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Determinants of research-based spin-offs survival

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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 1995 up to 2007 we analyze if founding conditions, parent organization 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 organization as advanced in previous studies.

Keywords: academic spin-offs; firm survival; duration analysis; group effects models

JEL Classification: L25, D22, O30, C41

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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 organizations (Mustar et al. 2006; Djokovic and Souitaris 2008). 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 organization (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 (Mustar 1997; Callan 2001; Smith and Ho 2006). Whereas, on average, 40% to 50% of the firms in a given market survive beyond the seventh year (Eurostat/OECD 2007), 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 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 (Lockett and Wright 2005; Walter et al. 2006; Jong 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 some studies 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 analyzes 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 characterize 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 organizations, the access to subsidized 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; Wright et al. 2007; Schwartz 2013).

Schwartz (2013) provides empirical support for these arguments. The author found that the incubated firms have higher survival rates than firms located outside incubator organizations. 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 hypotheses 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 (Mata et al. 1995; Agarwal and Gort 2002; Geroski et al. 2010). 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 organization

Previous evidence on corporate spin-offs has shown that their survival is linked to their parent organization 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 (Klepper and Sleeper 2005; Eriksson and Kuhn 2006; Thompson 2007; Klepper and Thompson 2010; Andersson et al. 2012). 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 (Lockett and Wright 2005; Johansson et al. 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; Rasmussen and Borch 2010; Heblich and Slavtchev 2013).

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 organization 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 organization rather than the result of social ties and meetings between local firms and scientists. Given this evidence we argue that the parent organization 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 organization.

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

H2c: RBSOs located near the parent organization 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 organizations. In this regard we started by collecting information from universities and other public research organizations in order to identify their spin-off firms. Whenever this information was not available, we contacted the organization 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 commercialization 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 organization 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 organization 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 Descriptive statistics

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 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.

Insert Figure 1 here

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 organization, 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 2). Only 3.33% of these firms fail in their first year of activity but failures increase substantially in the two subsequent years, to a cumulative total of 35% by the third year, which is in line with the stylized 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).

Insert Figure 2 here

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:

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

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:

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

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:

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

where the probability density function of T is

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

Besides the non-parametric approach, it is crucial to analyze 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:

$$h\left(t \middle| X_j\right) = h_0\,(t) exp\,(x_j\, \beta_x) \qquad (5)$$

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 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) parameterization (such exponential, Weibull and Gompertz models) or a log-time parameterization, 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:

$$h_0\,(t) = \exp(\gamma t)\, exp\,(\,\beta_0\,) \tag{6}$$

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

$$h(t|X_j) = h_0\,(t) exp\,(x_j\,\beta_x) \tag{7}$$

so the hazard function is

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

The shape parameter γ determines the shape of the hazard function. If $\gamma > 0$ then the hazard increases exponentially with time; if $\gamma < 0$ the hazard decreases exponentially with time. In the specific case of $\gamma = 0$ the 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 1 if 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 manufacturing high-tech and medium-high 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 1 presents the descriptive statistics of the dependent variable and covariates and Table 2 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.

Insert Table 1 here

Insert Table 2 here

5. Results

The non-parametric estimation of the survivor function plotted in Figure 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).

Insert Figure 3 here

In order to analyze 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. Considering that Portuguese spin-offs firms have different parent organizations 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. 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 parameterization (Table 3).

Insert Table 3 here

In order to select the parametric model that fits better our data we also estimated the Accelerate Failure-Time Parametric Models (Table 4)[1]. Since that only the exponential versus Weibull, and lognormal or Weibull versus generalized 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.

Insert Table 4 here

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 and Table 4). 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

[1] 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.

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 organization 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, organizational 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 organization fixed effects. We fit a standard fixed effects model including indicator variables for parent clusters. In this model the effect of the parent organization 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 5). 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.

Insert Table 5 here

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 database 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 organization 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 organization 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 organizations do no feel the same kind of pressure.

Another interesting result regards the spin-off physical proximity to its parent organization. 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 organizations should support RBSO firms by helping them to have more employees since their set-up. Second, parent organizations 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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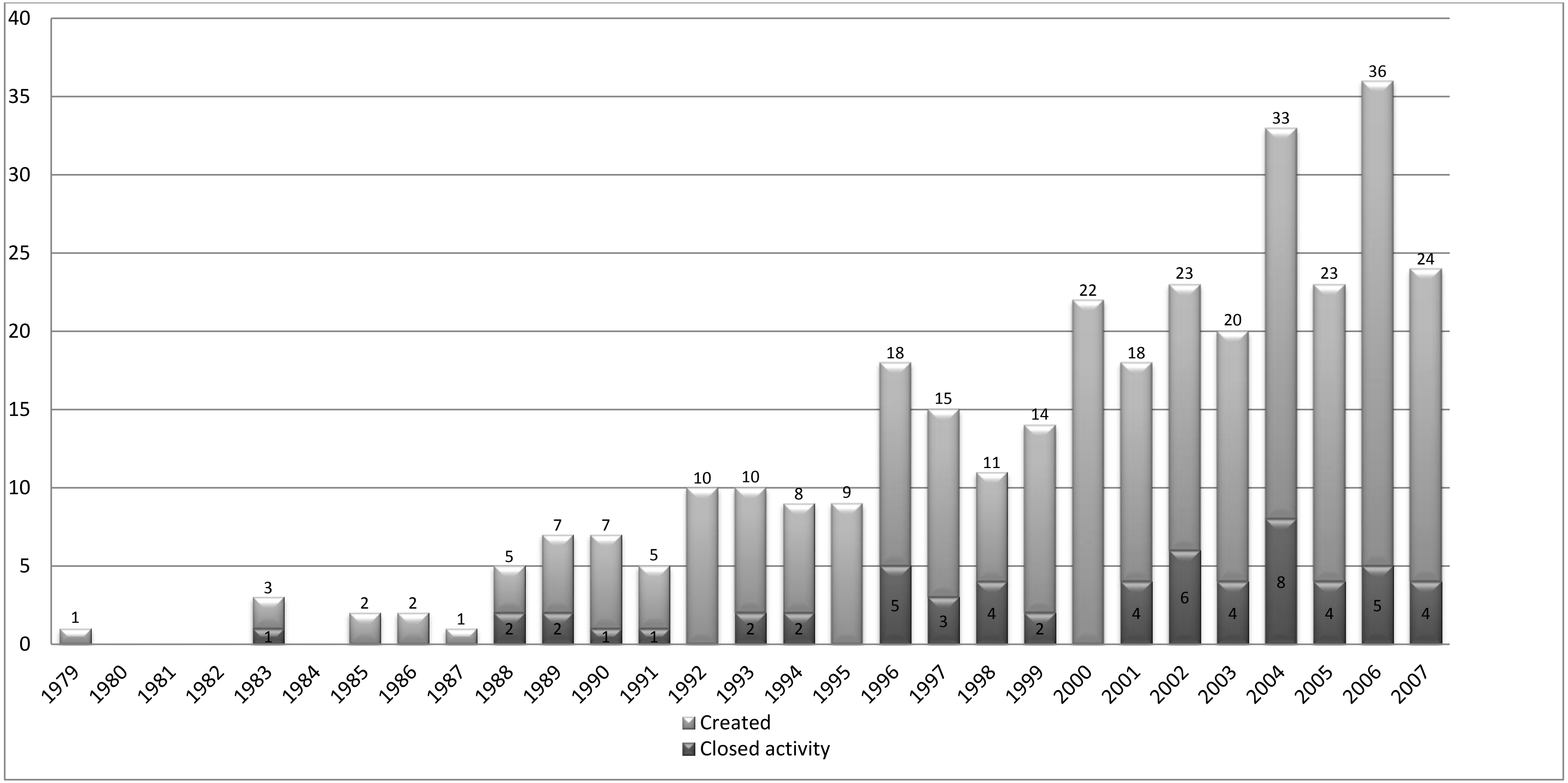
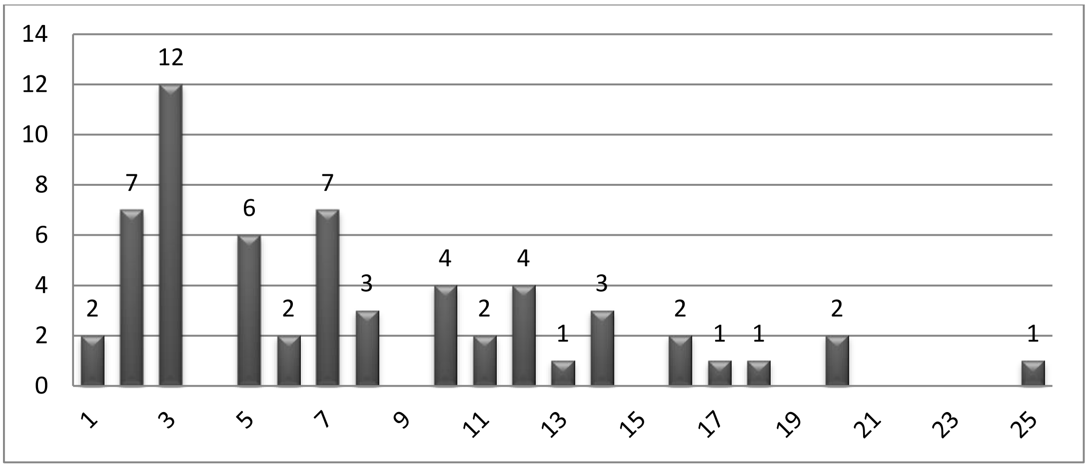
Figure 1. Number of Portuguese RBSOs by founding date (1979-2007).



Source: Own calculations.

Figure 2. Number of Portuguese RBSO that fail by their age.



Source: Own calculations.

Table 1. 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 = 327 firms, 2658 firm-year spells.

Table 2. 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.

Figure 3. Kaplan- Meier Survival Function of Portuguese RBSOs

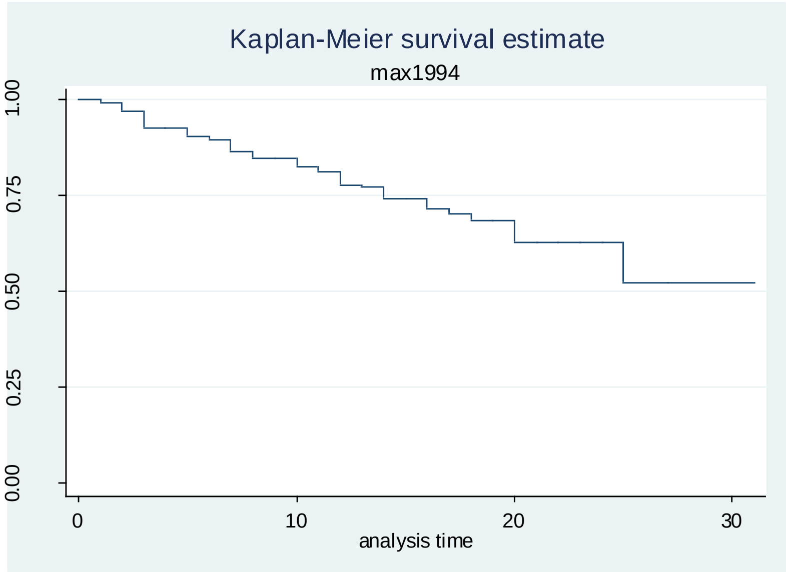


Table 3. Estimates of the determinants of RBSOs´ survival (Proportional Hazard Models).

Covariates	(1) Cox	(2) Exponential	(3) Weibull	(4) 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-up Size	-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 organization. ***, **, * means significant at 1%, 5%, 10% level, respectively.

Table 4. Estimates of the determinants of RBSOs´ survival (Accelerated Failure-Time Models).

	(1)	(2)	(3)	(4)
Covariates	**Exponential**	**Weibull**	**Log-logistic**	**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-up Size	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.

Table 5. Estimates of the determinants of RBSOs´ survival (Robust-cluster and Fixed Effects Models).

	(1)	(2)
Covariates	**Cluster**	**Fixed effects**
Founder PhD	-0.125	-0.133
	(0.313)	(0.302)
Incubated	-0.003	-0.234
	(0.308)	(0.352)
Start-up Size	-0.713***	-0.690***
	(0.143)	(0.146)
Age	-0.659*	-0.742***
	(0.368)	(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	-0.175
	(0.496)	(0.406)
Metropolitan Area	-0.358	-0.665*
	(0.432)	(0.349)
High-tech	-0.495*	-0.640***
	(0.269)	(0.239)
Entry rate	-0.270**	-0.342*
	(0.132)	(0.182)
Software	-0.307	-0.477
	(0.306)	(0.384)
Biotechnology	-1.319***	-1.682***
	(.177)	(0.526)
Energy	-2.137**	-2.532**
	(0.838)	(0.805)
Electronics	-1.172*	-1.229**
	(0.564)	(0.652)
Engineering	-0.097	-0.152
	(0.332)	(0.569)
Fixed Effects	–	YES
Constant	-4.733***	-7.798***
	(1.694)	(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.

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