Universidade do Minho
Escola de Economia e Gestão

Oscarina Susana Vilela da Conceição

Research based spin-offs: determinants of strategies and performance

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Abstract

Research-based spin-offs have become an important research subject, given their role as technology transfer mechanisms. They have been found to have a significant economic impact, both on the parent organisation and on regional and national development.

This thesis is particularly concerned with three key aspects of RBSO behaviour. The first study analyses the determinants of the variation on the RBSOs creation across regions. Using a unique self-collected dataset on the population of RBSOs created in Portugal between 1979 and 2007, it investigates the intensity of spin-off formation across regions, focusing on the characteristics of the region where the spin-off is created and those of universities located in the region. The results indicate that the quality and prestige of the universities, and the presence of university-affiliated incubators or research parks, on the one hand, and regional characteristics such as the availability of qualified human capital and regional demand size, on the other hand, influence the intensity of RBSO creation.

The second study analyses the survival of the population of Portuguese RBSOs, from its inception in 1979 until 2007, also using a unique data set. It investigates the role of three types of effects on firm' survival: founding conditions, parent organisation characteristics and characteristics of the region. The results show that start-up size, firm age, parent reputation and region characteristics are key determinants of RBSOs survival

The third study addresses the commercialisation decisions of RBSOs. Using cross-country data collected on the basis of questionnaire-based interviews, it focuses on the case of companies that target the market for technologies and investigates the conditions that influence the decision to adopt and the ability to pursue with this commercialisation strategy. The results suggest that these are determined by: the novelty of the technology being commercialised and the capacity to protect it since start-up; the situation in terms of access to downstream complementary assets, in particular the extent to which incumbent companies control those assets; the competence mix of the founding team. The research also calls the attention to the impact of early decisions, which can constrain firms' subsequent behaviour by reducing the margin for future choices.

The results from these studies provide some new insights into three important aspects of RBSOs behaviour – formation, strategy formulation and survival – highlighting conditions that enable them to perform a role in economic development. They offer some theoretical and empirical contributions to the literature on RBSOs and can also provide some guidelines for the formulation of more adequate policies to support RBSO development.

Resumo

As empresas spin-offs de investigação tornaram-se um importante objecto de pesquisa, dada a sua função enquanto de mecanismos de transferência de tecnologia, que lhes confere um papel significativo, quer ao nível da instituição de origem, quer em termos de desenvolvimento económico regional e nacional.

Esta tese incide em três aspectos fundamentais do comportamento dos spin-offs. O primeiro estudo analisa os determinantes da variação na criação de spin-offs entre regiões. A partir de uma base de dados única da população de spin-offs criados em Portugal entre 1979 e 2007, investiga o impacto das características da região e das características das universidades localizadas nessa região na intensidade de spin-offs aí criados. Os resultados apontam para o papel da qualidade e prestígio das universidades, da presença de incubadoras e/ou parques de ciência e tecnologia, bem como de características regionais, como a disponibilidade de capital humano qualificado e a dimensão da procura regional.

O segundo estudo analisa os determinantes da sobrevivência da população de spin-offs portuguesas, desde 1979 até 2007, também a partir de uma base de dados única. É investigado o papel das condições de criação, das características da instituição de origem e das características da região. Os resultados mostram que a dimensão da empresa à data de criação, a idade, a reputação da instituição de origem e as características da região são os principais determinantes da sobrevivência das empresas spin-offs.

O terceiro estudo aborda as decisões de comercialização das empresas spin-offs. Usando dados internacionais recolhidos através de entrevistas baseadas em questionário, aborda o caso das empresas que têm como alvo o mercado de tecnologias e investiga as condições que influenciam a decisão de adoptar e a possibilidade de prosseguir esta estratégia. Os resultados apontam para: a novidade da tecnologia comercializada e a capacidade de a proteger; as condições de acesso a activos complementares, nomeadamente o grau controlo destes por incumbentes; o mix de competências da equipa fundadora. Também é realçado o impacto das decisões iniciais, que podem reduzir a margem para escolhas futuras.

Os resultados destes estudos oferecem contributos teóricos e empíricos para três aspectos chave do comportamento das empresas spin-offs – criação, formulação de estratégia e sobrevivência - com destaque para as condições que lhes permitem desempenhar um papel no desenvolvimento económico. Também fornecem algumas pistas para a formulação de políticas mais adequadas para apoiar o desenvolvimento deste grupo de empresas.

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List of Abbreviations

AUTM Association of University Technology Managers

IPR Intellectual Property Rights

PRO Public Research Organisation

R&D Research and Development

RBSO Research based spin-off firm

TTO Technology Transfer Office

I. Introduction

1. Research-based spin-offs as a research topic

The motivation for this thesis is the growing importance that both the academic literature and technology and innovation policies attribute to research-based spin-off firms (RBSOs).

Although there is not, in the literature, a single definition of the concept of academic or research-based spin-offs, it is possible to describe them as firms whose creation is based on the formal and/or informal transfer of knowledge or technology generated in public research organisations (Djokovic and Souitaris, 2008; Mustar et al., 2006; Pirnay et al 2003).

In fact, RBSOs have been found to play an important role in the commercial exploitation of knowledge originating from research (Rothaermel el al., 2007; Wright et al., 2007). Given their function as a mechanism of technology transfer, RBSOs can have a significant economic impact - particularly in emerging fields - not only on the "parent" university, but also on regional and national development (Fini et al., 2011; Mustar et al., 2006; O´Shea et al., 2008; Wright et al., 2007).

These features made RBSOs particularly attractive to policy makers at various levels (institutional, regional, national, European), who have launched a variety of policies promoting their creation, in the expectation of extensive economic and social benefits (Claryssse et al., 2011; Mustar et al., 2008; Wright et al., 2007). However, contrary to what is often assumed by policy makers, RBSOs are heterogeneous companies, created in a diversity of conditions and displaying a variety of behaviours, with implications for the role(s) they effectively play in the transformation of scientific and technological knowledge into economic value (Druilhe and Garnsey, 2004; Heirman and Clarysse, 2004; Helm and Mauroner, 2007; Mustar et al., 2006). Thus, it is relevant to go into greater depth into the formation and behaviour of this type of company.

In this thesis we are particularly concerned with three key aspects of RBSO behaviour. Firstly, we look at the process of RBSO formation. Because these firms are often described as having an important role in regional development, we analyse the determinants of the intensity of the RBSOs creation across regions. Secondly, we address RBSOs survival. Technology-intensive companies in general and RBSO in particular are described as having a lower mortality rate than the average entrepreneurial start-up. Thus, we are interested in uncovering the determinants of RBSO survival, since their economic impact also depends on their ability to pursue with innovative activities over time. Thirdly, we address the process of commercialisation conducted by RBSOs. Since the value attributed to these companies largely rests on their ability to develop and bring to the market knowledge originating from academic research, we investigate the condition in which RBSOs perform this task and the resulting commercialisation strategies.

The research conducted along these lines will be briefly summarised below and will be developed in the following chapters, as autonomous papers. The results from these three studies provide some new insights into three important aspects of RBSOs behaviour – formation, strategy formulation and survival – highlighting conditions that enable them to perform a role in economic development. They offer some theoretical and empirical contributions to the literature on RBSOs and can also provide some guidelines for policy makers, enabling them to formulate policies that are more adequate to support RBSO development.

2. Overview of studies

2.1. Entry by research-based spin-offs

Recent studies show an increase in the number of research-based spin-offs (RBSOs) since the mid-nineties. According to a report of the Association of University Technology Managers (AUTM, 2007) over 5000 spin-offs were created in the U.S. between 1980 and 2005 were created, this increase registering their maximum values in the nineties. In Europe there was also a significant increase in the number of RBSOs, mainly from the late 1990s onwards (van Looy et al., 2011; Wright et al., 2007).

Given the increase of spin-off activity, the analysis of the determinants of RBSO creation became one of the major research streams on university entrepreneurship. The literature concerning entrepreneurial activity, points out several factors 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). In this paper we will address this issue from a regional perspective, investigating the determinants of the variation in RBSO creation across regions. Using a 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.

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 also seem to have an important effect on spin-off intensity across regions.

2.2. Determinants of research-based spin-offs survival

Existing literature has shown that research-based spin-offs firms usually exhibit lower death risks than other start-ups (Callan, 2001; Mustar, 1997; Smith and Ho, 2006). On average, 40% to 50% of the firms in a given market survive beyond the seventh year (Eurostat/OECD, 2007), whereas in the case of research-based spin-offs the survival rate can be as high as 90% (Smith and Ho, 2006).

Empirical evidence on the survival of RBSOs is still very limited. Whereas some studies have explored the topic, using cross-section data or case studies, so far, only Nerkar and Shane (2003) investigated the topic using duration analysis. Their data included 128 spin-offs from the Massachusetts Institute of Technology founded between 1980 and 1996. They found that having a radical technology and broad scope patents in a fragmented industry reduces RBSO´s failure.

Based on a unique self-collected database of the population of research-based spin-offs created in Portugal from 1979 up to 2007, we analyse if founding conditions, parent organisation characteristics and location characteristics play a role on their survival.

Our results suggest that start-up size is the founding condition that matters most to determine RBSOs´ survival, showing that the larger the start-up size the lower the probability of exit by the firm. A similar result is obtained for the role of age: the older the spin-off the lower the likelihood of it exiting the market, which is in line with most survival studies.

Regarding the parent organisation characteristics, intellectual eminence or reputation and size seem to exert an important effect on spin-off survival. But, contrary to previous studies, we do not find that the incubation process, or the presence of social ties with the parent organisation have an impact on spin-off survival.

Concerning the location characteristics, being located in a metropolitan area and in municipalities with higher density of firms in high-technology industries and with high entry rates seem to be important factors influencing the survival of spin-offs, corroborating the widely accepted view of the importance of local spillovers and agglomeration externalities in determining firms´ survival. As such, there seems to be no difference between RBSOs and other start-ups regarding the region´s role on survival.

2.3. The commercialisation decisions of research-based spin-offs: targeting the market for technologies

Research-based spin-off firms are, by definition, firms set-up to exploit scientific and technological knowledge developed in academic research (Mustar et al., 2006). In order to pursue with this goal, the new firm has to make a key strategic choice regarding the mode of capturing value from its knowledge assets: it may sell/license the actual technology, or engage in the development of products or services based on it. The decision on how to transform knowledge in economic value also corresponds to a strategic decision on the type of market to target: firms can opt for trading in the market for technologies, or chose to trade in the market for products (Arora et al., 2001).

This paper addresses the commercialisation decisions of RBSOs, focusing on the case of companies specialising in the production and sale of intellectual property – a model of entrepreneurial behaviour increasingly frequent in science-based fields and that research-based spin-offs may be more prone to adopt, given their specific characteristics.

We discuss the conditions that can influence firms' ability to operate in the market for technology, and advance some theory-driven hypotheses regarding key factors that are likely to determine it – nature of knowledge being exploited, appropriability conditions, location and degree of control upon complementary assets and institutional setting of origin – as well as their impact upon firms' decisions. These hypotheses are tested on a group of 80 European RBSOs, using data collected specifically for this purpose, on the basis of questionnaire-based interviews.

Our results suggests that firms willing to operate in these markets should pay particular attention to the following aspects: (i) the presence of stringent requirements in what concerns both the novelty of the technology being commercialised and the capacity to protect it since start-up, a key role being played in such protection by patents filed by the parent research organisation; (ii) the situation in terms of access to downstream competences and resources that are necessary to capture the value of the technology, in particular the extent to which incumbent companies control those assets; (iii) the set of competences possessed by the founding team, where a combination of high scientific competence (given the nature of knowledge requirements) and critical non-technological competences and networks (given the complex requirements of intellectual property trade) often emerges as a requisite. The research also calls the attention to the impact of early decisions, which can constrain firms' subsequent behaviour by reducing the margin for future choices.

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II. Entry by research-based spin-offs[1]

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 in the spin-off is located. Our results suggest that 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 the spin-off activity across regions.

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 to play 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 innovations, 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 due to both their crucial role as technology transfer mechanisms and their economic impact, not only to the parent

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university but also to 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 universities and public research organisations (van Looy et al., 2011; Wright et al., 2007). This European 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 the increase of institutional pressure on universities to commercialize research through licensing and/or RBSO, with the professionalization of 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- 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 such as regional infrastructure that impact on spin-off activity such as the venture capital availability, the knowledge infrastructure in the region and industry structures (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 analyzed 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 the 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 to 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).

However, 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 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 technology 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 the RBSO 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 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 capital stock which may be a crucial source for a 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 considers 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.

With regard to the broader social context of the university resources this factor 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, 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 is 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, the previous success in technology transfer, the financial resources and the full-time specialized employees in the TTO (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 these 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 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 allows support of spin-offs not only in terms of

[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.

strategic management and business orientation, access to knowledge that is essential for completing the development of technologies or products but also support of physical facilities, particularly access to 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 (33%); the availability of a variety of services (43%) as well as a lower rent (20%). In addition, 17% of the 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 research park to the university and by the sector/area in which the park specializes (in cases where it is the same as the company's 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-offs feel the need to cooperate in technology development with other knowledge besides their parent organization and when they need to access the scarce resources 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 its 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). Interregional characteristics assume a leading role in the location of RBSOs at the time of their creation.

For the knowledge-based and high-technology firms one of the relevant regional factors in location decision are the agglomeration or external economies i.e. positive externalities resulting from co-location. Several studies refer that the local high density of high-technology firms attracts companies to that research intensive region, allowing them access to 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 location of these knowledge-based firms, the availability of venture capital financing in the region and qualified human capital. Access to financial assets is crucial to the creation of spin-offs, particularly the availability of venture capital availability due to its greater propensity to finance start-ups with high risk[5] (Di Gregorio and Shane, 2003; Landry et al., 2006; Powers and Mc Dougall, 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 re4source so its existence directly influences the location decision (Audretsch et al., 2005; Evila et al., 2011¸ Kim et al., 2012; Woodward et al., 2006).

[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 the public funding policies are not regional but at national level. Similarly, the VC that invest in RBSO are nationwide. Therefore, the financial resources at national level 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.

Another feature of the region considered relevant in the choice of location for these companies is the regional demand size. In fact, the bigger the market the bigger the "power" to attract start-ups should be (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 high resources, concentration of institutions of higher education, 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 suggest 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.

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.

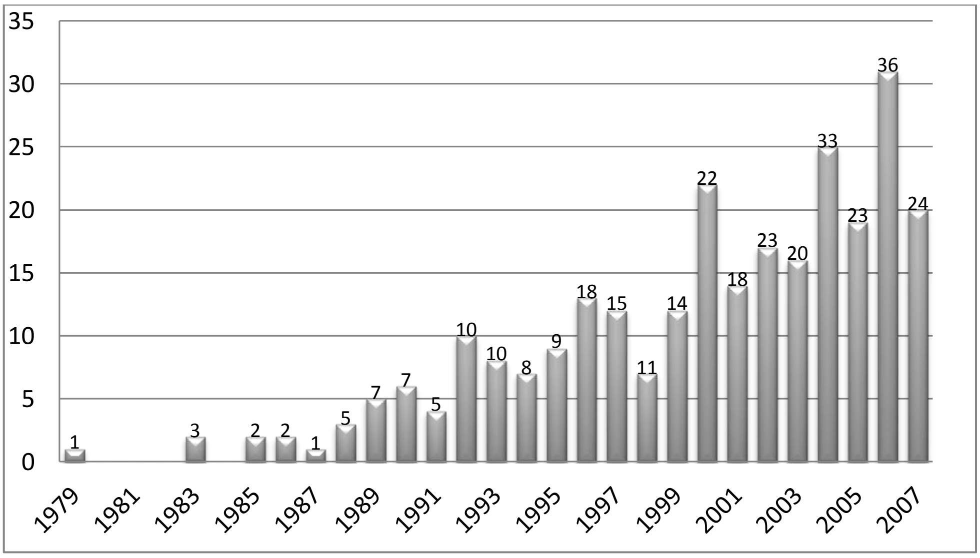
As a result of this search we ended-up identifying a total of 327 spin-off research firms legally set up until the end of 2007. For all these firms, we collected information on the year of creation, location, sector of activity, the number of employees on founding date and parent organization.

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 2.1). 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. 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). Please note that the policies of support for technology transfer and innovation may be heterogeneous across European countries (Mustar and Wright, 2010). When comparing policies to support RBSO creation in France and the UK, the authors concluded that these are different. In UK, policy is at university level, leading to the creation of diverse structures. In fact 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 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 (NTBF); promotion of venture capital investments; and simplification of the firm's relationship with the Public Administration. 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 PROs research activities and an increasing emphasis on the valorization of public R&D results, 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/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).

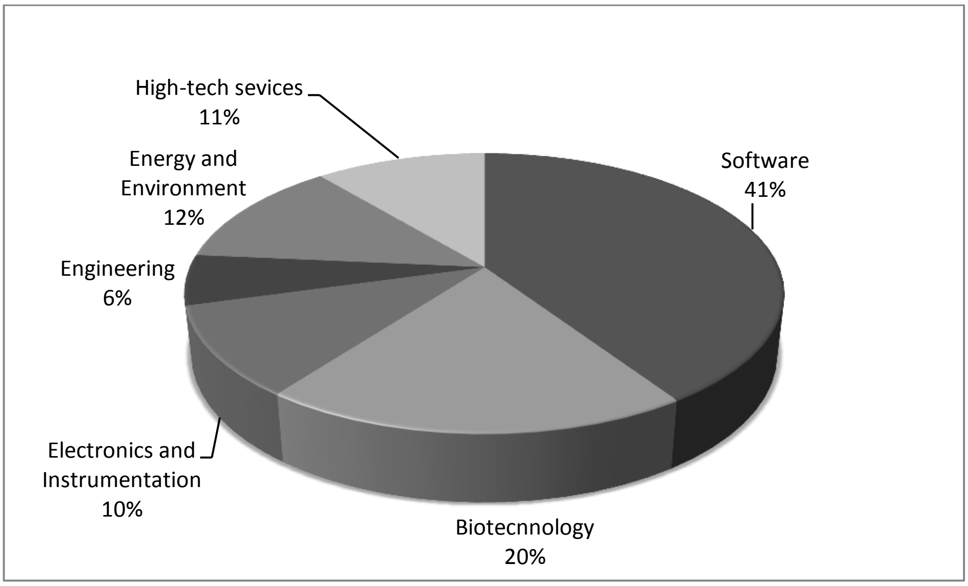
Figure 2.1- Number of Portuguese RBSOs by founding date (1979-2007) (n=327)



Source: Own calculations.

Regarding the sectorial distribution of the RBSOs, 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 RBSOs (5.81%) (Figure 2.2)

Figure 2.2 – Number of Portuguese RBSO by sector

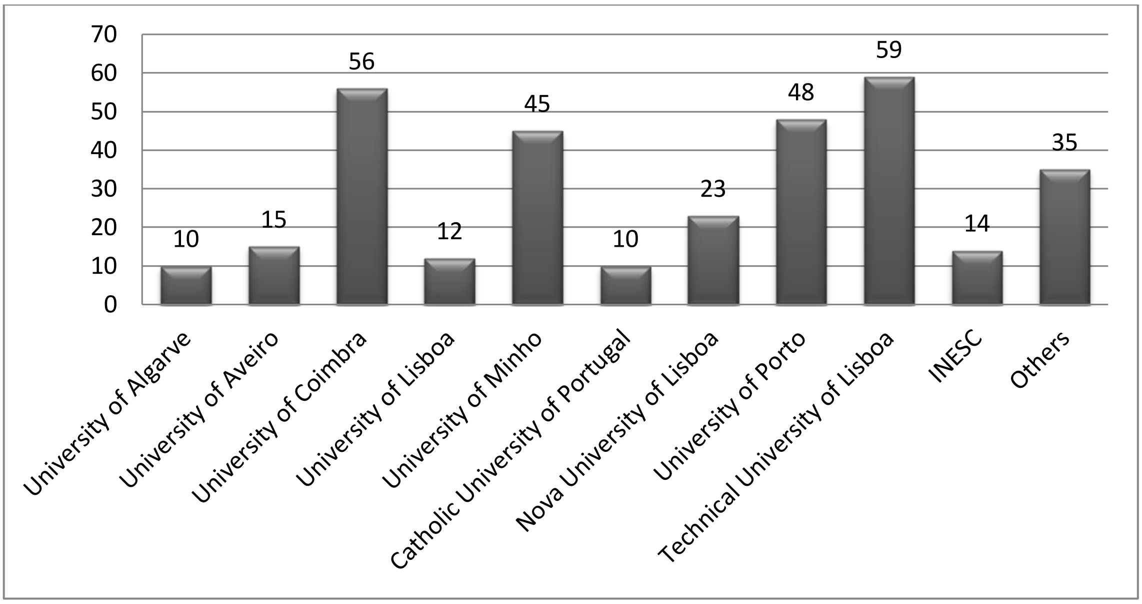


Source: Own calculations.

The vast majority of the RBSOs (78.9%) originate from the seven largest and most prestigious Portuguese public universities[6], 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 2.3). This is in line with the literature; in fact the spin-offs tend to originate in a small number from eminent universities. The world-class large scientific universities and prestige public research organizations which are focused on a specific sector 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).

[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*.

Figure 2.3 – 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 2.4 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 2.1).

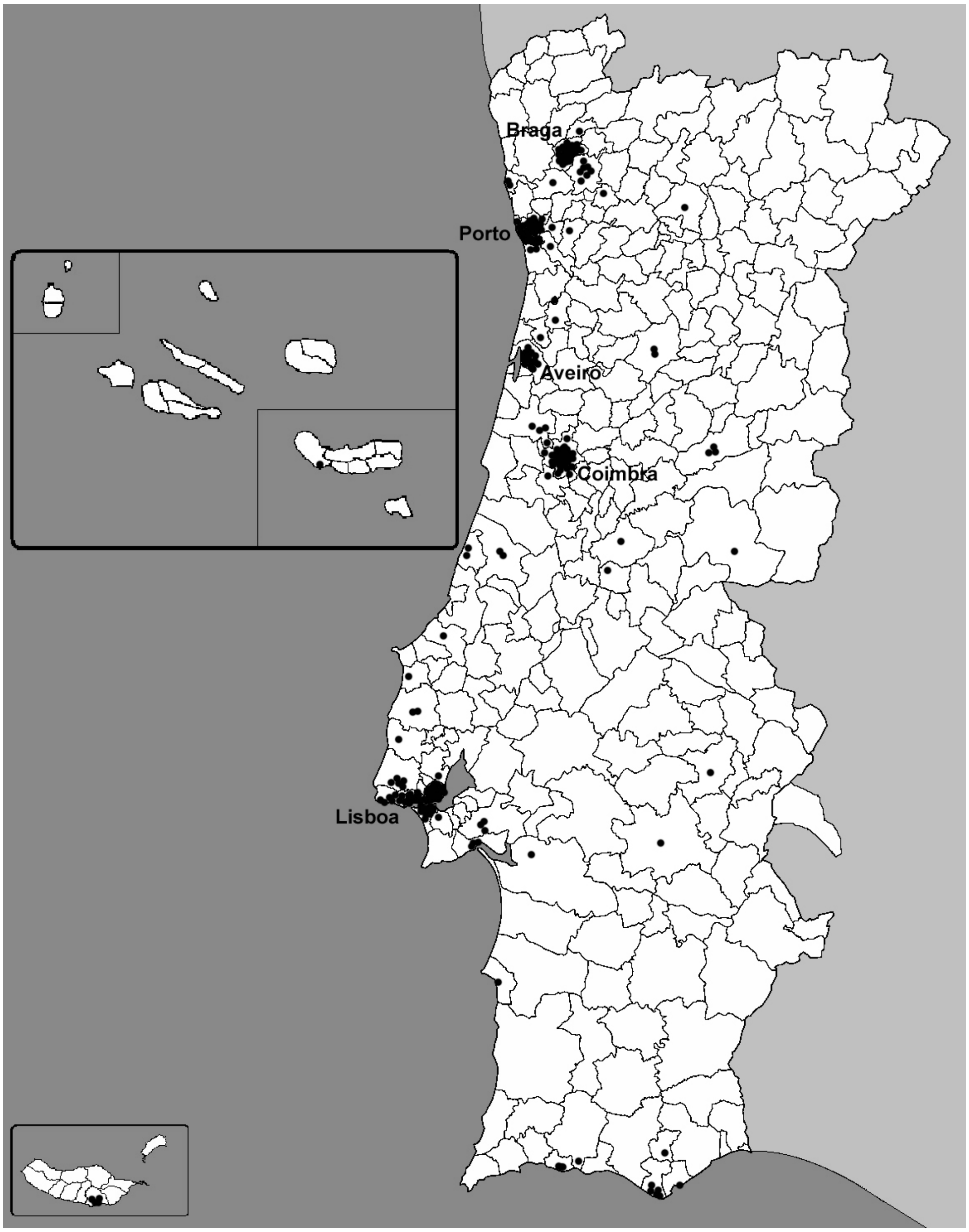
In Portugal, 79% of RBSOs, i.e. 258 firms, are located less than 25 km from parent, which is in line with the cluster pattern of the spin-offs. In 2000, AUTM reported that 80% percent of firms formed from university licenses operated in the state where the university was located. This number dropped 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 km of MIT and over 70% are located less than 100 km from MIT.

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

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.

Figure 2.4 – Spatial distribution of Portuguese RBSO per municipalities (1979 – 2007)



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

Table 2.1 – Distribution of Portuguese RBSO

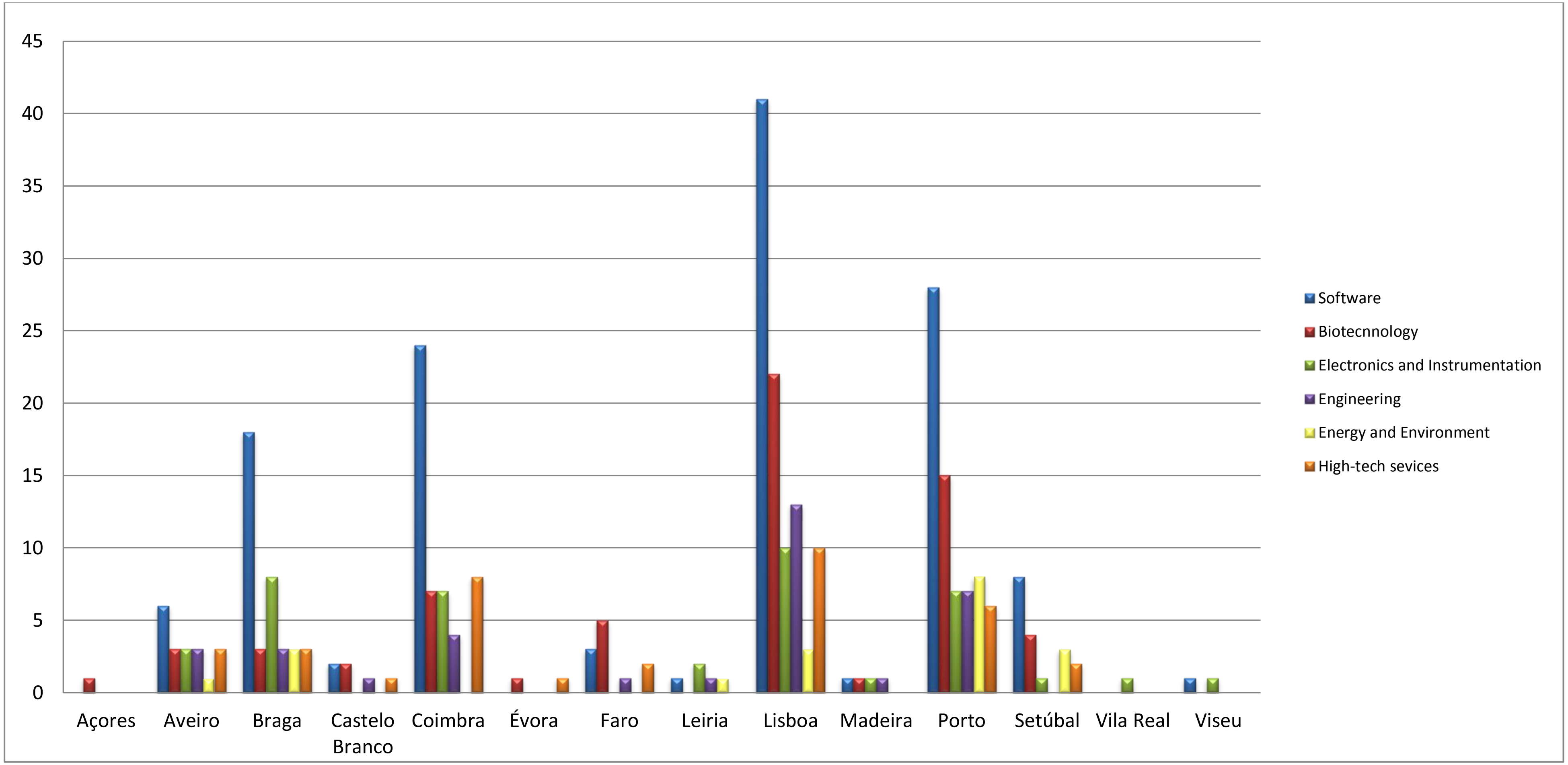
Districts	*RBSO Number*	*RBSO Percentage*
Aveiro	19	05.81
Braga	38	11.62
Coimbra	50	15.29
Lisboa	99	30.28
Porto	71	21.71
Others[1]	50	15.29
Total	327	100

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

Considering the districts with the largest number of spin-offs created, the sectorial distribution is quite similar (Figure 2.5). 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). For the remaining sectors it turns out that in the district of Porto these are distributed evenly (about 10% each). In the case of the district of Lisbon note the residual value of the sector of energy and environment (representing 0.3%).

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 values (about 15%), with the exception of the energy and environment sector, with little or no weight (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.

Figure 2.5 - Portuguese RBSO distribution by sector and district



4. Empirical Analysis

4.1. Data and empirical model

Data

After the various stages of our data collection of population of Portuguese RBSOs, described in section 3, we identified a total of 327 spin-off research firms legally set up until the end of 2007.

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 were also collected in terms 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, over these 13 years we noted 255 municipalities where RBSO creation never occurred. 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:

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

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 discrete nature of the dependent variable (Table 2.2) 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 2.2 - 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 = 261 firms; 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 2.3.

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 higher education institutions 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 we built a dummy variable that equals 1 if 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 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

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

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 (Baptista and Mendonça, 2010).

In Table 2.4 we 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 2.3 - 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.

Table 2.4 - 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

$$E(Y) = Var\,(Y) = \mu \tag{3}$$

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

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

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

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

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

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

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

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

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

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 we compare 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 2.5).

Table 2.5 - 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 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 shows 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 in fact the vast majority of our sample (52% in Lisbon and Porto) is actually located in the large Portuguese urban centers. 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, using a unique self-collected dataset that includes the population of RBSOs created in Portugal from 1979 until to 2007, we approached this topic from a regional perspective. 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 existence 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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III. Determinants of research-based spin-offs survival[9]

Abstract

Existing literature has shown that research-based spin-offs firms usually exhibit lower death risks than other start-ups. However, few studies have focused on the survival determinants of these particular firms. From a unique self-collected database of the population of research-based spin-offs created in Portugal from 1979 up to 2007 we analyse if founding conditions, parent organisation characteristics and location characteristics play a role on their survival. Our results show that start-up size, firm age, parent reputation and region characteristics are key determinants of research-based spin-offs survival, casting doubts on the role played by the incubation process and the social ties with the parent organisation as advanced in previous studies.

1. Introduction

The entry of new firms in the market bringing in new knowledge, technologies or products is seen as an important driver of economic growth (e.g. Shane, 2004; Vincett, 2010). Spin-off firms are a particular case of new firm entry. Academic or research-based spin-off (RBSO) relates to a firm whose creation is based on the formal and informal transfer of technology or knowledge generated by public research organisations (Djokovic and Souitaris, 2008; Mustar et al., 2006). The study of RBSO has assumed a growing importance in the literature reflecting the importance of these firms as a mechanism of exploitation and transfer of scientific knowledge produced in research institutions, serving also as measure of success of the parent organisation (Wright et al., 2007).

An empirical regularity emerging from recent evidence is that these firms exhibit lower death risks than other entrants in the same industry (Callan, 2001; Mustar, 1997; Smith and Ho, 2006). On average, 40% to 50% of the firms in a given market survive beyond the seventh year (Eurostat/OECD, 2007), whereas in the case of research-based spin-offs the survival rate can be as high as 90% (Smith and Ho, 2006). A possible explanation could be that RBSOs benefit from numerous advantages, either in the set up phase or throughout

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the life of the firm such as the high number of employees with PhD degrees, greater experience in research, privileged access to financial funds and networks with the academic system (Jong, 2006; Lockett and Wright, 2005; Walter et al., 2006). However, these firms usually have on average less experience in industry, which could act as a disadvantage and offset those potential advantages (Colombo and Piva, 2012).

Another explanation could be the innovative capacity of these firms. The degree of innovation of the firm and the fact that it is near of the technological frontier is regarded as relevant to increase their probability of survival (Audretsch, 1995; Fontana and Nesta, 2009). However, according to Agarwal (1996) the innovative activity can be both beneficial and detrimental to survival. On the one hand new firms have the greatest likelihood of survival with radical technologies, on the other hand the high level of uncertainty inherent to the innovation process can increase their hazard rate.

Empirical evidence on the survival of RBSOs is still very limited. Whereas somestudies have explored the topic using cross-section data or case studies, only Nerkar and Shane (2003) have so far investigated the topic using duration analysis. Their data included 128 spin-offs from the Massachusetts Institute of Technology (MIT) founded between 1980 and 1996. They found that having a radical technology and broad scope patents in a fragmented industry reduces the RBSO´s failure.

Using a unique dataset, this paper analyses the survival of Portuguese RBSOs from its beginning in 1979 to 2007. The study goes beyond prior research in using a larger and more comprehensive database than previous studies that corresponds to the population of Portuguese academic spin-offs. Moreover, this study provides an integrative view by simultaneously investigating the role that founding conditions, parent and location characteristics play on RBSOs´ survival.

In the following section we review previous evidence on spin-offs survival and propose the hypotheses to be tested. In Section 3 we describe the data collection and characterise spin-off firms in Portugal. In Section 4 we describe the methodology and empirical model. The results are discussed in Section 5. Finally in Section 6 we conclude and consider some policy implications.

2. Theoretical framework and hypotheses

Spin-off´s founding conditions

Industrial economists have shown that founding conditions are important determinants of firm's growth and survival, in particular, founders´ qualifications and the start-up size of the firm (Argawal and Audretsch, 2001; Geroski et al., 2010; Gimmon and Levie, 2010; Honjo et al., 2013).

In the case of RBSOs the founding team has also been pointed out as one of the peculiar genetic characteristics of these firms (Colombo and Piva, 2012). This is because academic spin-offs founding teams usually have a higher number of PhD degrees and greater research experience than high-tech start-ups. For instance, Colombo and Piva (2012), based on a sample of 64 Italian RBSOs conclude that the initial competences of the entrepreneurial team are a key source of competitive advantage, leaving an enduring imprint on the firm's development.

However this potential advantage may be offset by the fact that most academic entrepreneurs have an obvious lack of entrepreneurial skills that can translate into difficulties in terms of identifying business opportunities or identification of investors and customers (Heirman and Clarysse, 2004; Mustar et al., 2006). This argument is consistent with Astebro et al. (2012) who found that a recent graduate is twice as likely as her Professor to start a business within three years of graduation, and that the graduates' spin-offs are not of low quality. Buenstorf (2007) also found that in the German laser industry entrants with different pre-entry backgrounds differ systematically in their longevity, with startups from academic backgrounds exiting earlier than diversifiers and spin-offs from industry incumbents. Hence employee learning emerges as a primary driving force of corporate spin-off process *vis-a-vis* academic spin-off in the German laser industry.

Despite this opposite evidence, it is likely to expect that founding teams with PhD may have some additional advantage relatively to founding teams who do not have any PhD. This maybe because PhD team members are expected to have a deeper knowledge of the technology´s characteristics that might be critical to the market strategy. Given this we advance the hypothesis:

H1a: RBSOs with PhD in the founding team have lower probabilities of exit.

Allied to the spinout process there is in most cases an incubation process that gives the spin-off firm essential support in terms of strategic management and business orientation. The support received in the incubator helps the founding team's difficult task of defining the practical application of the technology and its marketing strategy. Various contributions have argued that the high start-up mortality is reduced with access of the incubated firms to such things as networking and credibility of incubator organisations, the access to subsidised rental space and collectively shared facilities, including laboratories and offices, and support of business assistance services, namely management support, marketing and accounting (Colombo and Delmastro, 2002; Schwartz, 2013; Wright et al., 2007).

Schwartz (2013) provides empirical support for these arguments. The author found that the incubated firms have higher survival rates than firms located outside incubator organisations. Salvador (2011) attained similar findings from surveys conducted at 30 Turin academic spin-off firms whose integration in an incubator was seen as the solution for the lack of managerial competence. Based on these arguments and evidence we advance the following hypothesis regarding founding conditions:

H1b: RBSOs that were in an incubator have lower probabilities of exit.

Another founding condition that may be crucial in determining RBSOs´ survival is its initial size. Previous studies on firms´ survival have shown that firms that had larger initial size have lower persistent probabilities of exit (Agarwal and Gort, 2002; Geroski et al., 2010; Mata et al., 1995). This is may be due to the effect of initial decisions that may persist because strategic decisions frequently involve the deployment of resources that cannot be reallocated later, that is, those that are sunk. When investment costs are sunk, there may be little point in reversing a decision, as costs cannot be recovered (Geroski et al., 2010). Furthermore, even if initial firm size is not at all important once all the adjustments are complete, the fact that firms adjust gradually toward their desired size makes it relevant to know their departing point as well as their current position (Agarwal and Gort, 2002; Geroski et al., 2010). RBSOs with larger start-up size are endowed with more resources and capabilities therefore have better chances of growing more and adjust more easily toward their desired size. As such we predict the following hypothesis:

H1c: RBSOs that had larger initial size have lower persistent probabilities of exit.

Spin-off´s parent organisation

Previous evidence on corporate spin-offs has shown that their survival is linked to their parent organisation characteristics. Factors such as reputation, size, access to formal and even tacit knowledge, as well as financial resources and network capabilities, have been pointed out as important features in the relationship between parent and spin-off (Andersson et al., 2012; Eriksson and Kuhn, 2006; Klepper and Sleeper, 2005; Klepper and Thompson, 2010; Thompson, 2007). Similar effects have been pointed out in the context of academic spin-offs with particular emphasis on the role of strong ties with the sponsoring university (Johansson et al., 2005; Lockett and Wright, 2005; Rothaermel and Thursby, 2005; Walter et al., 2006; Zhang, 2009). As such, it is common for RBSOs to locate near the parent university not only to benefit from pure cost advantages yielded by proximity but because their social ties enable them to access to academic knowledge and resources (Audretsch et al., 2005; Heblich and Slavtchev, 2013; Rasmussen and Borch, 2010).

So far, existing evidence has focused on the likelihood of spin-off creation rather than on their survival. Di Gregorio and Shane (2003) found that intellectual eminence of the parent organisation has a positive effect on new spin-off formation. Link and Scott (2005) found that being in the top 100 universities in terms of the level of R&D spending also had a positive effect on spin-off creation. Powers and McDougall (2005) obtained similar results by observing a positive effect of the level of university research funding and faculty quality on spin-off creation. However, Zucker et al., (1998) found that the concentration of startups in the biotechnology industry in the U.S.A. is more the result of a preference of scientists to locate near their parent organisation rather than the result of social ties and meetings between local firms and scientists. Given this evidence we argue that the parent organisation plays an important in the survival of spin-offs and we predict the following hypotheses:

H2a: RBSOs are more likely to survive the higher the reputation of the parent organisation.

H2b: RBSOs are more likely to survive the larger is the parent organisation.

H2c: RBSOs located near the parent organisation are more likely to survive.

Spin-off´s region

The geographical location of the firms seems to exert a positive effect on business rate of growth, where some regions that are characterized by high resources and wide market opportunities are more conducive to firm growth. As such, metropolitan areas hold strong attractions for small firms with high technological ability. Indeed the spatial concentration of institutions of higher education, technological research facilities and centers of knowledge in metropolitan areas increases information accessibility and has a positive influence on firms' innovative capacity (Frenkel, 2001; Holl, 2004; Smith and Bagchi-Sen, 2006).

Agglomeration externalities are frequently pointed out as an important determinant of firms´ geographical concentration. Audretsch et al., (2005) argue that knowledge spillovers represent a significant form of agglomeration externalities and that the location decision of new firms should be influenced significantly by access to the sources of such spillovers. The propensity to cluster geographically should be higher in industries where knowledge and innovation activities plays a more important role, namely for high technology and knowledge-based industries and services (Baptista and Mendonça, 2010; Magrini and Galliano, 2012). According to Woodward et al. (2006) the high-technology plant births are highly concentrated around some regions. From an empirical study of high-technology location decisions in U.S. counties, the authors found evidence that agglomeration effects, the availability of qualified labor and natural amenities, as well as, university R&D expenditures exert a positive influence on the decision to locate high-technology firms in a county.

Regarding start-ups, the literature postulates a positive link between entrepreneurship and innovation performance (Baptista et al., 2008) where high start-up rates are associated with higher levels of technological innovation in the developed countries (Anokhin and Wincent, 2012). Regarding the specific case of knowledge-based start-ups, the entry rate across regions measures the capacity of region on catching up start-up firms. The regions with high entry rates are more attractive for knowledge-based firms (Baptista and Mendonça, 2010). In view of this evidence we argue that location characteristics matters to RBSOs survival and we advance the following hypotheses:

H3a: RBSOs are more likely to survive if it is located in metropolitan area;

H3b: RBSOs are more likely to survive if it is located in regions with an agglomeration of high technology firms;

H3c: RBSOs are more likely to survive if it is located in regions with high entry rate.

3. Data collection and descriptive statistics

3.1. Data collection

In this study we use the population of Portuguese RBSOs created since 1979 until 2007. In order to identify the population of Portuguese spin-off firms, a comprehensive list was made of spinout firms from Portuguese public research organisations. In this regard we started by collecting information from universities and other public research organisations in order to identify their spin-off firms. Whenever this information was not available, we contacted the organisation to apply for the identification of their spin-offs. This process proved to be quite lengthy and particularly pertinent because it was crucial to ensure that all the spin-off firms were identified and checked.

Whereas the vast majority of the spin-off firms only make their legal registration when they actually have prospects of business or commercialisation of the technology (EC, 2003) it was necessary to verify the legal constitution of all the spin-off firms identified. After this procedure, carried out at the Institute of Registration and Notary Affairs (IRN – Ministry of Justice), we identified a total of 327 spin-off research firms legally set up until the end of 2007.

For all these firms, we collected information up to 2009 on the year of creation, location, sector of activity, the number of employees at founding date, parent organisation and year of death(if applicable).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 inquired the firms by e-mail and later, when necessary, we contacted them by phone.

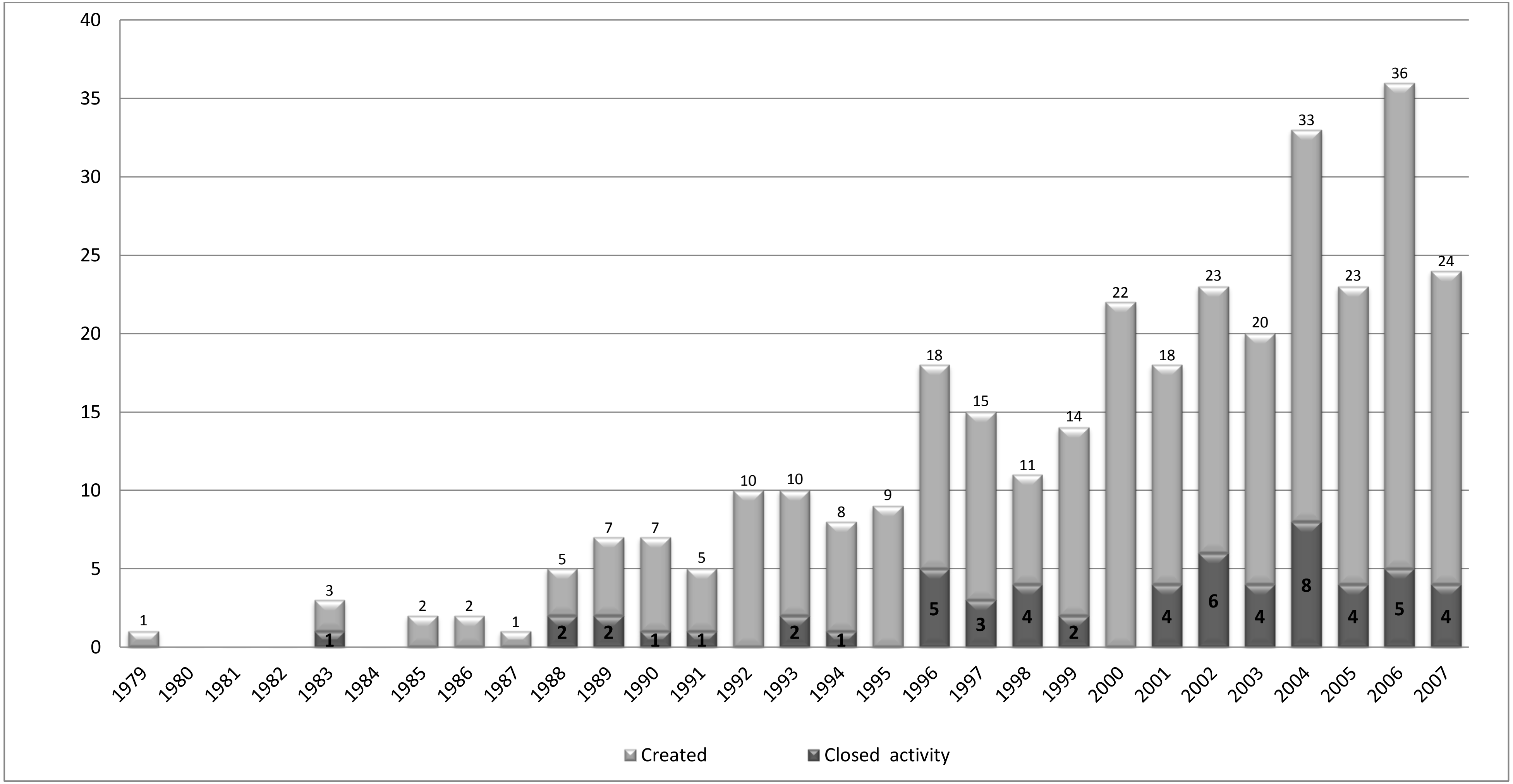
With regard to those firms considered inactive, we classified the firms as "dead" in the case where they actually declared inactivity with the Ministry of Finance. For this identification, we initially listed the firms where we saw subsequent ineffectiveness of the firm's services and the impossibility of telephone contact with it, then proceeded to confirm the inactivity of the firm concerned with the Ministry of Finance. It should be noted that, following Nerkar and Shane (2003) and Zhang (2009), we considered the acquired firms as survivor firms because despite the loss of "legal identity" the resources were maintained, both human and technological, even if integrated in another firm. During the observed period, 1979 – 2009, only 8 Portuguese spin-off firms were acquired by multinational firms, which thus began to exploit the technology previously developed by the spin-off firm.

Information regarding the parent organisation was collected from the Ministry of Science and Higher Education (MCTES) and from the *Webometrics Ranking of World Universities.* Data regarding the characteristics of the region where the spin-off is located was collected from *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.

3.2. Patterns of RBSOs survival in Portugal

The first Portuguese RBSO dates from 1979, although in fact, the emergence of this type of firm only started to be visible from the mid 1980's onwards (Figure 3.1). Analyzing the evolution in the process of Portuguese RBSO creation, it is important to note that the biggest – although not radical - transition in terms of increase in number firms took place in the early 1990's. Indeed, 39.45% of the firms were created between 1990 and 2000 and 54.13% after 2000.

Figure 3.1 - Number of Portuguese RBSOs by founding date (1979-2007).

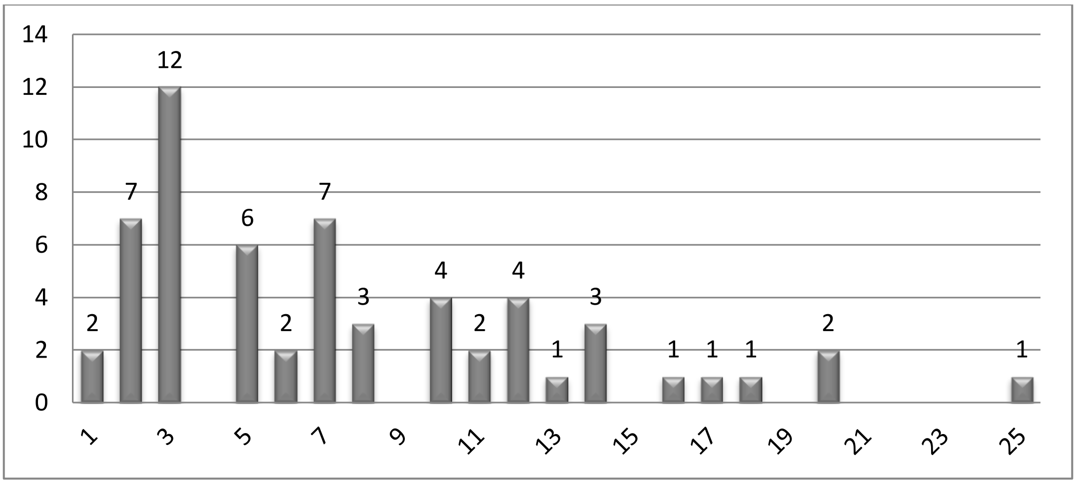


Source: Own calculations.

Of the 327 the total spin-offs created, only 60 firms closed their activity in the observed period of 30 years. This reduced death risk is in accordance with previous empirical studies that mention the high levels of survival of the RBSOs vis-à-vis other start-up firms (Zhang, 2009). For our research we will only consider the period from 1995 to 2009. This is due to data constraints regarding the parent organisation, which is only available from 1994 onward. It should be noted that between 1979 and 1994 no firm closed activity and that the evolution of spin-off research firms in Portugal occurred predominantly in the mid-nineties, as in the rest of Europe (EC, 2003).

Considering the survival levels by age of the spin-off firms, we observe that most of the failures occur in the early stages of the start-ups' life (Figure 3.2). Only 9.34% of these firms fail in their first year of activity but failures increase substantially in the two subsequent years, to a cumulative total of 28.66% by the third year, which is in line with the stylised fact that most of the unsuccessful start-ups fail in the early stages of their life. The probability of failure for the start-ups that survive the first years of activity declines steadily with the firm's age. This is consistent with evidence that older firms are more diversified and less risky than younger firms (Agarwal and Audretsch, 2001).

Figure 3.2 - Number of Portuguese RBSO that fail by age.



Source: Own calculations.

Regarding the start-up size of the Portuguese RBSOs, it should be noted that the average number of employees is 2.56, and only one firm have more than 50 full-time employees. The population of Portuguese RBSO is mostly made up of micro firms; 97.55% of the spin-offs have less than 10 full-time employees at founding date.

About 38% of the spin-off firms say they do not have any full-time worker at date of creation. In fact the human resources of RBSOs are commonly composed of researchers who are contractually linked to the educational and research institutions, including grant holders, graduate or PhD students and even part-time workers. Only at an advanced stage of product or business development do the spin-off firms have the financial capacity for the founders to decide to "break" their link with the universities and dedicate themselves exclusively to the firm and/or to hire workers (Corolleur et al., 2004).

Of the total of 60 firms that failed, 100% are in fact micro firms, thus having less than 10 full-time employees (Table 3.1). It should be noted that 78.33% of the firms that closed said they had no full-time employees at founding date.

According to the literature, Mustar (1997) emphasises that, although they survived, the RBSOs remained small and over 80% had less than 10 employees. In the same way Harrison and Leitch (2010) state that the RBSOs start small and remain small.

Table 3.1 – Number of Portuguese RBSO that fail by start-up size.

N.º of Employees at founding date	*Firms founded*		*Firms that fail*		*Death Rate*
	N.º	%	N.º	%	
Micro (0 - 9)	319	97.55	60	100.00	18.81
Small (10 - 49)	7	02.14	0	00.00	00.00
Medium (50 - 249)	1	00.31	0	00.00	00.00
Large (> 250)	0	00.00	0	00.00	00.00
Total	327	100	60	100	

Source: Own calculations.

Regarding the sectoral distribution of the RBSOs, the sector of software and multimedia Services represents 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 RBSOs (5.81%).

Considering the firms that closed activity, it should be noted that the high –tech services, that includes a variety of services for firms that operated in services such as health services, design, archaeology and sports, has the highest death rate (33.33%). Followed by the software sector and multimedia services in which 21.81% of the spin-off firms that were created ended by closing in the observed period. The sector with the lowest percentage of failures is the "energy and environment" in which only two firms closed (4.88%).

Table 3.2 – Number of Portuguese RBSO that fail by sector.

Sectors	*Firms founded*		*Firms that fail*		*Death Rate*
	N.º	%	N.º	%	
Software and multimedia	133	40.67	29	48.33	21.81
Biotechnology; Biochemistry	64	19.57	8	13.33	12.50
Energy and environment	41	12.54	2	3.33	4.88
Electronics ;Instrumentation	34	10.40	4	6.68	11.77
Engineering	19	5.81	5	8.33	26.32
High-tech Services	36	11.01	12	20.00	33.33
Total	327	100	60	100	

Source: Own calculations.

The vast majority of the RBSOs (78.9%) originate from the seven largest public universities, or from research organisations 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 organisations.

Considering the firms that have failed, it should be noted that the Catholic University of Portugal has a percentage of 40% of closures. This private university has a particularity because of a total of 10 firms created, 6 are from the biotechnology sector which could explain the high death rate. It should be pointed out that Technical University of Lisboa has the largest number of firms created (18.04%) and a survival rate of 91.52%.

Table 3.3 – Number of Portuguese RBSO that fail by parent.

Parent	*Firms founded*		*Firms that fail*		*Death Rate*
	N.º	%	N.º	%	
University of Algarve	10	03.06	1	1.67	10.00
University of Aveiro	15	04.59	3	05.00	20.00
University of Coimbra	56	17.13	10	16.67	17.86
University of Lisboa	12	03.67	3	05.00	25.00
University of Minho	45	13.76	9	15.00	20.00
Catholic University of Portugal	10	03.06	4	06.67	40.00
Nova University of Lisboa	23	07.03	5	08.33	21.74
University of Porto	48	14.68	9	15.00	18.75
Technical University of Lisboa	59	18.04	5	08.30	08.48
INESC	14	04.28	3	05.00	21.43
Others	35	10.70	8	13.33	22.86
Total	327	100	60	100	

Source: Own calculations.

4. Method and empirical variables

4.1. Method

In this paper the event is the failure of a research-based spin-off founded in Portugal from 1979 until 2007; the failure is define as a firm that ceases operations. For those firms that have not exited at the end of our period of analysis, we do not have information on how long they survive (our empirical approach deals with this right censoring). The probability that a firm remains in activity, i.e., survives, until time *t* is given by the survivor function as:

$$S(t) = \Pr(T > t) \quad (1)$$

The conditional failure rate of a firm, known as hazard function *h(t),* is defined as the (limiting) probability that the failure event occurs in a given interval, conditional upon the firm having survived to the beginning of that interval, divided by the width of the interval:

$$h(t) = \lim_{\Delta t \to 0} \frac{\Pr(\, t \,+\, \Delta t > T > t \mid T > t \,)}{\Delta t} \tag{2}$$

So the hazard function gives the instantaneous failure rate at *t* given that the firm has survived up to time. The hazard function is usually expressed in terms of the probability distribution F and the density function *f* of the firm's duration as:

$$h(t) = \frac{f\,(t)}{1 - F(t)} = \frac{f\,(t)}{S(t)} \tag{3}$$

where the probability density function of T is

$$f\,(t) = F'(t) = \,-S'(t), \qquad t\, \geq 0 \tag{4}$$

Besides the non-parametric approach, it is crucial to analyse the impact of covariates on the firms' survival by using a multivariate model of the life duration.

We can estimate the relationship between the hazard rate and the covariates without having to make specific assumptions about the underlying distribution. This approach results in models referred as semi-parametric. The Cox model (1972), as a proportional hazard model, assumes that the hazard rate is:

$$h\big(t \big| X_j\big) = h_0\,(t) exp\,(x_j\, \beta_x) \tag{5}$$

where $h_0(t)$ is the baseline hazard function, x is a vector of covariates variables and β is the vector of regression parameters. The Cox model makes no assumptions about the shape of the hazard over the time, i.e., the baseline hazard function can be left unestimated. Then it is possible to obtain estimates for β avoiding the risk of mis-specifying the baseline hazard function.

Considering that from the survival data is possible to specify the distribution of the baseline hazard function it may be advantageous to use parametric models. These models can be fit following a proportional hazard (PH) parameterisation (such exponential, Weibull and Gompertz models) or a log-time parameterisation, also known as the accelerated failure-time (AFT) metric (namely exponential, Weibull, lognormal, log-logistic and gamma models). Some models (for example the exponential and Weibull) models can accommodate both the PH and AFT assumptions, but they are still the same model.

The Gompertz model is suitable for modeling data with monotone hazard rates that either increase or decrease exponentially with time. It assumes a baseline hazard of the form:

$$h_0\,(t) = \exp(\gamma t)\,exp\,(\,\beta_0\,) \qquad (6)$$

where γ is the shape parameter estimated from the data and the scale parameter is parameterised as exp (β_0). Given a set of covariates, x_j, under the proportional hazard (PH) model,

$$h(t|X_j) = h_0\,(t)exp\,(x_j\,\beta_x) \qquad (7)$$

so the hazard function is

$$h(t|X_j) = \exp(\gamma t)\;\; exp\,(\beta_0\, +\, x_j\,\beta_x\,) \qquad (8)$$

The shape parameter γdetermines the shape of the hazard function. If γ>0 then the hazard increases exponentially with time; if γ< 0 the hazard decreases exponentially with time. In the specific case of γ= 0the hazard is $exp\,(\,\beta_0\,)$ for all *t*, i.e., it reduces to the exponential model.

4.2. Empirical variables

In order to test our hypotheses regarding founding conditions we included in our regression the following variables: *Founder PhD*, a dummy variable that equals 1if there is at least one founder with a PhD degree at founding date, and zero otherwise; *Incubated*, a dummy variable that equals 1 if the firm was located in an incubator, and zero otherwise; *Start-up Size*, was measured by the number of full-time employees at founding date.

Parent characteristics were measured by the variables *Parent Reputation* and *Parent Size*. For *Parent Reputation* we split universities created before and after the renewal of the university education policy in Portugal in 1973. Given the short life-span of the most recent Portuguese universities, the oldest ones are usually looked up with higher reputation than younger universities or institutions research institutions. This observation is sustained by the fact that there is a world ranking for younger universities, i.e., universities with less than 50 years old (see *Times Higher Education 100 under 50 University Ranking)*. Then we examined the overall academic rating score of universities published in the *Webometrics Ranking of World Universities* and we built a dummy variable that equals 1 if the oldest parent is among the Top 500. In Portugal these are University of Lisboa, Technical University of Lisboa, University of Porto and University of Coimbra.

Parent Size was measured by dummies variables for each of the following cohorts: first cohort valued 1 if the parent have no graduates, which includes public research laboratories; second group valued 1 if the parent has an average number of graduates between 1 and 1499; third group valued 1 if the parent has an average number of graduates between 1500 and 2999; finally a group valued 1 for parents with an average number of graduates above 3000. *Parent Proximity* is a dummy variable that equals 1 if the firm is located less than 50 km from its parent, and zero otherwise and is aimed to proxy the importance of ties between the spin-off and its parent.

Differences in the characteristics of the region where the spin-off is located factors were measured by the covariates *Metropolitan Area*, a dummy variable that equals 1 if the firm is located in the metropolitan area of Lisbon or Porto at founding date, and zero otherwise. *High-tech*, which controls for potential spillovers and is measured by the ratio of the number of firms on high-technology industries the total number of firms in the municipality (Baptista and Mendonça, 2010) in which the firm is located. Following Eurostat, high-technology industries included high-tech and medium-high manufacturing firms and, also, knowledge intensive services (KIS). *Entry rate*, is the ratio of the number of new firms entry to the total number of firms in the municipality and measures the capacity of region on catch up start-up firms (Baptista and Mendonça, 2010).

As additional controls we included the covariate *Age*, measured as the number of years elapsed from the founding date. Older firms are more diversified and less risky than younger firms, which increases their likelihood of survival (Agarwal, 1997; Agarwal and Audretsch, 2001). Finally, sectoral dummy variables were included in order to control for differences in the technological regime as well as market specific differences in the sector in which the firm operates. The sectors included are: *Software*, *Biotechnology*, *Energy*, *Electronics*, *and Services.* Table 3.4 presents the descriptive statistics of the dependent variable and covariates and Table 3.5 the correlation matrix. Correlation analysis indicates low levels of correlations (<0.3). The highest correlation was between the *Parent Reputation* and *Parent Size* (0.55), suggesting that multi-collinearity was absent.

Table 3.4 - Descriptive statistics of dependent variable and covariates.

Variable	%	Min	Max	Mean	S.D.
Dependent variable					
Died	2.26				0.15
Covariates					
Founder PhD	39.13				0.49
Incubated	75.81				0.43
Start-up Size		0	60	2.56	5.80
Age		1	30	7.07	5.16
Parent Reputation	53.24				0.50
Parent Size [0]	11.02				0.31
Parent Size [1-1499]	03.01				0.17
Parent Size [1500-2999]	18.92				0.39
Parent Size [>3000]	67.04				0.47
Parent Proximity	88.19				0.32
Metropolitan Area	54.51				0.50
High-tech		-6.93	-1.85	-4.29	0.63
Entry rate		-5.62	-0.47	-3.92	1.10
Software	45.11				0.50
Biotechnology	14.90				0.36
Energy	12.90				0.34
Electronics	11.66				0.32
Engineering	05.19				0.22
Services	10.23				0.30

Notes: N = 266 firms, 2658 firm-year spells.

Table 3.5 - Correlations for the dependent variable and covariates.

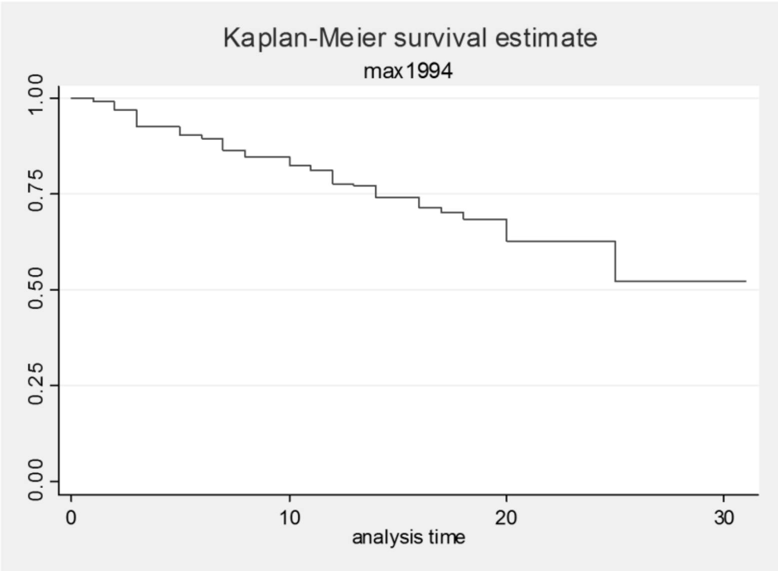
	1	2	3	4	5	6	7	8	9	10
Died										
Founder PhD	-0.02									
Incubated	-0.02	0.01								
Start-up Size	-0.05**	-0.02	0.10**							
Age	0.02**	0.01	-0.08**	0.08**						
Parent Reputation	-0.03	0.06**	0.12**	-0.05*	-0.03*					
Parent Size	-0.01	0.10**	-0.13**	-0.18**	-0.04*	0.55**				
Parent Proximity	-0.04*	0.03	0.10**	0.05**	0.10**	-0.07**	0.04*			
Metropolitan Area	-0.02	0.08**	0.09**	0.13**	0.09**	0.16**	-0.15**	0.15**		
High-tech	-0.08**	-0.03	-0.01	-0.04*	-0.10**	-0.06**	0.07**	-0.08**	0.09**	
Entry rate	-0.06**	0.02	-0.06**	-0.06**	-0.13**	-0.07**	-0.01	-0.15	-0.07	0.44

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

5. Results

The non-parametric estimation of the survivor function plotted in Figure 3.3 shows a survival rate of 99.27% after the first year, 89.52% after six years and 70.14% after seventeen years. These results are similar to those reported in previous empirical studies. In particular, Nerkar and Shane (2003) estimated a survival rate of 69% after seventeen years. Our results also reveal show that Portuguese RBSOs survival rate is superior to other Portuguese start-ups (Mata el al., 1995; Nunes and Sarmento, 2011).

Figure 3.3 - Kaplan- Meier Survival Function of Portuguese RBSOs.



In order to analyse the determinants of RBSOs' survival and test our hypotheses, we first use a semi-parametric approach and estimated a Cox proportional hazard (PH) model. This is shown in column (1) of Table 3.6. Considering that Portuguese spin-offs firms have different parent organisations and thus share common characteristics according to the parent of origin, we adjust the standard errors for a possible intra-parent correlation by clustering on the parent, and then obtained the robust estimates of variance. Regarding the proportional hazards assumption and based on Schoenfeld residuals test, we find no evidence that our specification violates the PH assumption (global chi-squared=8.42 with significance level 0.588).

Then we estimated the parametric proportional hazards models (Exponential, Weibull, Gompertz), columns (2) to (4) in Table 3.6. These models produce results that are directly comparable to those produced by Cox regression. In fact, in all PH models (semi-parametric or parametric), the exponential of estimated coefficient indicates the ratio of the hazard for a 1-unit change in the corresponding covariate, i.e., a positive coefficient reflects a higher hazard and a negative coefficient represents a smaller hazard. Thus comparing the estimated coefficients of the parametric models with those reported by Cox model we may verify that they are very similar evidencing an adequate parameterisation (Table 3.6).

Table 3.6 - Estimates of the determinants of RBSOs´ survival (Proportional Hazard Models).

	(1)	(2)	(3)	(4)
Covariates	**Cox**	**Exponential**	**Weibull**	**Gompertz**
Founder PhD	-0.155	-0.202	-0.148	-0.125
	(0.309)	(0.323)	(0.301)	(0.313)
Incubated	-0.086	-0.084	-0.027	-0.003
	(0.235)	(0.257)	(0.280)	(0.308)
Start-upSize	-0.620***	-0.579***	-0.650***	-0.713***
	(0.134)	(0.143)	(0.144)	(0.143)
Age	-0.249***	-0.001	-0.219**	-0.659*
	(0.094)	(0.038)	(0.087)	(0.368)
Parent Reputation	-0.417	-0.161	-0.539	-0.773***
	(0.295)	(0.369)	(0.333)	(0.225)
Parent Size [0]	-0.465	-0.135	-0.664*	-0.966**
	(0.383)	(0.309)	(0.367)	(0.467)
Parent Size [1-1499]	-0.577***	-0.130	-0.777***	-1.203***
	(0.207)	(0.195)	(0.219)	(0.270)
Parent Size [1500-2999]	-0.073	0.305	-0.259	-0.475**
	(0.206)	(0.300)	(0.307)	(0.230)
Parent Proximity	-0.569	-0.477	-0.455	-0.553
	(0.373)	(.340)	(0.411)	(0.496)
Metropolitan Area	-0.368	-0.333	-0.362	-0.358
	(0.323)	(0.272)	(0.357)	(0.432)
High-tech	-0.483	-0.558*	-0.578*	-0.495*
	(0.312)	(0.325)	(0.305)	(0.269)
Entry rate	-0.333***	-0.382***	-0.311**	-0.270**
	(0.117)	(0.120)	(0.140)	(0.132)
Software	-0.302	-0.188	-0.297	-.0307
	(0.330)	(0.401)	(0.392)	(0.306)
Biotechnology	-1.271***	-1.019***	-1.125***	-1.319***
	(0.216)	(0.280)	(0.242)	(0.177)
Energy	-1.938**	-1.591**	-1.869**	-2.137**
	(0.784)	(0.753)	(0.812)	(0.838)
Electronics	-1.112**	-1.010**	-1.136**	-1.172*
	(0.452)	(0.411)	(0.497)	(0.564)
Engineering	0.074	0.209	0.133	-0.097
	(0.316)	(0.369)	(0.372)	(0.332)
Constant		-6.090***	-7.151***	-4.733***
		(1.996)	(1.981)	(1.694)
Log-likelihood	-270.913	-148.701	-137.809	-128.417
AIC	561.826	317.402	295.618	276.834

Notes: Number of observations: 2658. Robust standard errors are shown in parentheses, clustered on the parent organisation. ***, **, * means significant at 1%, 5%, 10% level, respectively.

In order to select the parametric model that fits better our data we also estimated the Accelerate Failure-Time Parametric Models (Table 3.7)[10]. Since that only the exponential versus Weibull, and lognormal or Weibull versus generalised gamma are nested, we cannot use the likelihood-ratio and Wald tests to discriminate among all the parametric models. Considering the non-nesting evidence, an appropriate alternative is the Akaike Information Criterion (AIC). In assessing model fit, the AIC combines two criteria: parsimony and the log-likelihood. The smaller the AIC score, the more appropriate the model.

[10]In AFT models the effect of covariates is multiplicative with respect to survival time, whereas for PH models the assumption is that the effect of covariates is multiplicative with respect to the hazard. In the case of AFT models, the parameters measure the effect of the correspondent covariate on the mean survival time.

Table 3.7 - Estimates of the determinants of RBSOs´ survival (Accelerated Failure-Time Models).

Covariates	(1) Exponential	(2) Weibull	(3) Log-logistic	(4) Lognormal
Founder PhD	0.202	0.058	0.055	0.042
	(0.323)	(0.118)	(0.128)	(0.143)
Incubated	-0.084	-0.011	-0.011	0.079
	(0.257)	(0.111)	(0.111)	(0.135)
Start-upSize	0.579***	0.255***	0.241***	0.224***
	(0.143)	(0.046)	(0.043)	(0.040)
Age	0.001	0.086***	0.089***	0.087***
	(0.038)	(0.025)	(0.024)	(0.030)
Parent Reputation	0.161	0.212	0.266	0.275***
	(0.369)	(0.145)	(0.095)	(0.070)
Parent Size [0]	0.135	0.260	0.289	0.231
	(0.309)	(.149)	(0.227)	(.304)
Parent Size [1-1499]	0.130	0.305***	0.409***	0.448***
	(0.195)	(0.195)	(0.086)	(0.112)
Parent Size [1500-2999]	-0.305	0.102	0.179	0.219
	(0.300)	(0.078)	(0.110)	(0.134)
Parent Proximity	0.477	0.179	0.224	0.346**
	(0.340)	(0.127)	(0.163)	(0.176)
Metropolitan Area	0.333	0.142	0.137	0.159
	(0.272)	(0.151)	(0.168)	(0.182)
High-tech	0.558*	0.227*	0.239*	0.190
	(0.325)	(0.121)	(0.141)	(0.159)
Entry rate	0.382***	0.122*	0.125*	0.134*
	(0.120)	(0.068)	(0.074)	(0.074)
Software	0.188	0.117	0.124	0.160
	(0.401)	(0.159)	(0.173)	(0.205)
Biotechnology	1.019***	0.442***	0.406***	0.398***
	(0.280)	(0.103)	(0.119)	(0.133)
Energy	1.591**	0.733**	0.738**	0.755**
	(0.753)	(0.347)	(0.343)	(0.343)
Electronics	1.010**	0.446***	0.449***	0.528***
	(0.411)	(0.164)	(0.168)	(0.176)
Engineering	-0.209	-0.052	-0.073	-0.132
	(0.369)	(0.150)	(0.157)	(0.173)
Constant	6.090***	2.805***	2.665***	2.413**
	(1.996)	(0.897)	(0.976)	(1.069)
Log-likelihood	-148.701	-137.809	-139.543	-142.255
AIC	317.402	295.618	299.086	304.510

Notes: Number of observations: 2658. Robust standard errors are shown in parentheses. ***, **, * means significant at 1%, 5%, 10% level, respectively. Gamma model is not concave.

Comparing all parametric models, we conclude that Gompertz model fitted data better than other distributions in multivariate analysis. In fact this distribution presents the smallest AIC value and also the largest log-likelihood (see Table 3.6 and Table 3.7). Thus, we will comment on the Gompertz estimates.

Regarding the characteristics of the founding team, our results do not support our Hypothesis *1a*. Having a founding team member with PhD does not increase the likelihood of survival. This result seems to be in line with previous studies where there has been observed an ambiguous impact of founder's education on firm's performance (Helm and Mauroner, 2007). This result could also be explained by the argument that academic entrepreneurs have less skills regarding market and business management. However, in this regard we should be cautious in interpreting this result, as we do not know whether the PhD founding team member is actually an academic, though it is highly likely that it is.

Interestingly, being in an incubator does not seem to be relevant in determining the survival of the spin-off as the coefficient of the dummy variable *Incubated* is not statistically. Hence Hypothesis *1b* is not supported by the data, which raises some doubts regarding the importance of incubation on long-term spin-off survival.

However, *Start-up Size* does seem to be key in explaining spin-off survival since results show that a one-employee increase on start-up size decreases the hazard by 50.98%, therefore providing support to Hypothesis *1c*. This result is in line with previous evidence (e.g. Geroski et al., 2010). Likewise, if we consider the firm´s age, the results are in agreement with previous empirical studies, where older firms have higher probability of survival (Agarwal and Audretsch, 2001; Agarwal and Gort, 2002). One-year increase on *Age* decreases the hazard by 48.26%. Together, these results suggest that the key firm-level characteristics in determining RBSO spin-off survival are not different from those that are relevant to any other start-up.

Regarding parent characteristics results show a positive impact of *Parent Reputation* on the survival of the spin-off firm. If the parent is classified among the top 4 ranking then its spin-off faces a hazard that is 46.16% of the hazard faced by spin-offs coming from a parent that is not in the top 4 ranking, therefore providing support to our Hypothesis *2a*. This result is consistent with previous evidence that has found a positive role of intellectual eminence of the parent organisation on spin-offs´ survival (Di Gregorio and Shane, 2003; Link and Scott, 2005; Powers and McDougall, 2005).

Interestingly, we do not observe a monotonic relationship between *Parent Size* and spin-off survival hence Hypothesis *2b* is not supported. Indeed, results show that the smallest cohort of the variable *Parent Size* has a positive impact on the spin-off survival. Specifically a spin-off from a public research laboratory (parent with no graduates) is thus estimated to face a hazard that is 38.06% of the hazard faced by firms with a larger parent. Then, the hazard decreases in the following cohort as spin-offs from parents with an average number of graduates between 1-1499 are estimated to face a hazard that is 30.03% of the hazard faced by firms with a larger parent. Then, spin-offs whose parents have an average number of 1500-2999 graduates face a hazard that is 62.19% of the hazard faced by firms with a larger parent (number graduates above 3000). These results are then suggesting that being spin-off from parents with more graduates does not bring any additional advantage regarding survival.

Likewise, being located near the parent does not seem to have an impact on spin-offs survival. This result corroborates previous contributions that have argued that physical proximity may not be a necessary condition for knowledge exchange, as other types of proximity, such as cultural, organisational and relational proximity, might provide the advantages of physical proximity to firms' innovation activities (Helmers and Rogers, 2011) and that being located near the parent is simply the result of a preference among academics and not so much as the exploitation of social ties (Zucker et al., 1998). Thus Hypothesis *3c* is not supported.

Results show that the being located in a metropolitan area is not important in determining RBSOs survival, meaning that our Hypothesis *3a* is not supported. However, when the firm is located in a municipality with high density of firms on high-technology industries this decreases the hazard, i.e., a unit increase on high-tech firms rate decrease the hazard by 39.04%. This result supports our Hypothesis *3b*, thus the view that spillovers effects may be an important driver of RBSOs survival. Additionally, results also provide support for the positive influence of agglomeration economies on innovation (Magrini and Galliano, 2012). Spin-offs located in municipalities with higher capacity to capture start-up firms have higher probability of survival. Estimates show that a unit increase of the variable *Entry Rate* decreases the hazard by 23.66%. Thus, Hypothesis *3c* is supported.

Finally, results show that the probability of survival varies according to the sector in which the spinoff operates. Specifically, RBSOs operating in the *Biotechnology*, *Energy* and *Electronics* have smaller hazard than firms operating in *Services*.

In order to check the robustness of our findings we reestimated our model controlling for parent organisation fixed effects. We fit a standard fixed effects model including indicator variables for parent clusters. In this model the effect of the parent organisation are treated as fixed and share the same baseline function, i.e., we assume that the parent has a direct multiplicative effect on the hazard function.

Assuming the Gompertz distribution the fixed effects model presents similar results *vis-a-vis* the model with cluster (see Table 3.8). Estimates show a positive impact on RBSOs´ survival probability of *Start-up Size*, *Age* and location of spin-off firms in municipalities with high entry rates (*Entry Rate*) and high density of high-technology firms (*High-tech*). However, being located in a metropolitan area has now a significant and positive effect on survival. A RBSO located in a metropolitan area faces a hazard that is 51.43% of the hazard faced by a non-metropolitan firm, therefore providing support to Hypothesis *3a*. In both models the Gompertz model presents a positive shape parameter ($\gamma > 0$) thus we conclude that the hazard increases exponentially with time.

Table 3.8 - Estimates of the determinants of RBSOs´ survival (Robust-cluster and Fixed Effects Models).

Covariates	(1) Cluster	(2) Fixed effects
Founder PhD	-0.125 (0.313)	-0.133 (0.302)
Incubated	-0.003 (0.308)	-0.234 (0.352)
Start-upSize	-0.713*** (0.143)	-0.690*** (0.146)
Age	-0.659* (0.368)	-0.742*** (0.172)
Parent Reputation	-0.773*** (0.225)	_
Parent Size [0]	-0.966** (0.467)	_
Parent Size [1-1499]	-1.203*** (0.270)	_
Parent Size [1500-2999]	-0.475** (0.230)	_
Parent Proximity	-0.553 (0.496)	-0.175 (0.406)
Metropolitan Area	-0.358 (0.432)	-0.665* (0.349)
High-tech	-0.495* (0.269)	-0.640*** (0.239)
Entry rate	-0.270** (0.132)	-0.342* (0.182)
Software	-0.307 (0.306)	-0.477 (0.384)
Biotechnology	-1.319*** (.177)	-1.682*** (0.526)
Energy	-2.137** (0.838)	-2.532** (0.805)
Electronics	-1.172* (0.564)	-1.229** (0.652)
Engineering	-0.097 (0.332)	-0.152 (0.569)
Fixed Effects	_	YES
Constant	-4.733*** (1.694)	-7.798*** (1.734)
Log-likelihood	-128.417	-121.565
AIC	276.834	293.130
Gamma	0.81242	0.90211

Notes: Number of observations: 2658. Robust standard errors are shown in parentheses in column (1) and standard errors in column (2). ***, **, * means significant at 1%, 5%, 10% level, respectively.

Considering the group effect analysis we also reestimated our model controlling first for random effects (shared frailty) and second for a stratified assumption (Cleves et al., 2010). In the case of the shared frailty we model correlation by assuming that it is induced by an unobserved random effect, or frailty, that is, shared among a group that have the same characteristics and by specifying the distribution of this random effect (gamma and inverse-gaussian distributions). The likelihood-ratio test on the hypothesis that the frailty variance (theta) is equal to 0 presents a p-value of 1.000 and thus we find an insignificant frailty effect, i.e., no evidence of an unobserved heterogeneity.

In alternative we run a stratified model. In this case we allow baseline hazards to be different for each stratum (parent) rather than constraining them to be multiplicative versions of each other as in fixed effects model. According to Wald tests none of the baseline hazards is significantly different from the other.

6. Conclusions and policy implications

Previous studies have shown high levels of survival of RBSOs as soon as these exceed the so-called period of "infant mortality". Yet, few studies have focused on the determinants of these high survival rates. This paper fills this gap by providing evidence using a unique self-collected data base that comprehends the population of RBSOs created in Portugal from 1979 until to 2007. Specifically, we investigate the role of three types of effects that have been put forward in literature as being relevant to understand the survival of these particular firms, namely founding conditions, parent organisation characteristics and region characteristics where the spin-off firm is located.

Our results suggest that start-up size is the founding condition that matters most to determine RBSOs´ survival, where the larger the start-up size the lower the probability of exit by the firm. The possession of a PhD degree by the team founders and the fact that the spin-off was in an incubator do not seem to be relevant in discriminating survival rates among spin-off firms. In this regard our results indicate that certain inherent characteristics common to RBSOs are less important to explain differences among survival rates than the well-known start-up size effect that has been found in firm survival studies and is common across different types of firms. A similar interpretation applies to the role of age where the older the spin-off is the lower the likelihood of exiting the market, which is in line with most survival studies.

Regarding the parent organisation characteristics, intellectual eminence or reputation and size seem to exert an important effect on spin-off survival. An interesting result that emerges from our data is that of non-linearity in the relationship between parent size and spin-off survival. In fact being a spin-off from the largest parent does not increase the likelihood of survival when compared to smaller parents. A possible explanation could be that smaller parents are more concerned about their spin-offs survival as spin-offs may contribute to increase their market recognition, whereas larger parent organisations do no feel the same kind of pressure.

Another interesting result regards the spin-off physical proximity to its parent organisation. The non-significance of this covariate suggests that being located near its parent is more the result of a preference by academics rather than the importance of social ties, which corroborates Zucker´s (1998) findings. However, being located in a metropolitan area and in municipalities with high density of firms on high-technology industries and high entry rates seems to be important factors influencing the survival of spin-offs corroborating the largely accepted view of the importance of local spillovers and agglomeration externalities in determining firms´ survival. As such, there seems to be no difference between RBSOs and other start-ups regarding the region´s role on their survival.

Our results provide several implications from a policy point of view. First, public policy and parent organisations should support RBSO firms by helping them to have more employees since their set-up. Second, parent organisations should focus their efforts in promoting their reputation as this intangible asset exerts a strong positive effect on survival. Third, local governments should implement policies that help the start-up of firms and contribute to the ease of doing business, so that they can attract new firms into the region, as agglomeration economies and spillovers effects are more important to spin-offs survival than being located in an incubator.

A limitation of our data is that it does not allow us to properly identify the industry in which the firm operates according to the economic classification. We are only able to identify the technology area. Thus, two important lines for further research would be to explore the role played by market characteristics, namely competition, and by individual characteristics of the founding team members.

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IV. The commercialisation decisions of research-based spin-offs: targeting the market for technologies [11]

Abstract

This paper addresses the commercialisation decisions of research-based spin-off firms (RBSOs), focusing on the case of companies specialising in the production and sale of intellectual property – a model of entrepreneurial behaviour increasingly frequent in science-based fields and that research-based spin-offs may be more prone to adopt, given their specific characteristics. Combining insights from the economics of technological change and the strategic management of technology literature, we discuss the conditions that can influence firms' ability to operate in the market for technology, and advance some theory-driven hypotheses regarding key factors that are likely to determine it – nature of knowledge being exploited, appropriability conditions, location and degree of control upon complementary assets and institutional setting of origin – as well as their impact upon firms' decisions. These hypotheses are tested on a group of 80 European RBSOs, using data collected specifically for this purpose, on the basis of questionnaire-based interviews. This research adds to recent work on the determinants of the commercialisation strategy of technology-based SMEs, but by focusing on a particular group of companies – the RBSOs – we also take into consideration some distinctive characteristics of this group, which introduce some specificity in their innovative behaviour.

1. Introduction

Research-based spin-off companies (RBSOs) have recently become the focus of technology and innovation policies, being regarded as an instrument for the commercial exploitation of knowledge produced in public sector research organisations (Wright et al., 2007). However, contrary to what is often assumed by policy makers, RBSOs are

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heterogeneous companies, created in a diversity of conditions and displaying a variety of behaviours (Mustar et al., 2006), with implications for the role(s) they effectively play in the transformation of scientific and technological knowledge into economic value.

One potential source of heterogeneity is the strategy adopted by the RBSO to commercialise their knowledge assets. In fact, RBSOs may opt for selling or licensing their technology or rather, decide to pursue with the development of products or services based on it. This is a major strategic choice for start-ups (Arora et al., 2001), which can have an "imprinting" effect (Eisenhardt and Schoonhoven, 1990) and that is conducive to different modes of behaviour and thus to heterogeneity in the functions performed by RBSOs. To engage in the development of products or services and to bring them to the market, alone or in alliance with other firms, is the most typical strategy. However, the case of firms that specialise in the production and sale of intellectual property and thus operate in the "market for technologies" (Gans and Stern, 2003) is becoming more frequent, particularly in fields where markets for technology are more developed (Chesbrough, 2006). It remains, nevertheless, a relatively less understood phenomenon.

However, we believe that this particular strategy deserves greater attention. In fact, it can be argued that the firms adopting it perform a qualitatively different but relevant function in the innovation system. They conduct the upstream transformation of scientific knowledge in still basic, but already tradable technologies (Autio, 1997), thus acting as specialised technology brokers, that transform and "package" knowledge, making it visible and intelligible to firms, which might be interested in it. Considering that advanced knowledge developed by research organisations goes frequently unexploited – due to the difficulties often experienced by existing firms in identifying it and to the presence of knowledge asymmetries between knowledge producer and user that make their disembodied transfer and absorption particularly complex (Dasgupta and David, 1994) – this function can be an important element in the dissemination of advanced knowledge that should be acknowledged and sustained by policy makers. Thus, it is important to gain a better understanding of the factors that enable its performance, in order to assist the decision making process of spin-off entrepreneurs as well as to inform policy formulation.

This paper addresses the strategic decision made by RBSOs regarding the mode of commercialisation of their technology and its objective is exactly to understand the conditions associated with the option for selling or licensing intellectual property, as the firm main business. Drawing on two main theoretical sources – the economics of technological change and the strategic management of technology – and combining them with insights from previous research on the behaviour of new technology-intensive firms, we advance a number of factors that are expected to influence RBSOs' ability to adopt this commercialisation strategy and formulate a number of hypotheses regarding their impact upon RBSO decisions. These hypotheses are subsequently tested on a sample of European RBSOs.

Our research adds to recent work on the determinants of the commercialisation strategy of technology-based SMEs (Gambardella and Giarratana, 2007; Gans et al., 2002; Giuri and Luzzi, 2005; Hicks and Hedge, 2005; Novelli and Rao, 2007; Pries and Guild, 2007). However, by focusing is on one particular type of technology-based company – the RBSO – we take into consideration the specific characteristics of these companies, which are not addressed in other research and which may, in some cases, favour the operation in the markets for technology.

2. Commercialisation strategies of RBSOs

RBSO are, by definition, firms set-up to exploit scientific and technological knowledge developed in academic research (Mustar et al., 2006). In order to pursue with this goal, the new firm has to make a key strategic choice regarding the mode of capturing value from its knowledge assets: it may sell/license the actual technology, or engage in the development of products or services based on it. The decision on how to transform knowledge in economic value also corresponds to a strategic decision on the type of market to target: firms can opt for trading in the market for technologies, or chose to trade in the market for products (Arora et al., 2001). Firms that engage in product development may also chose to simultaneously sell (part of) their technologies, for various reasons (Lichtenthaler, 2008), although this option is less likely in resource constrained start-ups. These may nevertheless engage in some technology trade activities, while developing the core product (Kollmer and Dowling, 2004). The requirements for operating in each type of market are different (Gans and Stern, 2003) and thus, to explain the decision made by RBSOs concerning the mode of commercialisation of their technologies, it is necessary to understand the conditions that enable start-ups to comply with those requirements.

Early choices made by the entrepreneurs are not necessarily definitive. Subsequent learning processes may correct decisions made under limited information (given high technological and market uncertainty often coupled with lack of business experience) (Costa et al., 2004). Technological and market volatility may require adapting to changes in the competitive conditions (Druilhe and Garnsey, 2004). But even if firms' strategies can be readjusted through time, early choices are important because they will have an "imprinting effect" upon the company created (Eisenhardt and Schoonhoven, 1990; Stinchcombe, 1965). In fact, they influence the configuration of the new firm, guiding decisions regarding resource mobilisation, competence development and search for relationships. They may also constrain the firm's subsequent evolution, by reducing the margin for later choices (Arora and Gambardella, 2010). The decision on the mode of commercialisation is, therefore, a major strategic choice for start-ups, with impact on the organisation of their innovative activities, on the outcome of these activities and on the way they interact with their environment and thus on the functions played by the firms in the innovation system (Autio, 1997).

This research focuses on the companies that target the market for technologies – that is, markets where technology is traded in the form of intellectual property (IP) or other intangible forms, rather than embodied in products or processes (Arora et al., 2001). The option for trading in intellectual property assets – and particularly for doing it as the main business and not as a complementary or a transitory activity, while the core product or service is being developed – has been an exception, until recently (Teece, 2006). However, we observe an increase in the number of companies that adopt this commercialisation strategy (Chesbrough, 2006; Hicks and Hedge, 2005; Pries and Guild, 2007), which can be explained by institutional changes in the organisation of the academic system, the division of labour between private and public organisations, the intellectual property rights system and the financial system (Antonelli and Teubal, 2008; Arora and Gambardella, 2010; Bekkers et al., 2006; Coriat et al., 2003; Wright et al., 2007). These changes enabled extensive patenting of results of public research and encouraged company formation to exploit them, leading to the emergence of firms that perform basic research, appropriate its results through patenting and whose assets are intellectual property rights (IPR) instead of products or services, but who are able to obtain capital on the basis of the value attributed to that IP. The expansion of markets for technology, triggered by the strengthening of appropriability regimes and by changes in the technology strategies of large firms, created new opportunities for these research-based firms, enabling them to co-exist with established ones, to whom they act as specialised suppliers of contract research and basic technologies (Arora et al., 2001; Chesbrough, 2006).

The functions performed by these new firms can be viewed at the light of the "technological articulation process", described by Autio (1997), through which scientific knowledge is transformed in basic technologies, still generic in nature, which are then transformed into application specific technologies. Different actors will be involved in these processes, which may configure specific niches for different categories of firms. The first, upstream, transformation is more likely to be conducted by "science-based firms", which display characteristics that are frequently present in spin-offs from research. The tasks involved in this upstream transformation may not be easily tackled by people, who were not involved in the original development of the technology (Zucker et al., 1998) and can thus configure a business in itself, with which scientific entrepreneurs may find particular affinity.

In fact, RBSOs may be especially prone to engage in this type of business. First because the nature of the knowledge they are exploiting – scientific or technological knowledge originating from academic research – favours it (Jong, 2006; Shane, 2001). Second because it may be cognitively closer to founders' skills and identity as researchers: RBSOs entrepreneurial teams usually involve at least (or exclusively) some of the academic scientists, who developed the technology and thus scientific competences and networks, are likely to be prevalent, even if some teams integrate individuals with managerial experience (Ensley and Hmieleski, 2005; Murray, 2004). Finally, because RBSOs originate from a non-commercial environment, which not only may have culturally shaped the individuals involved in their creation, but can also exert (directly or indirectly) some influence on the decisions made at start-up, while being less likely to provide support in the access to non-technical competences and resources (Clarysse et al., 2005; Rothaermel and Hill, 2005). Thus RBSOs can be regarded as a particularly interesting setting to investigate this emerging strategic behaviour.

Despite some recent interest in this commercialisation strategy (Bekkers et al., 2006; Gans et al., 2002; Hicks and Hedge, 2005; Kollmer and Dowling, 2004), the conditions that are behind the emergence of these firms and that sustain their development are still relatively less understood, which makes them a relevant object of analysis. The particular case of RBSOs is even less explored: while some authors have described spin-offs' business models that fit within the technology trade strategy (e.g. Druilhe and Garnsey, 2004; Stankiewicz, 1994), attempts to explain the behaviour of these firms are rare (Pries and Guild, 2007). That is, therefore, the objective of this research.

Thus we formulate the following research questions:

- Which factors influence RBSOs start-up decision to target technology markets?
- Which factors influence RBSOs ability to operate in technology markets as the firm main business (at a steady state)?
- How determinant is the early decision in the subsequent positioning?

3. Conceptual framework

Our approach to the factors that influence RBSOs decision on the commercialisation strategy combines insights from two main theoretical sources: the economics of technological change and the strategic management of technology. Drawing on these two streams of literature we build a conceptual framework whose starting point is the notion that the main asset possessed by RBSOs is their knowledge/technology (Shane, 2001) and that, therefore, firms' decisions will be influenced by two types of factors: (a) those related with the technology and the nature of knowledge underlying it (Dosi, 1988; Malerba and Orsenigo, 1993); (b) those related with conditions that enable firms to capture the value from their technology (Arora et al., 2001; Gans and Stern, 2003; Teece, 1986). More specifically, we propose that the "technological imperatives" associated with the nature of the knowledge being exploited are likely to have a strong impact upon and thus condition/shape the commercialisation strategy adopted by the RBSO. But, since the capacity to profit from innovation requires going beyond the sole consideration of those imperatives, we also propose that the nature, location and mode of deployment of a set of non-technological competences and resources (described in the literature as "complementary assets") will equally influence the RBSOs' strategic choices. In addition, we propose that some features related with RBSOs academic origin and founders' background are likely to influence the decision process, namely through their impact upon the above mentioned dimensions (Vohora et al., 2004). The entrepreneurs' previous experience and networks can equally have a lasting effect on the ability to pursue with the chosen strategy (Barringer et al., 2005; Mosey and Wright, 2007; Wiklund and Shepherd, 2005).

In line with this framework, we advance that RBSOs decision regarding the commercialisation strategy will be influenced by four types of factors: (1) nature of knowledge being exploited; (2) appropriability conditions, i.e. capacity to protect the technology; (3) location and control of key complementary assets; (4) characteristics of the source environment, expressed both through the direct or indirect influence of the parent organisation and through the impact of founders background upon the firm early competence base. A variety of other factors – e.g. associated with founder personal characteristics, with funding modes and sources, with institutional incentives or government support policies and other environmental influences – may potentially have some influence on RBSOs decisions. However, we decided to focus on the more structural factors, which we expect to have a shaping effect upon the new company and therefore to be more powerful as determinants of this type of commercialisation strategy. These factors may impact differently upon the decision to target a given market and upon the ability to operate in that market (at a steady state) as the firm main business. We also advance that the start-up choice made by firms regarding the mode of commercialisation of their technologies will have an imprinting effect, thus contributing to determine firms' subsequent activity.

In the next sections we present in detail the theoretical foundations of this framework and formulate several hypotheses regarding how these factors influence the commercialisation strategy of RBSOs, focusing on the decision to target the market for technologies, which we will label as "technology market (commercialisation) strategy".

3.1. The impact of the nature of knowledge on RBSOs strategic decisions

In order to address the impact of factors related with the nature of knowledge being exploited upon the commercialisation strategies of RBSOs, we draw on the economic theory of technological change and particularly on the approach introduced by the "technological regime" framework (Malerba and Orsenigo, 1993; Nelson and Winter, 1982). Malerba and Orsenigo (1997), drawing upon Dosi (1988) description of the dimensions that characterise a technological regime, operationalise it as a combination of some fundamental properties of technologies: opportunity and appropriability conditions, degree of cumulativeness of technological knowledge and characteristics of the knowledge base, which include: levels of pervasiveness/specificity, tacitness and complexity. Opportunity is defined as the ease of innovating for a given investment in search for new solutions; appropriability as the possibility to protect innovations from imitation; cumulativeness as the extent to which current innovative activities are based on knowledge and innovations developed in previous periods (Breschi et al., 2000).

These properties provided an analytical device to address the nature of the technologies being exploited by RBSOs. According to this literature, conditions of high technological opportunity, particularly when associated with pervasiveness, high appropriability and low cumulativeness appear to be the most favourable for small entrants exploring new technologies (Malerba and Orsenigo, 1993; Marsili, 2002; Winter, 1984). When we consider exclusively the entry conditions regarding the nature of technology, it is to be expected that firms willing to operate in markets for technology will have stringent requirements concerning level of opportunity, pervasiveness and also of appropriability, since formal appropriation mechanisms are often the only effective means of protection for small firms (Hall, 2005). This argument is supported by the very limited research that took into consideration the impact of the nature of technology upon the strategic decisions of technology intensive companies. For instance, Hicks and Hedge (2005) concluded that small patent-based specialist suppliers that manage to survive and have long lasting success in the markets for technology, develop technology that is more general purpose, has a broader range of applications, has higher quality and is also more basic and closer to science. Similarly, Gambardella and Giarratana (2007), drawing on Bresnahan and Trajtenberg (1995) analysis of general-purpose technologies, concluded that the presence of those technologies favour technology trade, and thus that they are more likely to be licensed. Conversely, the generality of the technology can have a negative impact on new product development, because it makes it less suitable for specific application. Additionally, Shane (2001) found that the exploration of more important (measured through the economic value of invention), more radical and broader inventions was more likely to be conducted through a new firm.

RBSOs origin may provide them with the conditions to fulfil some of these requirements, although some variety is to be expected in that respect. In fact, since RBSOs are created to exploit new technological opportunities derived from academic research, it can be assumed that they will be operating under high opportunity conditions (Malerba and Orsenigo, 1993), as well as that scientific advances are often their main source of technological opportunity, as opposed to technological advances originating from the industry (Klevorick et al., 1995). The fact that firms are exploiting knowledge originating from academic research has three types of implications. First, knowledge that originates from outside the industry is less likely to be cumulative and when non-cumulative knowledge plays a more important role as source of opportunity, new firms are better positioned in relation to incumbents (Winter 1984). Second, new scientific knowledge is likely to be easier to appropriate, either because it benefits from the "natural excludability" often associated scientific discoveries (Zucker et al., 1998); or because its actual novelty and its abstract and codified nature makes patenting more viable (Saviotti, 1998). Third, new scientific knowledge – particularly the one associated with more basic research – tends to be generic in nature (Klevorick et al., 1995), opening up of a variety of search trajectories (Saviotti, 1998). This also means that these technologies are likely to be characterised by high pervasiveness, i.e. the possibility of using the same core knowledge in a variety of applications (Malerba and Orsenigo, 1993). In addition when pervasiveness is high, cumulativeness may not be a deterrent for new entrants, since diversified and specialist firms occupying different niches may co-exist, assuming different (and often complementary) strategic positionings, as the cases of biotechnology and more recently nanotechnology amply document (Orsenigo et al., 2001; Zucker et al., 2007).

The above discussion supports the formulation of a number of hypotheses concerning the impact of the nature of knowledge on RBSOs decisions on the commercialisation strategy. The presence of general purpose or pervasive technologies can provide firms with a "platform" that supports a continuous stream of developments (Bresnahan and Trajtenberg, 1995), which is critical for firms that intend to operate in technology markets (TM) in a sustained way. On the other hand, more generic technologies also tend to be more distant from applications and thus to be more difficult or take longer to convert into products (Gambardella and Giarratana, 2007). Therefore:

H1a. RBSOs are more likely to be in TM when they have pervasive technologies.

Technologies with a greater component of new knowledge can be more valuable for potential acquirers and thus offer a competitive advantage in the TM. Given their novelty they also have a greater possibility of being patented, as well as to provide more valuable patents (Shane, 2001), which, as we will see below, is equally important when operating in TM.

H1b. RBSOs are more likely to be in TM when they are exploring technologies that involve a high component of new knowledge.

Finally, since RBSOs technological competences are largely embodied in the founders, the type of technological experience and networks these possess also contribute to the nature of technological knowledge present in the firm (Ensley and Hmieleski, 2005). It can be argued that RBSOs that only have founders with academic research experience, as opposed to technological experience in industry, will be more likely to prefer to engage in research activities and build a technological portfolio, rather than to engage in the activities required to transform that technology in products, which require different skills (Marsili, 2002).

H1c. RBSOs are more likely to be in TM when they are created by founders whose technological backgrounds are exclusively academic.

3.2. Factors related with capturing value from the technologies

Despite the critical importance of the knowledge/technology asset, the transformation of technologies into products and their commercialisation requires the consideration of other aspects that are instrumental in enabling firms to capture the value from their technologies. This question has been addressed in greater detail by the strategic management of technology literature and particularly by the branch that focus on the markets for technology (e.g. Arora et al., 2001; Gans and Stern, 2003).

This literature draws a great deal on Teece (1986) seminal approach to the alternatives and also the hazards faced by firms in the introduction of their innovations in the market. The key dimensions of Teece analysis – the appropriability conditions and the nature, location and mode of deployment of a set of specialised non-technological competences and resources, that cannot be easily acquired in the market but are needed to capture rents from the innovation, labelled "complementary assets" – are retained as the basic analytical structure. Following Teece, the combination between these two factors is at the root of recent research on the conditions faced by young firms commercialising new technologies (Gans and Stern, 2003; Giuri and Luzzi, 2005; Novelli and Rao, 2007). However, these approaches move beyond Teece, by proposing that, in some conditions, it is possible for (small) innovating firms to avoid the ownership of specialised assets and still capture rents from their innovations, due to the development of the markets for technology (Arora et al., 2001).

3.2.1. Research on commercialisation strategies of technology intensive firms

Maybe the most comprehensive analysis was the one conducted by Gans and Stern (2003), who discuss the conditions in which new firms should compete directly in the product market with established firms; and those in which they should enter into agreements with them to take the technology to the market. One key aspect of this approach is that it explicitly considers the possibility that established firms both control key complementary assets and have an incentive to appropriate the innovation, thus making alliances with them potentially more risky. The drivers behind the choice are, therefore, the capacity to preclude imitation by incumbents, and the extent to which incumbents own complementary assets that contribute to the value proposition of the technology.

This issue has been empirically addressed by Gans et al. (2002) and a few other authors (Gambardella and Giarratana, 2007; Giuri and Luzzi, 2005; Kollmer and Dowling, 2004; Novelli and Rao, 2007; Pries and Guild, 2007). These authors typically address the case of patent-based small firms and consider the range of strategic options open to them and the factors that influence their strategic behaviour. Their research puts some emphasis on identifying and delimiting a strategy that focuses on technology trade and on distinguishing it from strategy(ies) focusing on product/service development. The distinguishing element between what can synthetically described as "technology market" and "product market" strategies is always whether the technology is sold as a disembodied good, or is incorporated into physical artefacts. But the way the strategies are defined depends on the way the various authors address the modes on which such incorporation takes place; and the relationship that the small supplier establishes with the buyers of the technology. In particular, the nature of the discussion on the role of specialised complementary assets depends on whether the authors focus exclusively on the in-house development of these assets, or also consider the possibility of establishing agreements with their owners. In our view this is a non negligible issue. In fact, Gans and Stern (2003) important insight about incumbents who have an incentive to expropriate the innovation, suggests that the viability of establishing such agreements in relatively advantageous conditions can be a key element in decisions on the commercialisation strategy.

Additional contributions come from the literature on technology licensing that discusses the conditions in which firms decide whether or not to license their technology, and how such licensing takes place (Arora and Fosfuri, 2003; Arora and Merges, 2004; Gambardella et al., 2007; Kollmer and Dowling, 2004). While most of this literature does not focus specifically on start-up companies, firm size or age often emerge as an important dimension in the decision process: strategies of small/young firms are found to be diverse from those of larger established firms and tend to be more strongly influenced by the level of IP protection and the conditions in the market for downstream assets.

On the whole, these various streams of literature seem to converge in the conclusion that the appropriability regime and the access to complementary assets (under various forms) are key elements in firms decision concerning the modes of technology commercialisation and that small technology intensive firms – and especially start-ups – given their limited resources and reduced bargaining power, are particularly vulnerable to conditions at these levels. They also suggest that, while the decision to concentrate on technology trade, avoiding the development of production/commercialisation assets, can be a favourable strategy to new entrants endowed with strong technological competences, this strategy has quite stringent requirements. These concern both the characteristics of the technology (e.g. its novelty, uniqueness and the ability to make its advantages known to potential buyers) and the strength of the IP protection. The strategy also has risks, mainly derived from engaging in contractual agreements with more powerful companies that may have an incentive to appropriate the technology. Given these risks and requirements, technology intensive start-ups should consider carefully the circumstances surrounding the commercialisation process and the alternatives open to them.

Thus, in order to fully understand the conditions that influence the RBSOs decision process, it is necessary to look in more detail into these aspects of the appropriability regime and access to complementary assets that are most relevant for this category of firms.

3.2.2. The impact of appropriability regime on RBSOs strategic decisions

The appropriability regime can be defined as the conditions concerning the protection of intellectual property assets against imitation, either through legal mechanisms (e.g., patents, copyright, formal non-disclosure agreements) or "natural" barriers to imitation, afforded by characteristics of the technology (tacitness, difficulty in reverse engineering) (Pisano and Teece, 2007; Zucker et al., 1998). In general, higher appropriability conditions increase the likelihood that companies earn profits from their innovation. But appropriability levels differ between sectors (Hall, 2005) and the appropriability mechanisms that are available and effective also vary (Hurmelina-Laukkanen and Puumalainen, 2007).

While there is some debate about the means through which small technology intensive companies can protect their intellectual assets, there is more agreement on the literature about the case of small technology suppliers, who wish to sell or license their technology. Legal protection, namely through patents, is regarded as indispensable (Arora and Merges, 2004; Gans et al., 2002), even if it is recognised that these firms may find it difficult to withstand cases of litigation. In fact, strong IP protection through patents, not only defends the supplier from expropriation, but also facilitates technology trade, by reducing the asymmetry of information that characterise transactions in technology markets (Arrow, 1962) and thus lowering transaction costs for both suppliers and buyers (Gambardella and Giarratana, 2007).

The above discussion enables us to put forward some hypotheses concerning the impact of appropriability conditions on RBSOs commercialisation strategies. First of all it suggests that legal protection through patents is critical for RBSOs operating in the markets for technology. However, appropriability conditions and effectiveness of patents as a protection mechanism differ between industries, which mean that the appropriability regime prevailing in a given industry will constrain the actual presence of markets for technology and RBSOs ability to operate in these markets. Thus, entrepreneurs' perceptions about the appropriability conditions in the industry segment where they are willing to operate may influence their strategic choice. Therefore:

H2a. RBSOs are more likely to be in TM if they operate in sectors where level of appropriability is (perceived as) higher.

While patent protection is usually described as the most effective mode of IP protection for RBSOs operating in TM, patents may not be a distinctive feature since they may also be used by firms developing and selling new products, as protection against imitation or for other strategic reasons (Arora and Ceccagnoli, 2006). However, the latter may have more possibilities to resort to alternative protection mechanisms and thus may give relatively less importance to patents or attribute them different roles (Cohen et al., 2000). Therefore, we can also hypothesise that:

H2b. RBSOs that operate in TM are more likely to have patents and to attribute them higher importance as protection mechanisms (as compared with other mechanisms).

The conditions, on which the knowledge was developed, namely the role effectively played by the parent research organisation, are also relevant, since they may influence both the nature of the knowledge and their protection status. It can be argued that when the knowledge being exploited was mostly developed still in the research organisation (as opposed to being mostly developed in the new firm on the basis of founders' tacit knowledge) there is a greater possibility that it was patented. In fact, not only new scientific knowledge is, in principle, more patentable, but research organisations are putting growing emphasis on patenting (Wright et al., 2007). These patents are often transferred or licensed to the new firm, granting it protection from start-up. In addition, patents filed by a reputed research organisation can have a function of quality endorsement of RBSOs (Lichtenthaler and Ernst, 2007). Thus presence of parent patents creates favourable conditions for operating in TM. This option may be further encouraged by the fact that inventions originating from the university tend to be more fundamental, generating patents of an embryonic nature, still needing substantial development before commercial application (Thursby et al., 2001). Therefore:

H2c. RBSOs are more likely to be in TM when they start-up with technology protected by patents granted to the parent organisation.

3.2.3. The impact of complementary assets on RBSOs strategic decisions

New firms engaging in the transformation of their technology into marketable products or services are confronted with the need to gain access (building or acquiring from others) to a number of non-technological assets (physical assets or knowledge and skills) that are necessary to sell a complete product or service: e.g., manufacturing capacity, marketing, sales and distribution, regulatory knowledge (Teece, 1986). Access to assets that are external to the firm can be done through market acquisition or through alliances with the owner (Aggarwal and Hsu, 2009). Those assets can be generic and supplied by the market in competitive conditions; or co-specialised to the innovation (Teece, 1986). The latter may not be readily available in the market, since their owners try to achieve control over them, and they may also be difficult to imitate, because they are built on the basis of a process of learning within the firm (Rothaermel and Hill, 2005).

The basic line of argument when discussing the commercialisation strategy of small technology-intensive firms is that when appropriability regimes are weak (and thus imitation relatively easy) the possibility to capture rents from the innovation depends on (privileged) access to complementary assets, specialised to the innovation, that are required to produce and commercialise it (Teece, 1986). New entrants will thus face a choice: they can build the key complementary assets internally; they can try to gain access to them, through market transactions or through alliances; or else they can avoid engaging in downstream activities at all (Arora et al., 2001). This choice can be addressed at two levels:

(a) that of the viability of gaining access to these assets in reasonably favourable conditions; and (b) that of the objectives pursued by the firm, i.e. whether its founders are willing to engage in a type of activity that requires downstream assets. These levels are not independent and it is their combined consideration that may contribute to explain RBSOs decisions.

As we saw above, the literature that deals with firms' positioning relatively to complementary assets (e.g. Arora and Ceccagnoli, 2006; Gans and Stern, 2003; Pries and Guild, 2011; Rothaermel and Hill, 2005) suggests that when key non-technological assets such as manufacturing capacity, marketing competences, sales and distribution facilities, regulatory experience, are perceived as controlled by existing firms, new firms will have a greater incentive to operate exclusively in the TM. Therefore, we can formulate the hypothesis that:

H3a. RBSOs are more likely to be in TM when downstream complementary assets perceived as key to capture the value from the technology are controlled by existing firms.

But the decision can also be influenced by the difficulty to build/acquire these assets, even if they are not controlled by incumbents. One basic element in this process is the type of competences present in the founding team, or those that can be mobilised through its networks (Mosey and Wright, 2007). Firms find it easier to build or gain access to assets in areas in which they already have previous knowledge (Vohora et al., 2004). Because RBSOs often lack non-technological skills and networks they will need to undertake greater efforts at this level. While firms may subsequently recruit people with the additional competences, at early stages the knowledge base of the firm is largely composed of the competences of the founding team. Thus, RBSOs whose founders have no previous industrial experience and/or no management competences may prefer to operate in TM:

H3b. RBSOs are more likely to be in TM when they do not possess the skills/networks to develop downstream complementary assets or access them in favourable conditions.

4. Empirical analysis

In this section we will test the hypotheses formulated above about the conditions that influence the adoption of a technology market commercialisation strategy by RBSOs, addressing both the factors that are expected to influence the decision to target technology markets and those that are expected to influence the ability to operate in those markets.

4.1. Sample and data

The hypotheses are tested examining the strategies adopted by a group of 80 RBSOs from six European countries (Belgium, France, Italy, Portugal, Slovenia and United Kingdom), selected from national databases on RBSOs, put together by the teams involved in the PICO project. The concept of spin-off adopted was the one defined in Mustar et al. (2006): new ventures created on the basis of formal or informal transfer of technology or knowledge generated by public research organisations.

The sample selection followed a two step process. A first set of firms was selected from the above databases on the basis of two criteria: age and "growth ambition". Since growth was not the focus of this research and considering the age of firms and the fact that the type of technologies being exploited may take some time to reach the market and start producing revenues, ambition to grow was judged to be more appropriate than actual growth. Only RBSOs that were at least 5 years and no more than 13 years old were included, in order to guarantee that the firm had survived the first critical years and achieved a reasonable level of development, but was not too distant from start-up, to limit the retrospective bias. The second criteria intended to exclude "life style companies" – i.e. firms created as side-business by founders whose main occupation remains in the academic sphere – and to retain firms that started-up with "an ambition to grow" (Delmar et al., 2003; Wiklund et al., 2003). Since it would not be possible identify firms denoting "growth-orientation" directly from a population, we defined the legal form of incorporation as a proxy to it, assuming growth-oriented companies are likely to wish to attract external financing and therefore also more likely to start up under (or adopt in the early years) a legal form – which varies between countries – that is flexible towards the capital/ shareholder structure. From this first set of firms we finally extracted a stratified sample of 80 companies, ensuring diversity in terms of country origin and firm size and activity. The distribution by country assumed four situations: (a) large countries with high RBSO activity – United Kingdom and France, which contributed with 22 and 20 firms respectively; (b) small countries with high RBSO activity – Belgium, with 15 firms; (c) large countries with low RBSO activity – Italy, with 13 firms; (d) small countries with low RBSO activity – Portugal and Slovenia, with 6 and 4 firms respectively. Regarding the latter, the final selection took into account the objectives of the research. Since commercialisation strategies differ across industries, it aimed at guaranteeing some sectoral diversity. Heterogeneity was also sought in terms of activities performed, in order to encompass firms operating or willing to operate in product and in technology markets. In addition, both firms with and without patents were included. While recent work in commercialisation strategy focuses on companies that patented, we were interested in looking at both groups and investigating the role of patents in the strategic choice.

The empirical investigation draws on data purposefully collected through questionnaire based interviews, conducted with the founders in 2007. Each interview lasted between 2 and 3 h and permitted to obtain unique data on firm's activity (early, current and expected in future), IP protection, origin of technology and source of technological opportunities, technological relationships with parent, presence/control of downstream complementary assets, background and competences of founders and management team and financial resources. Face to face interviews were conducted instead of a mail survey, since it was considered that the scope and complexity of the data being collected required a closer interaction with the respondents, in order to guarantee the quality and completeness of the questionnaire (questionnaire pre-tests confirmed this notion). While a closed question format was retained, to ensure data comparability across cases, this approach often enabled a more qualitative perspective on the firms' decisions.

The final sample was composed of 80 firms, 24 of which declared to have targeted the market for technologies at start-up. It included firms in biotechnology (25), software (23), instruments (15), electronics (10) and a residual category of "others" (include: energy/sustainability, materials, cartographic systems, fine chemicals and sports equipment). About 25% of the firms were 10 years old or more, while about one half were between 5 and 7 years old. Regarding the activities performed, as expressed by the main source of revenue at the time of the interview: 38.8% firms mentioned services, 30% products, 16.3% licenses and 15% did not have any revenue yet (these firms relied, directly or indirectly, on external sources of finance, such as external capital, public funding, founders additional activities). Only about one half of the firms had already completed the development of the first technology/product, so the firms' expectation regarding the main source of revenue in the future is also relevant: 53.8% expected to have products, 27.5% licenses and 18.8% services. Thus 45% of the firms anticipated that the main source of revenue in the future would be different from the current one. Among these, 12 firms (33.3%) expected to switch to licensing as main source of revenue.

The majority of the firms mentioned that the technology was mostly developed at the parent organisation, being transferred (37.5%) or licensed (26.3%) to the new firm at start-up and only about 1/3 considered that it was mostly developed in-house. Several of the former had their technology protected by patents filed by the parent organisation (36.3%). Still regarding IP protection, about half of the firms had filed own patent applications. Combining the two sources, we conclude that 68.8% of the firms had their technology protected by patents, either filed by the firm or by the parent organisation.

4.2. Description of the model

4.2.1. Data and variables

The data obtained from the questionnaire enabled us to build a number of variables that are used as multidimensional measures of the nature of the knowledge, appropriability and complementary assets, founders' background and influence of the parent organisation, as well as type of market targeted (Tables 4.1 and 4.2).

4.2.2. Dependent variables

Since our goal was to investigate both the conditions that influence RBSOs early decision to target the market for technologies and RBSOs ability to operate in that market (at a steady state) as the firm main business, we have defined two dependent variables, one for each stage of the analysis (Table 4.1).

For the first stage (early decision) we used as dependent variable a measure of whether or not the RBSO decided to trade in the market for technologies at start-up, based on firms' own evaluation of their business orientation at start-up. The variable *TM at start* is a categorical variable that distinguishes between firms that declared to have chosen "selling or licensing technology" as main business orientation at start-up and the firms that did not.

For the second stage (operation as main business, at a steady state) we used as dependent variable a measure of RBSOs capacity to earn money from the market for technologies, based on firms' expectation regarding the main source of future revenue. The variable *TM as main business* is a categorical variable that distinguishes between firms that expect to have licenses as main source of revenue and firms that do not. "Expected" source was chosen (instead of present source, which was also asked), to have a measure that is equivalent for firms in different stages of development, including firms that still do not have any revenue, or in which services are the only source of income while the technology is being developed. Firms still in earlier stages are thus answering about a more stabilised situation, towards which they are working. Expectations may always not be fulfilled, but we can assume that the factors that explain the ability to earn money in the market for technologies will already be at work for firms that conducting their activities in order to achieve this objective.

Table 4.1 - Dependent variable.

	Variable name	*N*	*Mean*	*Std. Deviation*
The company operates on market for technologies at start-up (0=No; 1=Yes)	Technology Market (TM) at start	80	0.30	0.461
The main source of revenue expected in future are licenses (0=No; 1=Yes)	Technology Market (TM) as Main Business	80	0.27	0.449

4.2.3. Independent variables

4.2.3.1. Appropriability measures.

The assessment of appropriability conditions at start-up was based on two types of measures: a) of firms' perceptions of the possibility and effectiveness of IP protection in the industry where they operate (IP Protection); b) of the actual presence of patents filed by the parent organisation and transferred or licensed to the new firm at start-up (*Parent Patent*).

When measuring appropriability conditions at current stage, two new elements were added that reflect the activities conducted by the firm after start-up: c) firms' perceptions of the importance of different IP protection mechanisms. The categories adopted were the ones defined in the Oslo Manual (OECD, 2005): perceptions on the importance of patents (*Patent Protection*) and firms' perception of the importance of other protection mechanisms, besides patents (*No-Patent Protection*), a meta variable obtained by averaging the importance attributed to secrecy, confidentiality agreements, lead-time, moving down the learning curve, (α-Cronbach 0,69); d) the actual presence of patents filed by the firm, which was combined with the presence of parent patents, leading to a new variable (Patents) that reflects the fact that the technology protected by patents (own or from parent). Patent applications (US, European, PCT) were used instead of granted patents, given the stage of development of the firms: the vast majority of firms with patent applications had not yet been granted the patent. PCT patent applications, that is "international applications" filed under the system established by the Patent Cooperation Treaty, were included because the PCT route is increasingly used as a first step towards international patenting, namely by research organisations, due to the advantages afforded by the PCT system (Dernis and Khan, 2004). Indeed it was found that 20% of the firms that mentioned patents had only filed PCT applications.

Since *Patent Protection* was highly correlated with *IP Protection* (R=-0.6) – suggesting that firms attributing greater importance to patents as a protection mechanism also considered IP protection in their industry more effective – only the latter was used. This is consistent with literature on small technology suppliers IPR that suggest that for this type of firms patents are the most (and often the only) effective IP protection mechanisms (Hall, 2005).

4.2.3.2. Nature of knowledge measures.

The level of novelty of the technology was measured by a seven-point variable – *Novelty* – that rates the extent to which firms considered that new knowledge had to be created to develop the technology (Eisenhardt and Schoonhoven, 1990).

To measure the pervasiveness of the technology, we used a proxy based on the firms' assessment of the relative importance of advances in academic research as source of the opportunity behind the development of their technology (1 – low to 7 – high) (Breschiet al., 2000; Klevorick et al., 1995). Since the literature presents pervasiveness as associated with high technological opportunity (Malerba and Orsenigo, 1993) and argues that technologies that are direct applications of scientific knowledge will tend to be more pervasive given the generic nature of that knowledge (Marsili, 2002), pervasiveness can be considered to be potentially higher when advances in academic research are more important as sources of technological opportunity.

The founder's technological competences were measured on the basis of data collected on the background of each founder at the time of creation (Ensley and Hmieleski, 2005). We built two variables: *Academic Experience* – sums up the number of founders with technical experience in academic research and the number of founders with a PhD degree, providing a measure of the strength of academic backgrounds; *Technological Experience in Industry* – a dummy variable valued 1 if at least one founder had previous technological experience in industry.

All these variables are based on data measured at the time of start-up, so they can be used in the analysis of early and current conditions.

4.2.3.3. Complementary assets measures.

Previous studies have used different proxies of complementary assets (CAs), for example: firm market share in a segment (Fosfuri, 2006); degree of interaction between R&D and production personal (Arora and Ceccagnoli, 2006); presence of production, marketing, sales facilities (Novelli and Rao, 2007). But only Gans et al. (2002), asked firms directly about their perceptions of the incumbent level of control upon CAs that are key to capture the value of their technology. While entrepreneurs may not have complete understanding of the competitive environment and while their perceptions may not reflect the actual situation in terms of ownerships/control of downstream of key CAs, it is their perceptions that influence decision making. Building on Gans et al. (2002) we also attempted to capture this dimension.

To measure firms perception of level of incumbent control upon the different assets, we asked each firm to consider the resources and competences judged to be key to earn profits from the innovation in three domains – manufacturing; marketing and advertising; sales and distribution – and to rank, on a seven-point scale, the relative position of the RBSO and of other firms, regarding the control upon them. The scale was designed to consider a set of possibilities that ranged from: the complete control by the RBSO, that corresponds to its ownership of the assets (extreme left of scale); through situations where there is relative control of the RBSO, i.e. the balance of power is on the side of the RBSO, who can establish favourable or mutually favourable agreements with other companies to guarantee access; through the situation when the assets are freely available in the market at competitive prices (mid-point of scale); through situations where there is relative control by established firms, i.e. the balance of power is on the side of the established (usually large) firm, who still establishes agreements with the RBSO, but given its financial capacity/market power have a dominant position and can make the rules; to complete control by established firms that own the assets themselves and can (and possibly do) constrain access (extreme right of scale).

A reliability analysis upon the variables obtained from the questionnaire – level of control upon manufacturing, upon marketing and upon sales – revealed a poor Cronbach alpha (0,54), that increased substantially when omitting the first one (0,72). This suggested the existence of two underlying dimensions, which was corroborated by a 2-dimensional PCA (principal components analysis) upon them. Consequently, a final measure was obtained on the basis of two variables: level of incumbent control upon manufacturing directly obtained from the questionnaire (*Control CA Manufacturing*); level incumbent control upon commercialisation assets (*Control CA Commercial*), which corresponds to the mean of the variables relative to level of control upon marketing and to level of control upon sales.

Data on perceptions on CA control were expected to reflect firms' understanding of the current situation, but not have enough explanatory power regarding early decisions. With respect to the latter, non-technological competences in the founder team were used as a proxy to firms' potential to build, acquire or gain access (through networks) to downstream complementary assets. Since academic entrepreneurs are described as having limited knowledge about and (in links to) the industry/market they are entering, this measure reflects the assumption that presence of founders with previous industrial background may increase such knowledge and networks (Ensley and Hmieleski, 2005). Thus, we used data collected on the background of entrepreneurs at the time of start-up to build a variable (*Managerial Experience*) that computes the number founding entrepreneurs with previous managerial experience in industry.

Table 4.2 - Independent variables.

	Variable name	*N*	*Mean*	*Std. Deviation*
Appropriability Conditions				
Is the technology protected by patents filed by the parent? (0=No; 1=Yes)	Parent Patent	79	0.39	0.491
Possibility and effectiveness of IP protection in the industry / sector (7-1)	IP Protection	79	3.38	2.021
How important are the patents to protect innovations to the firm? (1-7)	Patent Protection	80	5.05	2.449
Mean importance of the following methods to protect innovations to the firm: a) confidentiality agreements; b) secrecy; c) lead-time advantage; d) learning curve? (1-7)	No-Patent Protection	80	4.88	1.458
The technology is protected by patents (own and/or parent) (0=No; 1=Yes)	Patents	80	0.69	0.466
Nature of Knowledge				
Importance of advances in academic research resulting from applied sciences and engineering, as sources of technological opportunities (1-7)	Pervasiveness	79	3.41	2.367
To what extent did you have to create extensive new knowledge to develop your technology? (1-7)	Novelty	80	4.08	1.756
Number of Founders with PHD plus number of Founders with previous academic RandD experience (Min 0; Max 13)	Academic Experience	79	4.33	2.640
The founders had previous technological experience in industry (0=No; 1=Yes)	Technological Experience in Industry	79	0.63	0.485
Complementary Assets				
Number of Founders with previous managerial experience in industry (Min 0; Max 3)	Managerial Experience	79	0.63	0.819
Perception of level of incumbent control upon the resources and competences key to earn profits from the innovations: mean of marketing/advertising (1-7) and sales/distribution (1-7)	Control CA Commercial	80	2.89	1.717
Perception of level of incumbent control upon the resources and competences key to earn profits from the innovations: manufacturing (1-7)	Control CA Manufacturing	80	3.03	1.866

4.2.3.4. Control variables

Considering that the sample included firms from different European countries the first variable that was considered as control was the country. Table 4.3 shows the distribution of firms for the groups of countries defined in section 4.1., categorised by being or not in the TM at start-up and expecting or not to have TM as main business in the future. In both cases there is no evidence suggesting that countries have a relationship to the dependent variables. The exact tests for the 4x2 tables were not statistically significant (country groups vs. *TM at start*, p=0.11, and country groups vs. *TM as Main Business*, p=0.28). Thus, country was not controlled for in the tests of the hypothesis.

Considering that some industries are likely to be more favourable to the operation of markets for technologies (Coriat et al., 2003) the second variable that was considered as control was the industry. Table 4.4 shows the distribution for industry, categorised by being or not in the technology market at start-up and to expecting or not to have TM as main business in the future. Analyses of these data suggest that it is appropriate to include a control for being in the biotechnology industry in the tests of the hypotheses, as Fisher's exact tests on the 2x2 contingency tables were significant (biotechnology/other industry vs. firm *TM at start*, p=0.001, and biotechnology/other industry *TM as Main Business*, p=0.000).

Finally, age of firm at the time of the interviews (2007) was also elected as a control variable for the model at steady state. However, as age is a metric variable, a different approach was needed in order to check for its relevance. As the subsample for the firms that operate in the technology market is small (table 4.5) and there is no evidence that it can be considered drawn from a Gaussian population (Shapiro-Wilk test = 0.82, p= 0.000), the test on the difference of means could not be performed. Instead, the Kolmogorov-Smirnov test for two independent samples was requested, but did not allow to conclude that firm age have significantly different distributions on each subsample (p=0.149). Thus, age of the firm is not controlled for in the tests of hypothesis.

Table 4.3 - Distribution for countries.

Countries	*TM at start*			*TM as Main Business*		
	Yes	No	Total	Yes	No	Total
UK + France	17	25	42	15	27	42
Belgium	3	12	15	3	12	15
Italy	1	12	13	1	12	13
Portugal + Slovenia	3	7	10	3	7	10
Total	24	56	80	22	58	80

Source: Own calculations.

Table 4.4 - Distribution for type of industry.

Sectors	*TM at start*			*TM as Main Business*		
	Yes	No	Total	Yes	No	Total
Software	3	20	23	1	22	23
Electronics	3	7	10	2	8	10
Instruments	2	13	15	1	14	15
Biotechnology	14	11	25	17	8	25
Others	2	5	7	1	6	7
Total	24	56	80	22	58	80

Source: Own calculations.

Table 4.5 - Distribution for age.

	Age									
	5	6	7	8	9	10	11	12	13	Total
TM as Main Business										
Yes	1	6	8	3	2	0	1	0	1	22
No	1	7	15	12	5	8	3	2	5	58
Total	2	13	23	15	7	8	4	2	6	80

Source: Own calculations.

4.3. Empirical results

To test our hypotheses we used a two stage approach. First, we focused on the conditions that influence RBSOs early decision to target the technology market and defined one model (Model 1), whose dependent variable is the main business orientation at start-up (*TM at start*) and whose independent variables are measures of:

- appropriability: perception of appropriability regime in industry (IP Protection) and presence of a parent patent protecting the technology (*Parent Patent*);
- nature of knowledge: Novelty and Pervasiveness of technology, as well as indirect measures such as strength of founders academic backgrounds (*Academic Experience*) and presence of founders with technical experience in industry (*Technological Experience in Industry*);
- ability to build complementary assets: proxyed by the strength of non-technological competences in founding team (*Managerial Experience*).

Second we addressed the conditions associated with being in the market for technologies as the RBSO main business. We defined another model (Model 2) whose dependent variable is "licensing as main source of revenue in the future"(*TM as Main Business*)and since in this case we are considering the firms already in operation, we included as independent variables:

- new measures of appropriability: presence of patents (own or parent) protecting the technology (*Patents*) and firms' perception of the importance of other protection mechanisms, besides patents (*No-Patent Protection*);
- new measures of control over complementary assets: perceptions of control upon assets related with production and with commercialisation (*Control CA Manufacturing* and *Control CA Commercial*).
- measure of imprinting effect: for this purpose, we used as independent variables the early decision to operate in technology markets (*TM at start*) and therefore excluded from this model the variables identified in Model 1 as explanatory of that decision and included the variables that were not found to have explanatory power for the early decision: *IP Protection*, *Pervasiveness* and *Academic Experience*.

We run the models, using logistic regression due to the dichotomous nature of the dependent variables. Beforehand, presence of multicollinearity was checked for in two ways: (i) by inspection of the correlation matrix and (ii) running the corresponding multiple regression models and requesting the colinearity diagnostics. There is no evidence of strong linear relationships between independent variables, and the variance inflation factor (VIF) never exceeds 2, far below the often recommended threshold of 10. Results can be found in appendix A1 and A2.

Both models provide a good fit to the data: firstly, the chi-squared goodness-of-fit test for the change in the –2Loglikelihood value (which tests the null hypothesis that all logistic regression coefficients – except the constant – are zero) revealed to be statistically significant (model 1: $\chi 2(8) = 31.2$, $p < .001$; model 2: $\chi 2(9) = 52.3$, $p < .001$) which provides support for acceptance of both models as significant logistic regressions. Secondly, the overall rate of correct classification is rather high: around 87 percent for model 1 and 88 percent for model 2. Moreover, as it can be seen on Tables 4.6 and 4.7, observed sensibility (i.e. percentage of correctly classified cases within firms that operate in the technology market at start-up – model 1 – or expect to have TM as main business in the future – model 2) is very satisfactory, particularly for model 2 (around 70 percent, 16 out of 23 firms, in model 1 and 81 percent, 17 out of 21 firms, in model 2). Thirdly, the Hosmer-Lemeshow goodness of fit statistic (Hosmer and Lemeshow, 2000) was also requested: the significance of the H-L statistic was found to be, in all models, relatively large, as desirable (model 1: $\chi 2(8) = 9.0$, sig = 0.343; model 2: $\chi 2(8) = 2.3$, sig = 0.972). Given the reduced dimension of the sample, as well as the ordinal nature of some of the variables, results will be cautiously interpreted and mainly in terms of the qualitative, rather than quantitative impact.

Table 4.6 – Classification table of Model 1.

		Predicted TM at start		*Percentage Correct*
		No	Yes	
Observed TM at start				
	No	50	3	94.3
	Yes	7	16	69.6
Overall Percentage				86.8

Table 4.7 – Classification table of Model 2.

	Predicted TM as Main Business		*Percentage Correct*
	No	Yes	
Observed TM as Main Business			
No	51	5	91.1
Yes	4	17	81.0
Overall Percentage			88.3

Table 4.8 presents the results of the logistic regression, which are discussed in greater detail below.

Table 4.8 – Results of logistic regression.

Variables	Exp (B)	
	Model 1	Model 2
Parent Patent	4.853**	*n.a.*
Novelty	1.810**	*n.a.*
Technological Experience in Industry	0.106**	*n.a*
Managerial Experience	2.772*	*n.a.*
IP Protection	0.888	0.577*
Pervasiveness	0.804	0.999
Academic Experience	0.993	0.667
Patents	*n.a.*	0.327
No-Patent Protection	*n.a.*	1.289
Control CA Commercial	*n.a.*	1.950**
Control CA Manufacturing	*n.a.*	1.383
TM at start	*n.a.*	36.586***
Biotec	6.378**	25.455***
Constant	0.043**	0.015*
Pseudo-R^2Nagelkerke	0.476	0.715
Valid N	76	77

* Sig≤ 0.10; ** Sig ≤ 0.05; *** Sig ≤ 0.01

4.3.1. Factors that determine early decision (Model 1)

In the case of Model 1, estimated odd ratios, reported in table 8, provide strong support for the hypothesis that the novelty of technology (*Novelty*) increases the odds of opting for operating in the technology market (*H1b*). Regarding the impact of founders' backgrounds on the nature of knowledge, our results (as expected) show an inverse (as the proportionate change of odds (Exp b) is below 1) and significant relationship between the founding team's previous technical experience in industry (*Technological Experience in Industry*) and the decision to operate in the technology market. However, the strength of academic backgrounds of founding team (*Academic Experience*) was not found to have impact upon that decision. Thus, Hypothesis *1c* was only partially supported. Considering the appropriability conditions, the results show that protection by patents filed by the parent increased the odds of opting for operating in the technology market, providing support to the hypothesis that protection by patents granted to the parent organisation is important for the decision to operate in TM (*H2c*). Regarding our proxy for the ability to build complementary assets, we found that, contrary to the expected, previous managerial experience in industry (*Managerial Experience*) increases the odds of opting for operating in the technology market. Thus Hypothesis *3b* was not supported.

Finally we find an industry effect in our analysis: the results show that the odds of opting for operating in the technology market increase significantly when the industry is biotechnology (*Biotec*), confirming that firms in this industry are more likely to opt for operating in the technology market than those in other industries.

4.3.2. Factors that influence having TM as main business (Model 2)

In the case of Model 2, regarding the appropriability conditions, the results show that perceptions of high appropriability regime in industry (*IP Protection*) increase the odds ofhaving licenses as main source of revenues in the future, providing support for Hypothesis *2a*. The high correlation between *IP Protection* and *Patent Protection* suggests that firms that perceive a high level of appropriability in their industry also rate highly patents as protection mechanisms, providing also some support to Hypothesis *2b*. However, in the model, the variable *Patents* have no significant impact, which indicates that the presence of patents, per se, do not differentiate firms that expect to be in the TM as main business. Thus, there is only partial support to Hypothesis *2b*. As regards the control over complementary assets, we found that a higher level of incumbent control upon commercial assets (*Control CA Commercial*) increased the odds of having licenses as main source of revenues, providing support for Hypothesis *3a*.

Finally, the results suggest a significant impact of an early business orientation towards Technology Market (*TM at Start*) on the odds of having licenses as main source of revenues in the future, confirming the importance of the imprinting effect of early decisions and suggesting the persistence of the factors that influenced them.

An industry effect is also present: the results show, as in Model 1, that the odds of operating in the technology market increase significantly when the industry is biotechnology (*Biotec*).

5. Discussion

Regarding the conditions associated with adopting a technology market commercialisation strategy at start-up, the empirical research supported most of our hypothesis. Considering the nature of knowledge, it was found that this decision was more likely to be made when the technology involved a greater component of new knowledge (*H1b*), although the degree of pervasiveness of the technology did not appear to differentiate between RBSOs that choose to be in TM and those that did not (*H1a*). Nevertheless, pervasiveness was clearly relevant for the former: 90% attributed the highest rank to the respective variable. In addition RBSOs were more likely to opt for TM when the entrepreneurs had no previous technological experience in industry (*H1c*), although a greater strength of academic backgrounds did not offer additional explanatory power. These results are further supported by a closer analysis of the cases, which revealed that most of these firms spun-off from large research universities and that, frequently, either the founding team, or the university team responsible for the development of the technology, involved highly reputed scientists. The influence of appropriability conditions at this stage was also confirmed: firms were more likely to opt for TM when the technology was mostly developed in the parent organisation and was protected by a patent filed by the parent (*H2c*).

However, the results suggest that the decision to be in TM was more likely when founders with non-technological backgrounds were present in the entrepreneurial team, thus providing no support to the hypothesis that absence of skills/networks required to develop/access complementary assets would induce RBSOs to choose TM (*H3b*). A more detailed analysis of the actual cases confirmed that the RBSOs that opted for engaging in this type of business frequently brought into the founding team at least one experienced individual from outside the academia (60% of the cases). The reason for this was that, while these RBSOs did not need to develop traditional marketing and commercialisation competences, they were nevertheless confronted with the need to sell their technology, which involves identifying potential technology acquirers, capturing their interest, devising the most adequate technology selling strategies and conducting complex negotiation processes, frequently with more powerful companies (Arora et al., 2001). Finally, the results also show that firms active in the biotechnology industry were more likely to opt for TMs at start-up and also to expect to have TM as main business in the future, although this not exclusive of them. In fact 42% of firms that choose to be in TM are non-biotech, this proportion decreasing to 23% when we consider the expectation of having TM as the main business.

These results confirm the importance of a dimension often overlooked in research on commercialisation strategies: the nature of the knowledge being exploited (Nerkar and Shane, 2007). Some of these results also support the arguments about the parent technological influence, or more generally, about the relevance of RBSO features that are associated with their origin (Mustar et al., 2006). In particular, the impact of the presence of patents filed by the parent can be regarded as an indirect indicator of the significance of the technology developed in the academic context. The finding about the mixed composition of entrepreneurial teams is also important, since it suggests a higher than expected degree of strategic awareness among teams willing to target the technology market.

Regarding the conditions associated with the ability to sustain this commercialisation strategy, the empirical results also partly support our hypotheses (Table 4.9). The results suggest than RBSO will be more likely to operate in TM as main business when key downstream complementary assets related to commercialisation are perceived as controlled by existing firms (*H3a*). These results are consistent with recent research that brings complementary assets into the empirical analysis (Gambardella and Giarratana, 2007; Novelli and Rao, 2007), but refine it, by confirming Gans et al. (2002) insight that it is control upon complementary assets – and not just their presence in-house – that is the key element on start-ups' strategic decisions.

The results concerning appropriability are more complex. They show that RBSOs will be more likely to operate in TM as main business when they perceive IP protection to be possible and effective in their industry (*H2a*). Moreover, the strong association between this indicator and the perception of importance of patents suggests that, in this case, patents are seen as the most important protection mode (*H2b*) – and in fact 91% of these firms attribute them the highest rank. This is consistent with the extensive literature that presents the ability to protect the technology as indispensable to operate in technology markets (Arora and Merges, 2004). However, contrary to what has been proposed in the literature (e.g. Gans et al., 2002), presence of patents, per se, does not differentiate between the firms that expect to have TM as their main business and those that do not. This departure from other studies may derive from the fact that the vast majority of them has focused exclusively on firms with patents, which was not the case here. Besides, this result does not lessen the relevance of patents for those RBSOs operating in TM – indeed 64% had filed patent applications (even if only 5% already had patents granted) and 76% relied on patents filed by the parent and transferred or licensed to the new firm, this implying that 90% had some patent protection. It simply indicates that patenting appears to be a relatively widespread practice amongst RBSOs that are not "lifestyle companies". What seems to be specific to RBSOs operating in TM is the role played by parent patents, which becomes apparent when we look into the particular cases. Not only firms start-up with a technology that is already protected by patents filed by the parent, but this protection holds while they are further exploiting knowledge that is more science-based and thus further from application, requiring a more substantial transformation. Thus we have companies that are still developing their technologies and have not yet filed own patents or, even if they did, have not yet been granted these patents. In the meanwhile these firms rely strongly on the protection offered by the patents they inherited from the parent and, in some cases, also on the temporary "excludability" afforded by the very novelty of their technologies, as proposed by Zucker et al. (1998).

Thus, the empirical results provided total or partial support to most of the hypotheses formulated regarding the factors that influence RBSOs adoption and sustaining a technology marketing commercialisation strategy. Table 4.9 summarises these results, permitting us to conclude that, globally, factors related with the three main dimensions present in the conceptual framework – nature of knowledge, appropriability conditions and control over complementary assets – as well as with the transversal impact of the parent organisation and the entrepreneur's competences upon these dimensions, are likely to have some influence upon the behaviour of RBSOs, in what concerns the mode of commercialisation of their technologies.

Table 4.9 –Hypotheses tested: support vs. rejection

Hypotheses	Support
Nature of Knowledge	
H1a - Pervasiveness	No
H1b - Novelty	Yes
H1c - Academic Backgrounds	Partial
Appropriability Conditions	
H 2a - Perceptions on Appropriability	Yes
H 2b - Patent Protection	Partial
H 2c - Parent Patents	Yes
Complementary Assets	
H 3a - Incumbent control CA	Yes
H 3b - Managerial Experience	No

The results obtained also show that early choices can indeed have an imprinting effect: an early decision to target technology markets increases the propensity to operate in this market in the future. However, they also suggest that the conditions that influence the early adoption of a commercialisation strategy may not necessarily be the same that influence the subsequent ability to sustain that strategy, although some of them appear to remain relevant. This is nevertheless an issue that requires more in-depth – possibly longitudinal – research.

The analysis conducted has the limitation of being based on a small sample. This has implications from the statistical point of view, since when using logistic regression and therefore maximum-likelihood estimation of the parameters, larger samples are recommended. Because our objective is to take into consideration a combination of factors (measured in a multidimensional way), which we expected can provide a more comprehensive explanation of the phenomenon, it may be necessary to expand our sample, in order to increase the robustness of the results. However we should note that the results thus obtained revealed desirable statistical properties, as a fairly high percentage of correctly classified cases and adequate values for the goodness of fit statistics.

6. Conclusions and policy implications

This paper addressed the commercialisation decisions of research-based spin-off firms, focusing on the case of companies that choose to target the market for technologies. The objective of this research was to develop and empirically test a comprehensive analytical framework that contributed to explain the conditions behind the emergence of a model of entrepreneurial behaviour that is becoming increasingly frequent in science-based fields, but is still largely underexplored.

Combining insights from two streams of literature – economics of technological change and strategic management of technology – we discussed the conditions that can influence decision to adopt and ability to pursue with this commercialisation strategy; and advanced some theory-driven hypothesis regarding the key factors that are likely to determine RBSOs choice: nature of knowledge, appropriability conditions, location and degree of control upon complementary assets and characteristics of the (academic) source environment. Our analytical framework expands on previous ones, by taking in consideration a combination of factors that tend to be addressed separately and the respective impacts, as well as by bringing back into focus some aspects – namely those related with the nature of the knowledge being exploited – that are often overlooked.

The results of a first empirical test of these hypotheses on a sample of 80 European RBSOs offer some preliminary insights into the conditions that are associated with RBSOs decision to adopt a technology market commercialisation strategy, as well as with their capacity to maintain this strategic orientation beyond the early stages, assuming the operation in technology markets as their main business. More specifically, the research suggests that particular attention should be paid to the following aspects: (i) the presence of stringent requirements in what concerns both the novelty of the technology being commercialised and the capacity to protect that technology since start-up, stressing the role played in such protection by patents already filed by the parent organisation; (ii) the situation in terms of access to downstream competences and resources that are necessary for commercialisation, in particular the degree to which incumbent firms control those assets; (iii) the set of competences encompassed by the founding team, pointing to a combination of a high level of scientific competences (given the technological requirements) with critical non-technological competences and networks (given the complex requirements of IP trade). The research also calls the attention to the impact of early decisions, which can constrain firms' subsequent evolution by reducing the margin for future choices.

These results are still preliminary, being based on a relatively small sample. The small size of the sample and the limited number of firms operating in technology markets it encompasses, requires us to interpret the results with some care. However, this limitation is also the result of a decision to conduct direct interviews (as opposed to a more generic survey) and thus should be balanced against the advantages of this option. In fact, it enabled us to obtain more reliable and complete data on complex issues as well as to collect some additional, more qualitative information on the companies' behaviour, which we deemed to be particularly important when testing a new conceptual framework. The more qualitative data provided additional, more grounded support to some of our hypothesis and enabled us to clarify some "puzzling" results obtained from our models, thus permitting a better understanding of the processes at work in these companies. This suggests two main lines to be followed in subsequent research: more in depth qualitative research on firms operating in the markets for technology, in order to go into greater depth into these processes, thus enabling us to refine our conceptual framework; which should subsequently be tested in a larger sample in order to increase the robustness of the results.

Despite these limitations, we think that this research already contributes both conceptually and empirically for a better understanding of the factors behind firms' decision to specialise in the production and sale of intellectual property. Thus, it adds to the still incipient research on this emergent model of entrepreneurial behaviour and also to recent research on the determinants of the commercialisation strategy of small technology-intensive firms. The research is also relevant for policy makers and practitioners. First of all because it brings into focus one of the less understood routes through which RBSOs perform the transformation of scientific and technological knowledge into economic value. Firms adopting this model of business have specific functions in the innovation system that should be considered more attentively by policy makers and, if judged relevant, should be sustained by adequate policies. Second because the type of factors that were found to influence the decision to operate in technology markets suggest that academic entrepreneurs may have an increasing propensity to operate under this model, which is favoured by the nature of the knowledge they often exploit and may be cognitively closer to their identity and culture. Given the relative novelty of this model of business, it is relevant to call the attention to the fact that it has specific – and sometimes very stringent –

requirements and, above all, it is important to offer some guidance to the actors who might be involved in the decision processes associated with creation and early development of this type of companies. This includes, both the entrepreneurs, who will have to consider carefully the circumstances surrounding the commercialisation process and assess the alternatives effectively open to them; and the support organisations operating in the academic context (such as TTOs or incubators) that often assist in these processes and can of have a determinant influence in the way they are conducted. Finally it also concerns policy makers, since different types of requirements may also require different policies, that contribute to reinforce the strengths and to ease the difficulties of small firms operating in technology markets.

Appendix A. VIF and correlations for the independent, control and dependent variables.

Table A4.1 –VIF and Correlations for the independent, control and dependent variables-Model 1

	VIF	1	2	3	4	5	6	7	8
Dependent Variable									
(1) TM at start									
Independent Variables									
(2) Parent Patent	1.454	.39**							
(3) IP Protection	1.416	-.31**	-.42**						
(4) Pervasiveness	1.566	.25*	.22	-.21					
(5) Novelty	1.227	.35**	.22	-.31**	.34**				
(6) Academic Experience	1.084	.13	.09	-.22	.10	.16			
(7) Technological Experience in Industry	1.469	-.02	.30**	-.11	-.07	.05	-.07		
(8)Managerial Experience	1.759	.28*	.45	-.36**	.30	.12	.13	.45**	
(9)Biotec	1.428	.35**	.33**	-.30**	.44**	.21	.08	.23*	.28*

***Sig≤ 0.05; ** Sig ≤ 0.01**

Table A4.2 –VIF and Correlations for the independent, control and dependent variables-Model 2

	VIF	1	2	3	4	5	6	7	8	9
Dependent Variable										
(1)TM as Main Business										
Independent Variables										
(2) IP Protection	1.675	-.39**								
(3) No-Patent Protection	1.130	-.04	.11							
(4) Patents	1.710	.29*	-.51**	.05						
(5) Pervasiveness	1.350	.29*	-.22	-.04	.39**					
(6) Academic Experience	1.118	.03	-.22	.06	.24*	.10				
(7) Control CA Commercial	1.065	.24*	-.16	-.05	.19	.15	.00			
(8) Control CA Manufacturing	1.565	.38**	-.51**	-.18	.42**	.28*	.24*	.17		
(9) TM at start	1.252	.58**	-.30**	-.14	.17	.25*	.13	.07	.23*	
(10)Biotec	1.638	.62**	-.30**	.10	.44**	.44**	.09	.17	.38**	.33**

***Sig ≤ 0.05; ** Sig ≤ 0.01**

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