on the factors that influence university entrepreneurship. However, empirical studies that investigate the determinants of variation on RBSO creation across regions are scarce. Using a unique self-collected dataset that comprehends the population of RBSOs created in Portugal from 1979 until to 2007 we investigate the intensity of spin-offs creation across regions, by focusing on the characteristics of the universities and the region in which the spin-off is located. Our results suggest that the quality and prestige of the universities located in a municipality, as well as the presence of university-affiliated incubators and/or university research parks have a positive impact on the intensity of RBSO creation. Regarding the regional characteristics, the availability of qualified human capital and the regional demand size seem to exert an important effect on spin-off activity across regions.

Keywords: academic spin-offs; firm creation; location decision; count data analysis

JEL Classification: L25, D22, O30, C41

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1. INTRODUCTION

The commercialisation of scientific and technological knowledge produced in public research organisations (PROs) such as universities, laboratories and research centres is considered by policy makers to have a fundamental role in wealth creation and regional economic growth (Ndonzuau et al., 2002; Mustar el al., 2008; Wright et al., 2007). In addition to the traditional licensing of technology, special attention has been given to the role played by the creation of new firms that further develop and/or take to the market technology and knowledge generated by PROs – the so-called academic or research-based spin-offs - RBSOs (Bathelt et al., 2010; Djokovic and Souitaris, 2008; Mustar et al., 2006; Rothaermel el al., 2007).

RBSOs have become an important subject of study, both due to their crucial role as technology transfer mechanisms and to their economic impact, not only on the parent university but also on regional and national economic development (Fini et al., 2011; Mustar et al., 2006; O´Shea et al., 2008; Wright et al., 2007). In fact, according to the Association of University Technology Managers (AUTM 2001), between 1980 and 1999, RBSOs from American academic institutions have contributed 280,000 jobs to the US economy and $33.5 billion in economic value-added activity (Shane, 2004).

In the case of Europe, the "spin-off phenomenon" takes place mainly from the late 1990s, when we see an increase in the creation of spin-offs from higher education and public research organisations, subsequently generically denoted as "universities" (van Looy et al., 2011; Wright et al., 2007). This trend reflects the adoption, by several European countries (including Portugal), of regulatory frameworks that define the conditions and terms under which universities can maximize the value of their knowledge/research through the regulation of intellectual property rights, similar to what occurred in the U.S. with the Bayh-Dole Act (OECD, 2003; van Looy et al., 2011). The consolidation of the entrepreneurial mission of universities in Europe is directly related to an increase of institutional pressure on universities to commercialize research through licensing and/or RBSO, with the professionalization of technology transfer offices (TTOs) at the universities and the availability of public funds to support entrepreneurial activities (Claryssse et al., 2011; Mustar et al., 2008; Wright et al., 2007).

Given the increase of spin-off activity, the analysis of the determinants for the creation of the RBSOs became one of the major research streams on university entrepreneurship. In the literature concerning entrepreneurial activity, several factors are pointed out as relevant to the creation of spin-offs (Asterbo and Bazzazian, 2011; Djokovic and Souitaris, 2008; Gilsing et al., 2010; O´Shea et al., 2008; Rothaermel el al., 2007).

Considering the different levels of spin-off activity, the following factors are highlighted : (1) the founder's personal characteristics, namely motivation, career experience and faculty networking (Clarysse et al., 2011; Karlsson and Wigren, 2012; Landry et al., 2006); (2) the universities' characteristics, such as faculty quality and high quality of research (Di Gregorio and Shane, 2003; van Looy et al., 2011; Wright et al., 2008); (3) the broader social context of the university resources, i.e. entrepreneurial orientation/climate that support commercialization activity, namely technology transfer infrastructure, e.g. TTO and incubators (Lockett and Wright, 2005; O´Shea et al., 2005; Powers and McDougall, 2005); (4) the nature and type of technology, namely their pervasiveness, novelty and intellectual property protection (Conceição et al., 2012; Gilsing et al., 2010; Shane, 2001);and (5) the external characteristics, i.e. the regional infrastructures that impact on spin-off activity, such as venture capital availability, knowledge infrastructures and industry structure (Audretsch et al., 2005; Stam, 2010; Woodward et al., 2006).

In this paper we will address this issue from a regional perspective, investigating the determinants of the variation in RBSO creation across regions. Using an unique self-collected set of data, we analyze the impact of factors related to the characteristics of the existing universities in the region – as a source of knowledge spillovers and supplier of resources – as well as other regional characteristics, in the intensity of RBSO creation in a given region.

This issue is rarely addressed in the empirical literature. In most empirical studies carried out, research is conducted primarily in the perspective of the parent organization, i.e. the determinants of variation in spin-off creation across universities are analyzed as a measure of success of its marketing strategy of technological knowledge (e.g. Algieri et al., 2013; Avnimelech and Feldman, 2011; Di Gregorio and Shane, 2003; Landry et al., 2006; O´Shea et al., 2005).

But studies that analyze the determinants of variation in spin-off creation across regions are scarce (Buenstorf and Geissler, 2011; Egeln et al., 2004; Heblich and Slavtchev, 2013). Buenstorf and Geissler (2011) conclude that the geography of a high-technology industry - the laser industry - was shaped by the local availability of potential entrants and urbanization economies, in particular research spin-offs, rather than by localization economies. Egeln et al. (2004) conclude that regional demand is the most important determinant of spin-offs' location decision. In their study, they find that a significant fraction of public research spin-offs locate rather distant from their parent institution, in order to facilitate cooperation with clients or other partners. These authors assess the impact of regional factors in spin-offs' location decisions, but they do not include the characteristics of the universities installed in the region in their analysis. They only take in consideration the availability of qualified human capital (namely graduates). Heblich and Slavtchev (2013) investigate the importance of universities in the location of academic start-ups. They find that only the parent university influences academic entrepreneurs' decisions to stay in the region, while other universities in the same region play no role. However, they do not consider the impact of more generic regional characteristics in their analysis; they simply include regional dummies in their model.

This study goes beyond prior research by considering both the impact of the characteristics of the universities and the region in the location decision, and combining them in the analysis of the intensity of research spin-off creation across regions.

Moreover, this study uses a larger and more comprehensive dataset than previous ones, which corresponds to the population of Portuguese academic spin-offs created between 1979 and 2007.

In the following section we review the extant literature on determinants of spin-off creation and put forward a number of hypotheses to be tested. In Section 3 we describe the data collection and provide a brief characterization of the population of spin-off firms created in Portugal. In Section 4 we describe the methodology and the empirical model. The results are discussed in Section 5. Finally in Section 6 we conclude and consider some policy implications.

2. DETERMINANTS IN RBSO CREATION

RBSO, given their technological and academic basis, combine both the traditional problems associated with the start-up of a new business and the difficulties associated with the development and commercialization of new technologies (Oakey et al., 1996; Vohora et al, 2004). In the process of RBSO creation, access to key resources is crucial, namely technical knowledge, specialized human capital, financial resources, physical assets, e.g. laboratories, and organizational support (Knockaert et al., 2010; Lockett and Wright, 2005; Mustar et al., 2006; Wright et al., 2012). Thus the presence of these resources becomes decisive in the location of the new company. Egeln et al. (2004) describe the spin-off decision of where to locate in order to succeed in the actual creation of the company as an optimization problem.

The literature emphasizes that, in the specific case of RBSOs, the location depends on the assessment made of traditional regional mechanisms i.e. if the regions in which the new spin-offs operate provide these resources; but it also depends on the existence of university level support mechanisms. In fact the resources made available by universities can be complementary or even substitutes for resources at local level, in particular access to academic incubators, university venture funds and specialized human capital through their students and graduates (Fini et al., 2011).

Several studies mention that RBSOs tend to be clustered around the parent institution, as a firm strategy to access knowledge spillovers (Asterbo and Bazzazian, 2011; Egeln et al., 2004; Shane, 2004). Several authors suggest that being in the vicinity of a university provides important cost advantages. In particular, the spatial proximity to the university facilitates research collaboration and favors the flow of tacit knowledge. In addition, by keeping a formal relation with their parent university, spin-offs can minimize investment in fixed capital as they can make use of the infrastructures of the parent, as well as benefit from its reputation/credibility. On the other hand, by staying in the parent region, it will be easier for the spin-off founders to mobilize their social capital, which may be a crucial source for the successful start of a new firm (Audretsch and Stephan, 1996; Druilhe and Garnsey, 2003; Fontes, 2005; Heblich and Slavtchev, 2013; Lejpras and Stephan, 2011; Zucker et al., 1998).

In fact, it has been observed that the number and characteristics of the universities in the region leads to an increase in the number of spin-offs created, highlighting the role of universities as anchors of regional development (Audretsch and Feldman, 1996; 2004; Casper, 2013).

Regarding the characteristics of universities, several empirical studies demonstrate the positive impact of University's reputation and prestige on the number of spin-offs created (Avnimelech and Feldman, 2011; Link and Scott, 2005; O´Shea et al., 2005; Powers and McDougall, 2005; Wright et al., 2008). Di Gregorio and Shane (2003) using a sample of the start-up activity of 101 U.S. universities demonstrate a positive relation between spin-off creation and intellectual eminence/faculty quality. According to van Looy et al. (2011) the academics from top universities may have easier access to resources for spin-off creation due to reputation effects. Colombo et al. (2010) also consider that the characteristics of the local universities, such as the size of the university research staff and the quality of university research, influence RBSO's growth potential. The results show that the university's reputation and prestige as well as the university's policies toward technology transfer, in particular policies for making equity investments and maintaining a low investor´s share of royalties, increase the creation of new firms.

Considering the disciplinary area of research, O´Shea et al. (2005) conclude that a strong science and engineering funding base with an orientation in life science, chemistry and computer science disciplines have a positive impact on the number of spinoff companies generated by a university. According to Audrestch et al. (2004) location is more important in the natural sciences, reflecting the specialized nature of scientific knowledge.

Finally, the broader social context of the university resources includes both institutional norms that maximize an entrepreneurial culture in the academic context[2], and mechanisms and infrastructures that support the technology transfer and commercialization activity. The literature emphasizes that the university policies toward technology transfer are decisive to increase the creation new firms (Di Gregorio and Shane, 2003; Friedman and Silberman, 2003; Lockett and Wright, 2005; Lockett et al., 2003; O´Shea et al., 2005). These policies include equity investments, the royalty regime of the university, funding, expenditure on intellectual property protection, specialized competences to support technology transfer and entrepreneurship and infrastructures such as incubators and science parks.

In fact the existence of a technology transfer office (TTOs) and the quality of its staff are considered crucial in the process of creating a RBSO[3]. Several studies highlight that the number of spin-offs created is positively influenced by the experience/age of the TTOs, their previous success in technology transfer, their financial resources and full-time specialized employees (Algieri et al., 2013; Belenzon and Schankerman, 2009; O´Shea et al., 2005; Powers and McDougall, 2005).

The universities' support to technology transfer is also reflected in the existence of infrastructures such as university-affiliated incubator and university research parks; these commercial resources are considered essential in the process of RBSO creation (O´Shea et al., 2005).

The business development capabilities of the TTOs and incubators make it possible to support spin-offs in the early stages, both in terms of opportunity recognition and in defining the

[2] In Portugal, the policies to support technology transfer, in particular stakeholder policies, % for investors, intellectual property rights (IPR) are similar for all universities. These will not be taken into account in our analysis because we only consider factors that may affect difference in RBSO creation across regions.

[3] All universities in Portugal have a TTO; thus the impact of the existence of the TTO in the creation of RBSO will be measured by the existence of the university itself.

suitable business model, thus minimizing the frequent lack of business competences of academic entrepreneurs and enhancing the success of the spin-off (Clarysse and Moray, 2004; Heirman and Clarysse, 2004; Lockett and Wright, 2005; Mustar et al., 2006; Vohora et al., 2004).

The literature concludes that the creation of spin-offs often takes place in the context of an incubator, and that they are often inserted into a university-affiliated incubator during the initial development stages. This incubation supports spin-offs development, not only in terms of strategic management and business orientation and of access to knowledge that is essential for completing the development of 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; Mian, 1996; Wright et al., 2007). According to Salvador (2011), who analyzed the relationship between RBSOs and science parks/incubators, the main advantages perceived by the firms interviewed, concern the access to managerial competence; the availability of a variety of services, as well as a lower rent. In addition, several firms also pointed-out the increased visibility as an advantage. In this regard, the author stresses the importance of location in the science park or incubator as a mechanism of reputation, similar to the one offered by the parent research organization.

In the specific case of science parks, Link and Scott (2005) consider that the creation of RBSO included in science parks is positively influenced by the research park characteristics, such as the age of the park, the geographical proximity of the park to the university; and by the sector/area in which the park specializes (in cases where it is the same as the company, e.g. biotechnology focus).

In view of this evidence, we argue that the universities' characteristics matter to the intensity of RBSO creation in a given region and we advance the following hypotheses:

H1a: RBSOs are more likely to be created if located in a municipality with a high number of universities;

H1b: RBSOs are more likely to be created if located in a municipality with quality/prestige universities;

H1c: RBSOs are more likely to be created if located in a municipality with universities that have a strong science and engineering funding base;

H1d: RBSOs are more likely to be created if located in a municipality with research parks and/or incubators;

Although the assessment of opportunities of access to spillovers and other advantages derived from locating in the vicinity of universities is a key element in decision-making about location, the RBSOs created must still assess the regional characteristics, i.e. the resources available in a given region.

The joint consideration of the conditions found in the university and at regional level may lead to the RBSO deciding to locate in a region distinct from its parent. This happens when the spin-off feels the need to engage in technological cooperation with other knowledge sources, besides the parent organization; and when it needs to access resources that are scarce in that region, such as highly qualified labor or supplier networks (Egeln et al. 2004). On the other hand, the spin-off may decide to stay in the region of its parent organization for reasons not related to the parent, as for example the fact that entrepreneurs reside in that region and have built social networks that allow access to resources needed for creating the company (Casper, 2013; Fontes, 2005; Stam, 2010).

In this sense, several studies show that different factors associated to regional characteristics are also considered crucial for the location of the new knowledge and high-technology firms (Audretsch and Feldman, 2004; Audretsch et al., 2005; Baptista and Mendonça, 2010; Buenstorf and Geissler, 2011; Woodward et al., 2006). Thus, regional characteristics assume a leading role in the location of RBSOs at the time of their creation.

One of the relevant regional factors in location decision of knowledge-based and high-technology firms are the agglomeration or external economies, i.e. positive externalities resulting from co-location. Several studies refer that an high density of high-technology firms attracts companies to that research intensive region, allowing them access knowledge spillovers[4] (Armington and Acs, 2002; Audretsch et al., 2005; Friedman and Silberman, 2003; Lach and Schankerman, 2008).

On the other hand, several studies highlight the importance of the availability of venture capital financing and of qualified human capital in the region. Access to financial assets is crucial to the creation of spin-offs, particularly the availability of venture capital, due to its greater propensity to finance hog-risk start-ups[5] (Di Gregorio and Shane, 2003; Landry et al., 2006; Powers and

[4] The literature presents several case studies regarding the dynamics of the technical and industrial clusters, in particular the cooperation among local firms involving several small and medium-sized enterprises (SMESs) and larger technology companies. See for example: Feldman (2003), Harrison et al. (2004) and Saxexian (1994).
[5] In Portugal public funding policies are not regional, but mostly at defined at national level. Similarly, the venture capital companies that invest in RBSO operate nationwide. Therefore, the access to financial

McDougall, 2005). With regard to human capital, the literature shows that regions that have a high level of employees with higher educational levels are related to higher levels of start-up activity (Armington and Acs, 2002; Figueiredo et al., 2002). In the specific case of knowledge-based firms, access to specialized and qualified labor is indeed an essential resource, so its existence directly influences location decisions (Audretsch et al., 2005; Evila et al., 2011¸ Kim et al., 2012; Woodward et al., 2006).

Another feature of the region considered relevant in the choice of location for these companies is the regional demand size. In fact, the larger the market the bigger its "power" to attract start-ups (Baptista and Mendonça, 2010). This suggests that urban areas can be particularly favorable locations, given the high population density and thus the relative ease of access to customers (consumer demand) (Buenstorf and Geissler, 2011; Stam, 2010). Urban areas are also more likely to offer the inputs required for the firm's operation: capital, labor, suppliers.

The literature confirms this idea. According to Figueiredo et al. (2002) the regional concentration of companies is also explained by the need of start-ups to be located in metropolitan areas and urban centers that are characterized by extensive resources, concentration of higher education institutions, technological research facilities and a wide range of market opportunities. Subsequent studies confirm that this proximity to urban centers is a crucial factor for the science-based firms (Baptista and Mendonça, 2010; van Geenhuizen, 2008; Woodward et al., 2006).

Therefore, considering that regional characteristics do matter with regard to the intensity of RBSO creation in a given region, we advance the following hypotheses:

H2a: RBSOs are more likely to be created if located in a municipality with a high level of agglomeration externalities;

H2b: RBSOs are more likely to be created if located in a municipality with a high level of human capital available;

H2c: RBSOs are more likely to be created if located in a municipality with a high level of demand size;

H2d: RBSOs are more likely to be created if located in a municipality near the major urban areas.

resources do not determine the location at regional level, and so are not considered in our analysis - we only consider factors that may affect differences in RBSO creation across regions.

3. CREATION OF RBSOS IN PORTUGAL

This study uses the population of Portuguese RBSOs created between 1979 and 2007. In order to identify this population we started by collecting publicly available information on the spin-outs from universities and other public research organisations. In the case of organisations that did not have that information available, or where only the more recent spin-offs were listed, we contacted the university and/or its TTOs or incubators, asking for the required data. This was a lengthy process, but it proved to be important, because it enabled us to identify all the spin-off firms created (to the best of our knowledge) and to check the data available on them.

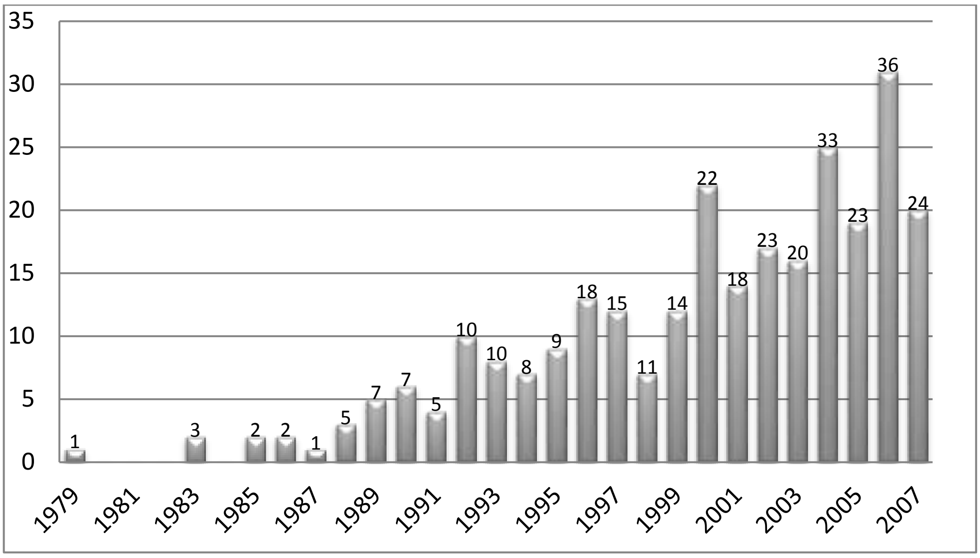
The next step was to confirm whether all the spin-offs identified had been through the process of legal constitution and when this had exactly taken place. This was because spin-off firms tend to make their legal registration only when they actually have prospects of business or commercialization of the technology (EC, 2003). For this purpose we resorted to the Institute of Registration and Notary Affairs (IRN – Ministry of Justice) database.

As a result of this search we ended-up identifying a total of 327 spin-off research firms legally set up until the end of 2007. For all these firms, we collected information on the year of creation, location, sector of activity, number of employees at founding date and parent organization.

This gathering of information was carried out by phases. We began by accessing the data published by the firms themselves in their annual reports and websites (official pages). For more specific information we asked the firms by e-mail and later, when necessary, we contacted them by phone.

The first Portuguese RBSO was created in 1979 (to the best of our knowledge), but the formation of spin-off firms in universities and other research organizations only became more frequent from the mid 1980's onwards (Figure 1). A closer analysis of the evolution of Portuguese RBSO creation over time shows that their numbers started to increase in the 1990s and continued to grow into the 2000s. Indeed, 39.45% of the firms were created between 1990 and 2000, and 54.13% after 2000.

Figure 1- Number of Portuguese RBSOs by founding date (1979-2007) (n=327)



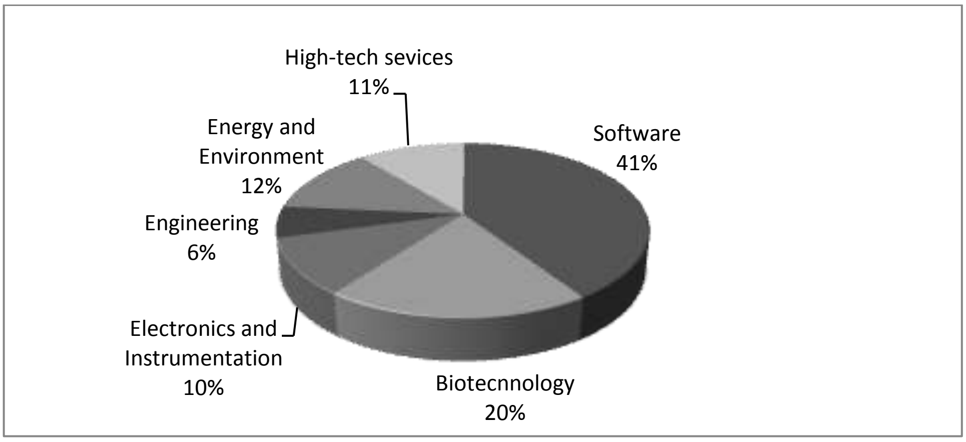
Source: Own calculations.

This evolution follows the European trend and reflects the adoption, by several European countries (including Portugal), of regulatory frameworks to promote the entrepreneurial mission of universities (Claryssse et al., 2011; Mustar et al., 2008; Wright et al., 2007). However, policies of support for technology transfer and innovation may be heterogeneous across European countries. For instance, Mustar and Wright (2010) compared policies to support RBSO creation in France and the UK and concluded that these are different. In UK, policy is defined at university level, leading to the creation of diverse structures. Spin-offs are a part of a policy to commercialize technology and knowledge created by universities. In France, in contrast, the emphasis is on the development of high technology new ventures as part of a country level technological entrepreneurship policy.

In Portugal, there are four types of public measures which are relevant to foster university spin-off creation, although most of them are not specifically oriented to spin-offs: incentives to university knowledge transfer; promotion of new technology-based firms; promotion of venture capital investments; and simplification of procedures for firms' legal constitution. The first relevant public interventions in this domain began in the 1980s, but it was especially after 2000, along with a growing focus on the economic usefulness of activities conducted by public research organizations and an increasing emphasis on the valorization of results from publicly funded R&D, that specific measures to support academic entrepreneurship became more widespread. In fact, although there is a variety of generic programs supporting the creation of entrepreneurial/innovative firms (to which academic entrepreneurs can also resort), a number of funding organizations have more recently started to promote entrepreneurial programs and business idea competitions that specifically target the commercialization of research originating from the university. Institutional initiatives from higher education institutions in this area have also been increasing, particularly through their association to science parks and incubators and the promotion of entrepreneurship competitions and/or training programs. Frequently, these institutional initiatives are supported by private institutions, such as banks, trade associations or firms (Fontes et al., 2009; Matias and Fontes, 2013).

Regarding the sectorial distribution of the RBSOs identified, the software and multimedia services sector represent 40.67% of the population with 133 RBSOs, followed by the biotechnology and biochemistry with 64 firms (19.57%). The smaller proportion corresponds to engineering and materials with 19 firms (5.81%) (Figure 2)

Figure 2 – Number of Portuguese RBSO by sector



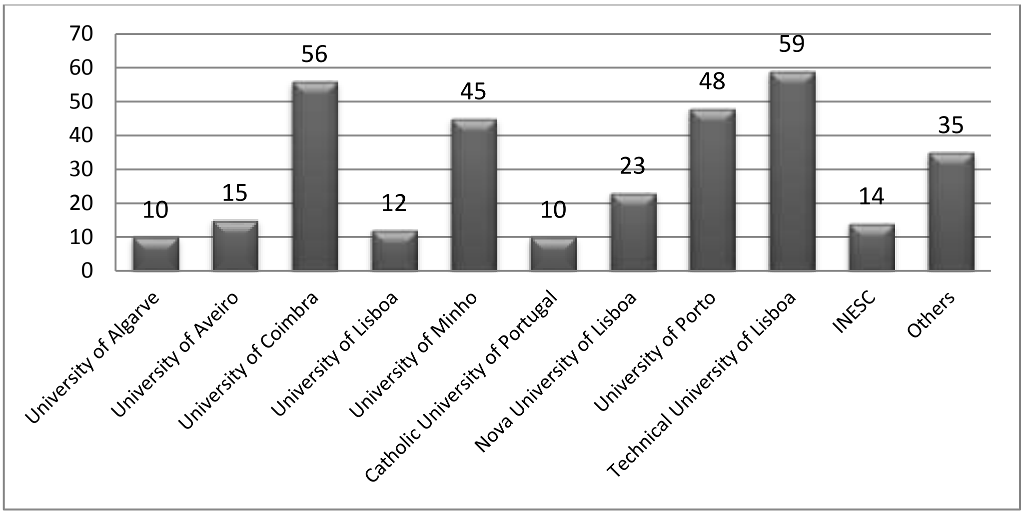
Source: Own calculations.

The vast majority of the RBSOs (78.9%) originate from the seven largest and most prestigious Portuguese public universities6, or from research organizations associated to them. The remaining RBSOs originate from other public universities and public research laboratories, although there are also some private universities and a couple of polytechnic institutions among the parent organizations (Figure 3). This is in line with the literature; in fact the spin-offs tend to originate from a small number of eminent universities. The large, world-class scientific universities and prestige public research organizations, which are focused on a specific sector

[6] These seven universities represent the only Portuguese universities included in the Top 500 academic rating score of universities published in the *Webometrics Ranking of World Universities.*

tend to generate more RBSOs than the "small" universities without a strong research specialty (Di Gregorio and Shane, 2003; Mustar el al., 2008; Rasmussen and Borch, 2010).

Figure 3 – Number of Portuguese RBSO by parent organization



Source: Own calculations.

3.1 Location standards of the RBSOs created

Concerning the location, Portuguese RBSO firms tend to be located in the main cities or in their metropolitan areas. The Portuguese mainland is divided into eighteen districts[7] and 308 municipalities; in fact we only recorded RBSO creation in just 53 municipalities. It should be noted that over the period observed only 27 spin-offs (8.26%) changed their starting location.

As can be seen in Figure 4, the RBSOs created are mostly concentrated in the largest cities of the coast and spin-off creation in municipalities of the interior of the country is residual. In fact, all of the spin-offs created, 52%, are located in municipalities belonging to the districts of Lisbon and Porto (30.28% and 21.71%, respectively) followed by the districts of Coimbra (15.29%), Braga (11.62%) and Aveiro (5.81%) (see also Table 1).

In Portugal, 79% of RBSOs, i.e. 258 firms, are located less than 25 km from parent, which is in line with the cluster pattern of the spin-offs. In 2000, AUTM reported that 80% percent of firms formed from university licenses operated in the state where the university was located. This number dropped to a total of 72 % in 2007 (AUTM, 2001, 2008). Shane (2004) analyzing a sample of 72 MIT spin-offs between 1980 and 1996, revealed that 50% are located within 20

[7] *District* is a higher administrative region, which is composed by several adjacent municipalities (*concelhos).*

km of MIT and over 70% are located less than 100 km from MIT. Asterbo and Bazzazian (2011) discovered that a dominant fraction of spin-offs are located very close to their parent, within 50 km.

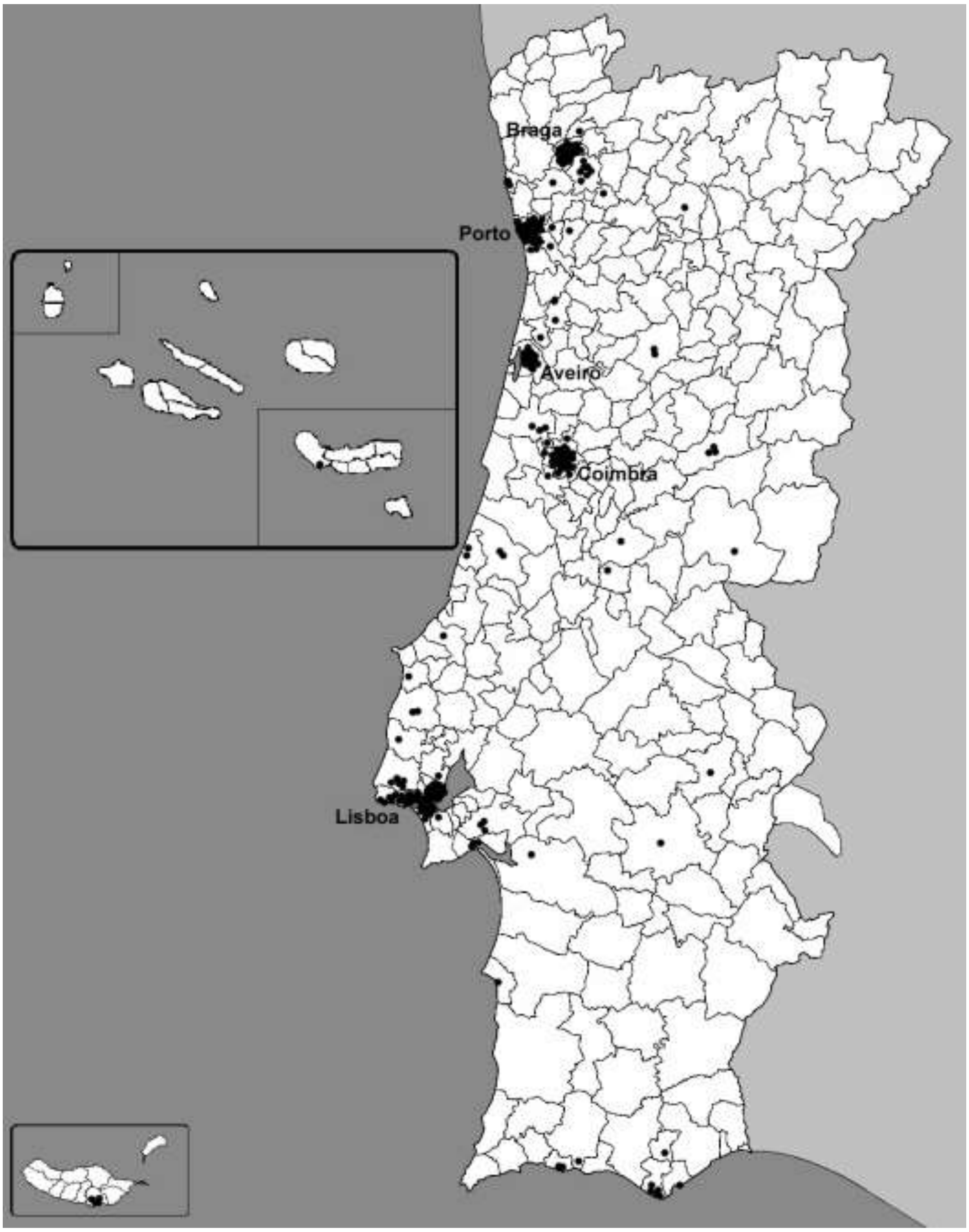
Of these 100 companies, 38.76% were actually located in the parent's premises on the date of creation (0 km distance). And 77% of Portuguese spin-offs (i.e. 253 firms) were effectively integrated in a university-affiliated incubator on the date of creation.

Table 1 – Distribution of Portuguese RBSO

Districts	*RBSO Number*	*RBSO Percentage*
Aveiro	19	05.81
Braga	38	11.62
Coimbra	50	15.29
Lisboa	99	30.28
Porto	71	21.71
Others[1]	50	15.29
Total	327	100

[1]*Others* relate to 8 Districts with less than 10 spin-offs firms. Source: Own calculations.

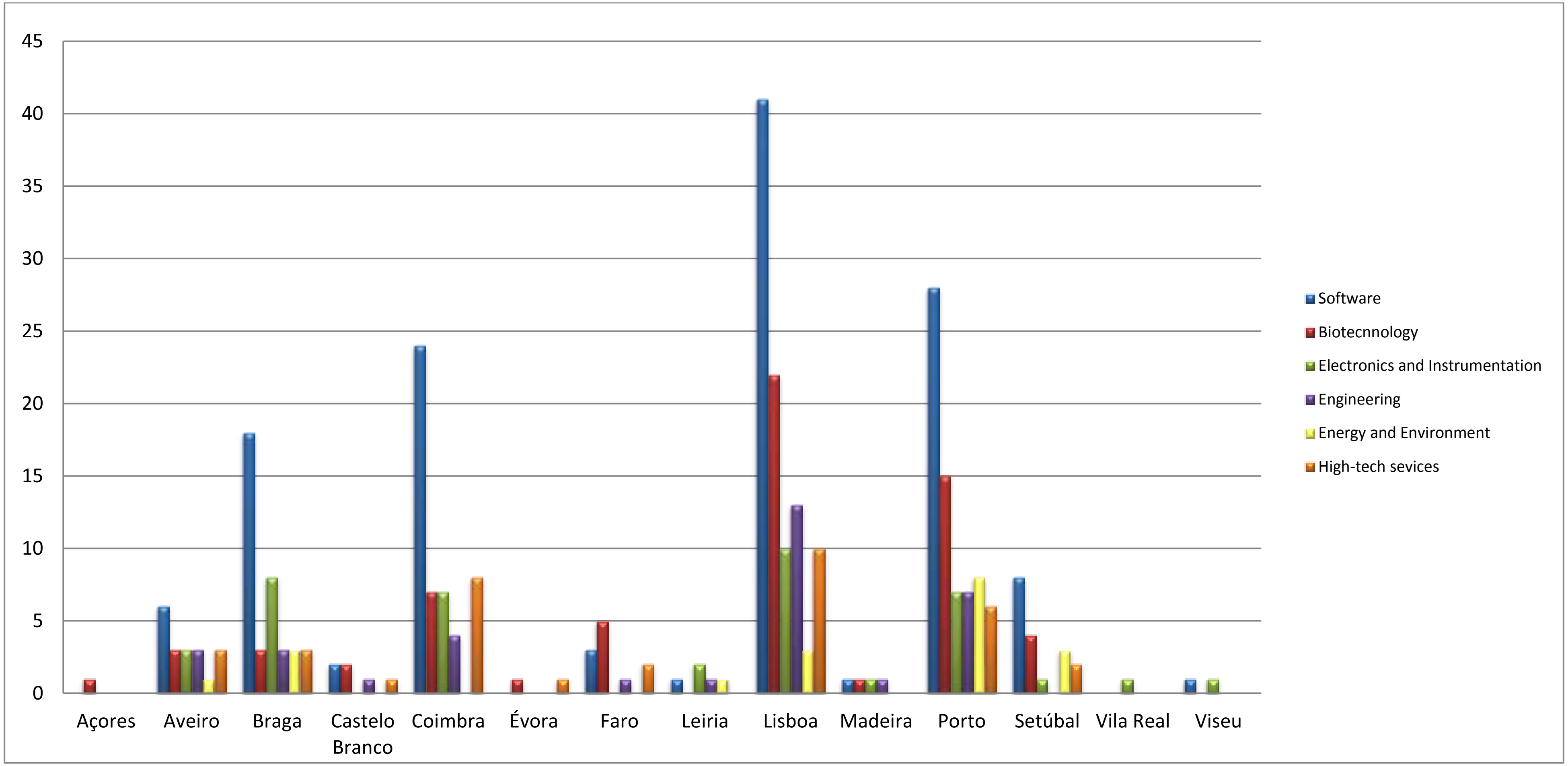
Figure 4 – Spatial distribution of Portuguese RBSO per municipalities (1979 – 2007)



Note: Each dot = 1 spin-off firm. Source: Own calculations.

Considering the districts with the largest number of spin-offs, the sectorial distribution is quite similar (Figure 5). In the districts of Lisbon and Porto most companies focus on two sectors: software and multimedia activities (41% and 39%, respectively) and biotechnology and biochemistry (22% and 21%, respectively). With respect to the remaining sectors, they are distributed evenly in district of Porto (about 10% each). In the case of the district of Lisbon the sector of energy and environment have a residual value (representing 0.3%).

Figure 5 - Portuguese RBSO distributionby sector and district



The "leadership" trend of the software and multimedia sector remains in the districts of Coimbra, Braga and Aveiro (48%, 47% and 32% respectively). In the district of Braga second place goes to the electronics and instrumentation sector with 21% while in the districts of Coimbra and Aveiro the remaining sectors have very similar weights (about 15%), with the exception of the energy and environment sector, also with a residual value (0% and 0.5% respectively). Among the districts with the lowest number of companies, the weight of the biotechnology and biochemistry sector in the district of Faro (45%) stands out.

4. EMPIRICAL ANALYSIS

4.1. Data and empiricalmodel

Data

The analysis focuses on the 327 Portuguese research-based spin-offs legally set up until the end of 2007, identified through the various stages of data collection described in section 3.

Each RBSO created was assigned to the respective Portuguese municipality (*concelho*). The information concerning the characteristics of the universities, and the characteristics of the region was also collected at the level of municipalities - our regional unit of analysis.

As mentioned in section 3 (Figure 4) the creation of RBSOs in Portugal is concentrated in just 53 municipalities. In fact, we noted 255 municipalities where RBSO creation never occurred, over these 13 years. Since the object of this paper is to analyze the determinants of the intensity of creating RBSOs in a given location and considering the specifics of this event, we will restrict our analysis to the municipalities where the event under analysis actually took place.

Data regarding the municipalities was collected from the "*Quadros de Pessoal*" database, which results from information gathered yearly by the Portuguese Ministry of Social Security and Labor, for the period 1986 to 2009, on the basis of mandatory information submitted by firms. Additional data related to population density and the distances between municipalities were collected at the National Institute of Statistics (INE). Regarding the public and private research organizations the data was collected from the Ministry of Science and Higher Education (MCTES) and from the *Webometrics Ranking of World Universities.*

For our analysis we will only consider the RBSO created in mainland Portugal between 1995 and 2009, in a total of 261 firms. This is due to data constraints regarding the universities, which is only available from 1994 onwards. It should be noted that the evolution of spin-off research firms in Portugal occurred predominantly in the mid-nineties, as in the remaining Europe (EC, 2003). This sample keeps the pattern of cluster location identified in the population; in fact 78.54% of the spin-offs created between 1995 and 2009 are located less than 25 km from the parent.

Empirical model

Our aim is to investigate the intensity of spin-offs that are created across regions, by focusing on the characteristics of the university and the region in which in the spin-off is located. Thus, our reduced form model is:

$$RBSO_{it} = f(U_{it}, R_{it}) \qquad (1)$$

where, $RBSO_{jt}$ denotes the entry of spin-off firms in region $i$at time period t, $U_{it}$is a vector of university characteristics, and R_{it}, is a vector of region-specific characteristics that vary across region and time.

The dependent variable used is a count of the number of RBSO created in each year in each region (municipality). The preponderance of zeros, the small values and the discrete nature of the dependent variable (Table 2) suggest that we could improve the linear model with a specification that accounts for these characteristics (Cameron and Trivedi, 1998; Faria et al., 2003).

Table 2 - RBSO Creation: frequency distributions.

Count	0	1	2	3	4	5	6	7	Mean	Variance
Frequency	444	83	28	15	5	4	5	1	0.446	1.066
Relative frequency	0.759	0.142	0.048	0.026	0.009	0.007	0.009	0.002		

Notes: N = 261firms; 585 municipality-year spells, i.e., 45 municipalities*13 years

In order to test our hypotheses we use as predictors variables the measures for universities' characteristics and regional characteristics at municipality level. The respective descriptive statistics are presented in Table 3.

Regarding the universities' characteristics we included in our regression the variables *Universities Number*, *Top Universities*, *Tech Universities* and *Incubators.*

Concerning the existence of universities and their intensity in the region, we included the variable *Universities Number*; which is the number of private and public universities and polytechnics per municipality (Baptista and Mendonça (2010). For *Top Universities* we examined the overall academic rating score of universities published in the *Webometrics Ranking of World Universities* and built a dummy variable that equals 1if there is at least one university among the Top 500 located in the municipality, and zero otherwise. In Portugal these are Nova University of Lisbon, Technical University of Lisbon, University of Aveiro, University of Coimbra, University of Lisbon, University of Minho and University of Porto.

Concerning the disciplinary research area of the universities, we include in *Tech Universities* a dummy variable that equals 1 if there are, in the municipality, universities with technological focus, and zero otherwise.

Regarding the commercial orientation of universities we include in *Incubators* a dummy variable that equals 1 if there are, in the municipality, infrastructures to support technology transfer and entrepreneurship such as incubators and/or science parks, and zero otherwise. The identification and location of science parks was made according to *TecParques- Portuguese Association of Science and Technology Parks*.

Concerning the characteristics of the region, to measure the agglomeration economies we included the variable *High-tech*, which controls the potential for spillovers and is measured by the ratio of the number of firms in high-technology industries by the total number of firms per municipality (Baptista and Mendonça 2010). Following Eurostat, high-technology industries included high-tech and medium-high manufacturing firms and, also, knowledge intensive services (KIS).

Regarding the availability of *Human capital*, we took into account the level of qualified human capital available in the region, measured by the ratio of the number of employees with high school education, or higher, to the total number of employees in the municipality.

We also included a measure for *Demand Size*; following Baptista and Mendonça (2010), we used as a proxy of regional demand size the logarithm of total population per square meter. [8]

Finally in order to measure the urban accessibility, we included two variables (Figueiredo et al., 2002, Baptista and Mendonça, 2010). For measuring the *major urban accessibility*, i.e, access to largest markets, we considered the distances in kilometers (km) to the two major urban areas of Portugal (Lisbon and Porto). Regarding *minor urban accessibility*, i.e., access to regional markets, we measured the distance in km from each municipality to the corresponding district's administrative center.

As additional controls we included the covariate *Years* dummies to account for annual variations in spin-off activity. We also included *Regional* dummies in order to control regional differences, namely dummies for the Districts (Lisbon, Porto and others) and additional dummies for the NUT 2 regions (North, Centre, Lisbon, Alentejo, Algarve) (Baptista and Mendonça, 2010).

Table 3 - Descriptive statistics of predictor variables.

Variable	%	Min	Max	Mean	S.D.
Universities Number		0	38	2.28	5.63
Top Universities	13.33				0.34
Universities Tech	53.33				0.50
Incubators	31.11				0.46
High-tech (ln)		-6.93	-1.85	-4.51	2.22
Human capital (ln)		-5.04	-1.39	-2.84	0.60
Population density (ln)		2.20	8.91	5.90	1.50
Distance to administrative center		0	127	26.67	27.66
Distance to Porto		0	564	215.28	175.50
Distance to Lisboa		0	399	214.58	118.64

Notes: All variables are defined at municipality level unless otherwise stated.

[8] Woodward et al. (2006) use the regional population density as a proxy for Land Costs.

In Table 4we present the correlation matrix. Correlation analysis indicates medium to low levels of correlations. The highest correlation was between the *Universities Number* and *Top Universities* (0.62), suggesting that multi-collinearity was absent.

Table 4 - Correlations for the dependent variable and predictor variables.

	1	2	3	4	5	6	7	8	9	10
RBSOs creation										
Universities Number	0.56***									
Top Universities	0.54***	0.62***								
Universities Tech	0.28***	.035***	0.37***							
Incubators	0.43***	0.38***	0.58***	0.53***						
High-tech	0.05	0.04	0.07*	0.18***	0.07*					
Human capital	0.41***	0.41***	0.36***	0.25***	0.35***	0.29***				
Population density	0.35***	0.47***	0.38***	0.35***	0.22***	0.38***	0.39***			
Distance to administrative center	-0.25***	-0.27***	-0.28***	-0.37***	-0.33***	-0.30***	-0.33***	-0.39***		
Distance to Porto	-0.09**	-0.03	-0.15***	-0.23***	-0.08**	-0.20***	0.08**	-0.36***	0.21***	
Distance to Lisboa	-0.09**	-0.22***	-0.07	0.04	0.07*	0.03	-0.27***	0.02	-0.23***	-0.49***

Note: **, * means significant at 1% and 5% level, respectively.

4.2. Method

Given the discrete nature of our data, i.e., the number of spin-off firms created in a given region, we employed count data regression analysis.

The starting point for count data regression is the Poisson model (Hausman et al., 1984), where the univariate Poisson distribution for the number of occurrences of the event y over a fixed exposure period has the probability function

$$\Pr(Y = y) = \frac{e^{-\mu}\mu^{y})}{y\,!}, \qquad y = 0, 1, 2, \ldots. \tag{2}$$

where μ is the shape parameter which indicates the average number of events in the given time interval. The Poisson distribution assumes that the mean and the variance of the process are equal

$$E(Y) = Var\ (Y) = \mu \qquad (3)$$

This equidispersion assumption is violated when *overdispersion* (*underdispersion*) of the data is observed, i.e, the variance exceeds (is less than) the mean. Among the reasons that may lead to the violation of this assumption are the unobserved heterogeneity and a high frequency of zeros in the data (Cameron and Trivedi, 1998).

The negative binomial model (NB) provides a solution for the unobserved heterogeneity by incorporating an unobserved specific effect α. The NB probability distribution of Y is

$$\Pr(Y = y \backslash \mu, \alpha) = \frac{\Gamma(\alpha^{-1} + y)}{\Gamma(\alpha^{-1})\ \Gamma(y+1)}\ \left(\frac{\alpha^{-1}}{\alpha^{-1} + \mu}\right)^{\alpha^{-1}}\ \left(\frac{\mu}{\mu + \alpha^{-1}}\right)^{y} \ldots. \qquad (4)$$

where Γ is the gamma function. The mean of the negative binomial distribution (like the Poisson) is μ but the variance is μ (1 + αμ), where α is called the dispersion parameter. The NB model is more general than the Poisson model because it accommodates over dispersion and it reduces to the Poisson model as α →0.

Considering longitudinal count data regression models, Cameron and Trivedi (1998) define that are standard count models, with the addition of an individual specific term reflecting individual heterogeneity.

For count models for longitudinal data or panel data the Poisson regression model with exponential mean function and multiplicative individual specific term α_i

$$y_{it} \sim \mathrm{P}\ (\mu_{it} = \alpha_i \lambda_{it}) \qquad (5)$$

$$\lambda_{it} = \exp(x'_{it}\ \beta) \qquad i = 1, \ldots \ldots . n, \qquad t = 1, \ldots \ldots \ldots ., T.$$

In the random effects model for count data the Poisson random effects model is given by (5), that is, y_{it} conditional on α_i and λ_{it} is idd Poisson ($\mu_{it} = \alpha_i \lambda_{it}$) and λ_{it} is a function of x_{it} and parameters β. Different distributions for α_i lead to different distributions for $y_{i1}, \ldots \ldots y_{iT}$.

Hausman et al. (1984) proposed a conjugate-distributed random effects where the gamma density is conjugate to the Poisson and additionally considered the negative binomial case. The joint density for the i^{th} individual in Poisson random-effects model (with gamma –distributed random effects) is given by

$$\Pr(y_{i1},\dots\dots y_{iT}) = \left[\prod_t \frac{\lambda_{it}{}^{y_{it}}}{y_{it}\,!}\right] \frac{\delta}{\sum_t \lambda_{it} + \delta} \left(\sum_t \lambda_{it} + \delta\right)^{-\sum_t y_{it}} \frac{\Gamma\left(\sum_t y_{it} + \delta\right)}{\Gamma(\delta)} \quad (6)$$

where α_i is idd gamma (δ, δ) so that E [α_i] = 1 and V[α_i] = 1/ δ

Regarding the negative binomial random effects model the joint density for the i^{th} individual is given by

$$\Pr(y_{i1},\dots\dots y_{iT}) = \left[\prod_t \frac{\Gamma(\lambda_{it} + y_{it})\,!}{\Gamma(\lambda_{it})\,!\;\Gamma(y_{it} + 1)}\right] \frac{\Gamma(a+b)\Gamma\left(a + \sum_t \lambda_{it}\right)\Gamma\left(b + \sum_t y_{it}\right)}{\Gamma(a)\,\Gamma(b)\Gamma\left(a + b + \sum_t \lambda_{it} + \sum_t y_{it}\right)} \quad (7)$$

5. RESULTS

In order to investigate the determinants of the intensity of RBSOs creation across regions we employed a count data regression analysis for a span year of 13 periods compiled for this study.

Assuming unobserved heterogeneity is randomly distributed across municipalities we rely on a random effect model (Baptista and Mendonça, 2010; Hausman et al., 1984). In fact, the high variability in the number of spin-offs creation across municipalities excludes a fixed effects model. Regarding regional differences we decided to add to the initial model (Model 1) regional dummies corresponding to Model 2.

Concerning count models for longitudinal data we first run Poisson regression models and then compare them with negative binomial models. In fact, in our data the sample variance is higher than the sample mean (see Table 2.2), i.e., the *equidispersion* Poisson distribution assumption is rejected because of *overdispersion* of dependent variable.

The likelihood-ratio test on the hypothesis that the *overdispersion* parameter alpha is equal to 0 presents a p-value of 0.000 in Model 1 and a p-value of 0.077 in Model 2 and thus we find alpha is significantly different from zero and thus reinforces that the Poisson distribution is not appropriate to our sample (Cameron and Trivedi, 1998).

Given the presence of considerable *overdispersion* in our data, the negative binomial model should be considered (Table 5).

Table 5 - Poisson and negative binomial estimates of the intensity of RBSOs in Portuguese regions

	(1)		**(2)**	
Covariates	**Poisson**	**Negative Binomial**	**Poisson**	**Negative Binomial**
Universities Number	-0.001	-0.001	-0.009	-0.009
	(0.017)	(0.017)	(0.015)	(0.015)
Top Universities	0.571*	0.577*	0.614*	0.616*
	(0.306)	(0.307)	(0.318)	(0.320)
Universities Tech	0.067	0.085	0.136	0.148
	(0.282)	(0.287)	(0.261)	(0.265)
Incubators	0.908***	0.873***	1.010***	1.000***
	(0.287)	(0.298)	(0.268)	(0.274)
High-tech	-0.068	-0.066	-0.070	-0.069
	(0.079)	(0.080)	(0.071)	(0.072)
Human capital	1.100***	1.110***	1.177***	1.169***
	(0.355)	(0.362)	(0.422)	(0.428)
Population density	0.164*	0.162*	-0.030	-0.033
	(0.097)	(0.098)	(0.167)	(0.168)
Distance to administrative center	-0.001	-0.003	-0.006	-0.007
	(0.006)	(0.006)	(0.006)	(0.007)
Distance to Porto	-0.001	-0.001	-0.000	-0.000
	(0.001)	(0.001)	(0.003)	(0.003)
Distance to Lisboa	-0.000	-0.000	-0.004	-0.004
	(0.001)	(0.001)	(0.003)	(0.003)
Dummy for Years	YES	YES	YES	YES
Dummy for Distrito	_____	_____	YES	YES
Dummy for Nut2	_____	_____	YES	YES
Constant	0.118	3.022	0.298	3.259
	(1.505)	(2.056)	(2.598)	(3.057)

Notes: Number of observations: 585. Standard errors are shown in parentheses. ***, **, * means significant at 1%, 5%, 10% level, respectively.

Considering Model 1 and regarding the characteristics of the universities, our results reveal that the total number of public and private universities in a municipality (*Universities Number*) has no impact in the intensity of spin-off creation, hence Hypothesis *1a* is not supported. In fact it seems that it is not the quantity of universities but their quality and reputation that positively influence the spin-off creation activity in a given region, The existence of universities of recognized quality and prestige (*Top Universities*) has a positive impact on spin-off creation, therefore providing support to Hypothesis *1b*. This result is in line with previous evidence (e.g. Avnimelech and Feldman, 2011; Di Gregorio and Shane, 2003; O´Shea et al., 2005; van Looy et al., 2011).

On the other hand, the existence in the municipality of universities with technological focus does not seem to be relevant in determining the intensity of the spin-off creation, as the coefficient of the dummy variable *Universities Tech* is not statistically relevant. Hence Hypothesis *1c* is not supported by the data.

The presence of university-affiliated incubators and/or university research parks (*Incubators*) in the municipality does seem to be key in explaining the intensity of spin-off creation in that location. Results show that the existence of university incubators and/or university research parks in the municipality increases the spin-off activity, therefore providing support to our Hypothesis *1d*. This result is consistent with previous evidence that has found a positive role of university infrastructures that support technology transfer and commercialization activity of spin-off creation (e.g. Colombo and Delmastro, 2002; Link and Scott, 2005; Salvador, 2011; Wright et al., 2007).

Interestingly, with regard to regional characteristics, we do not observe a significant relationship between agglomeration economies and intensity of spin-off creation, hence Hypothesis *2a* is not supported. Indeed, results show that the density of firms in high-technology industries (*High-tech*) have no significant impact on the variation on spin-offs creation. This result is in line with the results of Buenstorf and Geissler (2011) in a similar study – the authors found no evidence that regions with existing industry agglomerations experienced higher rates of academic entrepreneurship.

Our results show that the availability of qualified human capital in the municipality (*Human capital*) increases significantly the intensity of spin-offs creation, therefore providing support to our Hypothesis *2b*. Additionally, results also provide support for the positive influence of regional demand (*Population density*) on spin-off activity (Egeln et al., 2004). Spin-offs are more likely to be created in municipalities with higher population density and thus relatively easier access to customers (Buenstorf and Geissler, 2011; Stam, 2010). Thus, Hypothesis *2c* is supported.

Finally, urban accessibility does not seem to have an impact on the intensity of spin-off creation. Thus Hypothesis *2d* is not supported. This result seems to indicate that for spin-off firms the transportation cost does not matter for location decision. However, this result should be analyzed with special care, because the vast majority of our sample is actually located in the large Portuguese urban centers (52% in Lisbon and Porto). Baptista and Mendonça (2010) when analyzing the location of Portuguese knowledge-based start-ups also found some "puzzling" results concerning this variable.

In order to control for other regional differences in the response behavior, we decided to include regional dummies (Model 2). When we take into account these regional dummies, the estimates are similar with the exception, not surprisingly, of the variable *Population density* which is no longer significant (see Guimarães et al.(2000) for a similar effect).

6. CONCLUSIONS AND POLICY IMPLICATIONS

Reflecting the increasing number of research based spin-offs (RBSOs) created since the nineties, previous studies focus their analysis on the factors that influence university entrepreneurship. However, empirical studies that investigate the determinants of variation on RBSO creation across regions are scarce.

In this paper we approached this topic from a regional perspective, using a unique self-collected dataset that includes the population of RBSOs created in Portugal from 1979 until to 2007. More specifically, we investigated the impact of factors related to the characteristics of existing universities in the region and of other regional characteristics, on the intensity of RBSO creation across regions.

Our results suggest that the quality and prestige of the universities located in a municipality is a crucial factor for the intensity of RBSO creation. In fact the presence of top universities has a positive impact on RBSO creation, while the number of universities or the existence of universities with technological focus in the municipality do not seem to be relevant in discriminating the spin-off activity across regions. On the other hand the results show an important effect of the presence of university-affiliated incubators and/or university research parks in the municipality on spin-off creation across regions.

Regarding the regional characteristics, the availability of qualified human capital and the regional demand size seem to exert an important effect on the intensity of spin-off creation. An interesting result that emerges from our data is the non-significance of the impact of proximity to urban centers. The non-significance of this predictor variable suggests that transportation cost is not an issue for spin-off location decisions. A possible explanation could be the effective concentration of our sample in urban centers – most spin-off firms have distances from Porto or Lisbon close to zero. Another interesting result is with regard to the agglomeration economies. In fact the high density of firms on high-technology industries in a municipality has no impact on variation of spin-off creation across regions. As such, there seems to be no differences between RBSOs and other start-ups regarding the industry agglomerations impact on their location (see Buenstorf and Geissler(2011) for a similar result).

In Portugal, it is clear that the regions with top universities are actually the ones with the best regional resources – more qualified human capital available and high population density – so it is natural that RBSOs show a high concentration in these regions.

Our results have several implications from a policy point of view. They point out the importance of the quality rather than the quantity of existing universities in the municipality in RBSO location, as well as the relevance of the educational level of human capital. Similarly, the importance of the existence of infrastructures to support the commercialization of technology is emphasized, namely incubators and science parks. All these factors point to the need for policies that put a greater focus on the quality of Portuguese universities, as well as on policies that support the innovation commercialization efforts made by individual universities.

The main limitation of our data is the impossibility of assessing the specific characteristics of the TTO, namely age, experience of staff and dimension of staff. With regard to lines for further research, it would be important to explore the role of local R&D capabilities, as well as the impact of factors related with individual choices - such as whether founders live and work in the region and are reluctant to move – on the location decision of RBSOs.

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