Analysis of the survival determinants of University Spin-Offs in a crossnational sample

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Abstract: An understanding of the dynamics related to university spin-off's survival is a critical point for many scholars and policy makers, especially in the technology transfer process. Drawing on the population and organizational ecology perspectives and the resource-based view of the firm, this paper aims to investigate the survival determinants of University Spin-Offs (USOs). After applying event analysis techniques in a cross-national dataset of 1,275 Italian and Spanish USOs over the period 2005-2013, the findings show that firm size, firm age, industrial partners, and firm efficiency positively influence USOs' survival, whereas patent activity decreases USOs' chances to survive. Additionally, a U-shaped relationship between financial leverage and USOs' survival emerges. Based on the emerging evidence, some policy and managerial implications are provided in order to help USOs to cross their "Valley of Death".

Keywords: university spin-off; firm survival; event analysis, cross-national, resource-based theory.

1 Introduction

Translating knowledge and technologies into marketable goods and services by converting discoveries and ideas into successful innovations represents a common and increasing dilemma in several countries (Barr et al., 2009; Good et al., 2019); this is significantly recognized in Europe (European Commission, 2017). In this regard, the knowledge-based economy has considerably underlined the role of universities in commercializing the knowledge produced in their research activities (Hayter and Link, 2018; Wu et al., 2017) through the creation of academic start-ups or University Spin-Offs

(USOs), among other ways (Rasmussen et al., 2014; Fini et al., 2017; Rodríguez-Gulías et al., 2018). Indeed, USOs play a critical knowledge bridging function by placing otherwise unexploited technologies and know-how into industry in order to create socio-economic value (Zahra et al., 2007; Miranda et al., 2018).

Nevertheless, not all of the USOs reach this goal and a significant part of them fail. The missing linkage in shifting from a new technology to setting up a market-driven and profitable business has been indicated by the literature as the "Valley of Death" (Barr et al., 2009; Markham et al., 2010; Midler, 2019). Concerning USOs, projects and ventures originating from university research that have potential to produce marketable products and services fail in commercial application because they have not yet been developed enough to be profitable (Abereijo, 2015). Consequently, the effective technology transfer from university to industry is prevented, negatively affecting the USOs' growth and survival (Clayman and Holbrook, 2003; Lundqvist, 2014; Ries, 2011; Hirsch and Tambuyzer, 2015;).

The nature of USOs as mainly knowledge-based firms (Miranda et al., 2018) leverages the common problems linked to the launch of a new venture with the difficulty of innovation development (Berbegal-Mirabent et al., 2015). As a result, USOs are very sensitive to several types of market failures, mainly through the start-up phase (Hall and Rosenberg, 2010; Parmentola and Ferretti, 2018), which threaten their survival. In detail, the embryonic nature of USOs' knowledge, together with the extensive time lag between the research phase, product development and its launch to the market (Rasmussen and Rice, 2011; Wu et al., 2017), create significant risks and uncertainties in commercialization. This prevents investors from financing emerging early-stage innovation, putting a substantial brake on further development and the survival prospects of the USOs.

Additionally, USOs are typically resource-constrained and not familiar with forecasting the resources needed to overcome the liabilities of both newness and smallness (Skute, 2019; Novotny, 2020). Clearly, USOs show several limitations in attaining the finance needed to support their growth and also their survival (Sørheim et al., 2011; Galati et al., 2017). In addition, university entrepreneurs general show limited managerial capabilities (Oliveira et al., 2013; Lundqvist, 2014) as well as little prior expertise in industry (Rasmussen and Borch, 2010; Drivas et al., 2018).

This emerging setting calls for a better understanding of the survival determinants of USOs. Up to now, most of the literature on the field has focused on USOs' growth and creation determinants (Hesse and Sternberg, 2017; Ramaciotti and Rizzo, 2015; Bock et al., 2018). Although this approach is useful to understand the success of university entrepreneurship, the study of factors affecting the extent to which USOs survive is still limited (Wennberg et al., 2011) and fragmented (Gilsing et al., 2010; Miranda et al., 2018; Prokop et al. 2019).

This study aims to fill these gaps. Mainly drawing on population and organizational ecology perspectives and the resource-based view of the firm, this paper analyses the firm-level determinants of USOs' survival in a cross-national sample of 1,275 Italian and Spanish USOs over the period 2005-2013. Both Mediterranean European countries have intensively developed policies geared towards boosting the creation of these kinds of firms in the last two decades (Yagüe and March, 2012; Ramaciotti and Rizzo, 2015; Miranda et al., 2017). In spite of this, the USOs phenomenon has not been fully explored, and a widespread study about the effectiveness of universities at creating surviving firms is needed.

This paper contributes to the literature on the effectiveness of university technology transfer trough USOs, which it is still rather limited (Kroll and Liefner, 2008). In particular, the paper provides new insights about the success determinants of USOs, with particular focus on firm survival. By combining theoretical arguments from the resource-based view with those from population ecology perspectives, it provides a better understanding about the mechanisms generating differential survival expectations in USOs. Further, unlike previous studies in the topic, the use of a larger dataset englobing firms from two national contexts over an eight-year period, as well as a new set of financial and innovation variables, spreads the understanding about USOs´ survival and potentially improves the reliability and generalizability of the emerging findings.

This paper is organized as follows: Section 2 introduces the literature background and presents the research hypotheses. In Section 3, the methodology is described. Section 4 presents the findings of the study. In Section 5 the main results are discussed, while Section 6 provides some managerial and policy implications. Section 7 presents the main limitations and conclusions of the study.

2 The determinants of USOs' survival and research hypotheses development

The elements affecting firm survival, especially new entrants, have been widely investigated in the literature related to Industrial Organization (see Josefy et al. (2017) for a recent review). This trend has not similarly pervaded studies focusing on the specific case of USOs. Besides some general descriptive research into the survival rates of USOs (e.g., Lowe 2002), little evidence is available on the determinants of USOs' survival. Shane and Stuart (2002) and Nerkar and Shane (2003) examine respectively how organizational endowments (i.e., social capital) and patents affect the probability of survival of new technology ventures originating at the Massachusetts Institute of Technology. Conceiçao and Faria (2014) place the emphasis on a few firm-level characteristics (i.e., size, age, and parent university reputation) and on regional factors. Rodríguez-Gulías et al. (2016) pay attention to the effect of USOs' financial performance on firm survival, whereas Prokop et al. (2019) focus on the role played by the "externals" (i.e., investors, entrepreneurs….). Finally, Fernández-López et al. (2020) analyse how the interaction between innovation and export activities affects a USO's survival. Despite these studies, there is no widely accepted theoretical approach in the analysis of USOs' survival.

In contrast, literature on USOs has shown that the resource-based view of the firm provides a critical framework in the study of spin-out process effectiveness by universities (Vinig and Van Rijsbergen, 2010; Rodeiro-Pazos et al., 2012; Berbegal-Mirabent et al., 2015). Stemming from this approach, the failure risk may be lower for firms with a systematic and well-established set of resources and capabilities which encompass the initial and critical start-up phase and help buffer against hard luck during the rest of their entrepreneurial life (Bruderl and Schussler, 1990). Also, from the organizational and population ecology perspectives, firm survival is a function of the amount and type of resources a firm controls (Chung and Cheng, 2019; Hodgson et al., 2017). Concerning the study of USOs' survival, both theoretical perspectives have been observed to support the understanding of the evolution of the university technology transfer to industry (Cardozo et al., 2011).

Hence, the theoretical framework used in this study to explain USOs' survival is based on the arguments related to both the resource-based view of the firm and the population and organizational ecology perspectives. In detail, the focus of the analysis is on nine firm-level characteristics widely researched as survival drivers in the literature on firm survival, but these are frequently overlooked by the scarce studies on USOs' survival. In so doing, the specific nature of USOs and how these characteristics may differently affect firm survival has been taken into account. These firm-level characteristics are (1) firm size, (2) firm age, (3) patent activity, (4) high-technology sector, (5) venture capital, (6) industrial partnership, (7) firm profitability, (8) firm efficiency, and (9) financial leverage.

Previous studies about the survival of innovative firms claim the relevance of the firm size and its impact on the organizational outcomes. This is an issue related to the "liability of smallness" from the population ecology perspective (Audretsch and Mahmood, 1991; Aldrich and Auster, 1986). In this regard, scholars remark on different logic behind the superior survival rates for larger firms as compared to their smaller counterparts (Agarwal and Audretsch, 2001; Mas-Verdú et al., 2015; Esteve-Pérez and Mañez-Castillejo, 2008), which may not be able to gain the adequate critical resources required to survive (Chang et al., 2008).

Larger firms have superior resources to allocate to innovative activities and tacit knowledge transfer activities (Tamer et al., 2003). They are also expected to hire more employees with specialized know-how in science and engineering as well as in management (Laursen and Salter, 2004), which are critical for knowledge-based firms such as USOs. Similarly, literature points out that larger firms have greater availability to achieve a minimum efficiency threshold under which firms typically fail (Fritsch et al., 2006). In this respect, Giovannetti et al. (2011) highlight that in industries characterized by a high level of technological innovation, such as those related to USOs, or that are at an early stage of their life cycle, firm size represents a critical and vital competitive advantage. In brief, the superior survival rates of larger firms are linked with the presence of economies of scale, which reduce the average cost of the firm, together with improved access for both financial markets and human resource capital (Mata et al., 1995; Geroski et al., 2010).

Although the topic has been well-recognized in the literature on firm survival, the analysis gains relevance in the USOs' context since scholars claim that these firms tend to remain small in size for long time with a significant deficit of resources that impedes their growth (Galati et al., 2017). The "size deficit" affecting a USO's growth may also create obstacles to their survival prospects. Without an adequate resource endowment, both the growth and existence of the firm is compromised (Colombo and Piva, 2008). Thus, Conceiçao and Faria (2004) and Fernández-López et al. (2020) found a positive effect of size on a USO's survival, while Rodríguez-Gulías et al. (2016) documented an inverted U-shaped relationship between both variables, and non-significant results were reported by Prokop et al. (2019). Drawing on previous arguments, the following is assumed:

H1: Firm size is positively related to USOs' survival probability.

Age also has a substantial effect on firms' survival prospects (Phillips and Kirchhoff, 1989; Sapienza et al., 2006). From the organizational ecologist perspective, newcomers are exposed to the "liability of newness" (Susarla and Barua, 2011). Thus, during the development-stage of a firm, a learning process takes place that allows the business to unfold (e.g., carry out investments, develop specific knowledge and routines, build social networks, etc.) (Mudambi and Zahra, 2007). As time goes by, firms are expected to have more advanced routines and well-known processes than their younger counterparts (Salimath and Jones, 2011). Additionally, firms gain external legitimacy, increasing their likelihood of survival. From the resource-based view, limited resources and know-how can be risky for young firms (Wiklund et al., 2010; Carr et al., 2010), making the commercialization of research knowledge a significantly hazardous activity and increasing the premature mortality of the firm.

The above-mentioned arguments are especially relevant to USOs, which usually develop their core technology early during their lifespan (Gübeli and Doloreux, 2005; Zahra et al., 2007). This period of time is fundamental to effectively boost the learning process and overcome the "liability of newness". In fact, Conceição and Faria (2014) report that the failure rate increases after the first year of activity and considerably grows until the third year, supporting that USOs fail in the early stages of their life. In contrast, the likelihood of failure for the USOs that survive the first 2/3 years of activity falls gradually with the firm's age. Hence, the following hypothesis is advanced:

H2: Firm age is positively related to USOs' survival probability.

According with the resource-based view, patents represent an intangible resource that support firms in acquiring competitive advantages in their industries. The availability of patents signals that an organization has an inimitable set of resources protected from imitators. This "direct" benefit from patenting is especially relevant for small newcomers whose activity is subject to high uncertainty and asymmetric knowledge (Shane, 2002; Geuna and Muscio, 2009). Thus, previous research reports a positive association between patenting and firms' survival rates (Cockburn and MacGarvie, 2006; Cockburn and Wagner, 2020). Additionally, patenting produces "indirect" effects that may significantly improve the competitive advantage of newcomers. Indeed, literature on NTBFs reveals that patent activity also serves to gain access to external funding and reputation, which in turn positively influence the survival dynamics of the firm (Löfsten, 2016).

In spite of the above-mentioned arguments, the links between patent activity and USOs' survival remain unclear as the only study concerning this issue has found a negative relationship between patenting and firm survival (Fernández-López et al., 2020). Stemming from the theoretical arguments, the following is advanced:

H3: Patent activity is positively related to USOs' survival probability.

The firm's sector also influences the firms' survival rate (Colombelli et al., 2013; Tavassoli and Jlienwatcharamongkhol, 2016). Particularly, the differences in firm survival between low-, moderate- and high-tech sectors have been analysed from the population and organizational ecology perspectives (Mahmood, 2000; Ebert et al., 2019). More specifically, high-technology firms have higher chances to survive (Motohashi, 2005; Helmers and Rogers, 2010). The rationales for this relationship include not only the innovative activity performed by these firms, which represents a fundamental dimension to boost their competitive advantage (Cockburn and Wagner, 2020; Delmar et al., 2013; Nerkar and Shane, 2003), but also the growth potential of high-technology sectors. Indeed, firms starting their business in growing sectors also have superior growth prospects and consequently an improved likelihood of survival (Mas-Verdú et al., 2015).

These arguments become relevant in the context of USOs, since most of them operate in high-technology sectors. However, solid evidence of an industry effect on USOs' survival remains virtually non-existent. Thus, whereas Nerkar and Shane (2003) conclude that the concentration of the USO's industry moderates the effect of the radicalness of technology on the USO's probability of failure, a non-significant relationship between firm survival and operating in high-tech industries is found by Rodríguez-Gulías et al. (2016) and Fernández-López et al. (2020). In spite of this empirical evidence, the following hypothesis is proposed:

H4: Operating in high-technology sectors is positively related to USOs' survival probability.

Venture capitalists positively influence the survival of venture-backed firms (Giot and Schwienbacher, 2007). First, they apply rigorous selection criteria, investing in the most talented firms in terms of growth potential and economic return (Motta et al., 2015) Second, the presence of this kind of inside investor provides signals that attract critical resources such as human capital, marketing, managerial resources, and other external investors (Krishnan et al., 2011). Third, venture capitalists are actively involved in monitoring their investment to alleviate moral hazard issues (Wang and Zhou, 2004). The monitoring activity is especially fundamental for firms such as the USOs operating in industries with high-growth opportunities where assets are chiefly intangible (Gompers, 1995; Myers, 1984) and subject to high information asymmetry concerns (Burchardt, et al., 2016; Beatty et al., 2010) (Sørheim et al., 2011). Moreover, this monitoring role of a venture capitalist becomes especially relevant for USOs, as they are usually founded by non-market-oriented individuals (Goethner et al., 2012). Thus, it is likely that USOs governed only, or mainly, by academics are less focused on economic efficiency, with a reduction of firm development and survival prospects; while USOs governed by investors and/or qualified management teams show sustainable firm development, reducing the risk of failure (Prokop et al., 2019).

Although the positive relationship between venture capital and a USO's growth has already been evidenced (Ayoub et al., 2017; Bock et al., 2018; Rodríguez-Gulías et al., 2018), the links between this kind of external investor and firm survival remains ambiguous. Indeed, Fernández-López et al. (2020) find a positive relationship between the presence of venture capital and a USO's failure risk. In spite of this empirical evidence and stemming from the arguments of the resourced-based view, the following hypothesis could be advanced:

H5: The presence of venture capital is positively related to USOs' survival probability.

Scholars have pointed out the role of industrial partners in firm's success (González, 2014). Thus, the resource-based view and population ecology perspectives indicate that industrial partnerships occur when firms demand additional resources that cannot be acquired via market transactions. In this regard, firms can improve their competitive position and chances to survive by establishing stronger relationships with clients and alliances with prominent organizations (Susarla and Barua, 2011; Benghozi and Salvador, 2014).

The role of industrial partnerships in firm survival is particularly relevant for USOs. Universities have researchers with a qualified advantage in the development of new technologies, but they usually lack experts with know-how in product development and management (Colombo and Piva, 2012). USOs lack the market acquaintance and industry familiarity to convert their knowledge into a profitable business (Harrison and Leitch, 2010; Iacobucci et al., 2011). In this context, the collaboration with industrial partners may become a cornerstone for a USO's success. In this line of reasoning, Benghozi and Salvador (2014) observe that an industrial partnership is a critical element for both the survival and the growth of research spin-offs, remarking that partnerships with dominant firms provide access to new knowledge and the resources required to survive. Similar results were found by Prokop et al. (2019) after analysing 870 USOs in the U.K.

H6: The presence of industrial partners is positively related to the USOs' survival probability.

Firm profitability may also influence firm survival. More specifically, it contributes to generate positive cash flows and accumulate slack resources (George, 2005), which increase the firm's chances to acquire critical resources in accordance with the arguments related to the resource-based view theory (Esteve-Pérez and Mañez-Castillejo, 2008). Similarly, high profitability denotes superior efficacy of the organizational processes in financial terms, thanks also to a better harmonization between cost structures and market prices, which significantly improves the chances of survival. In this line of reasoning, Davidsson et al. (2009) show that small- and medium-sized enterprises (SMEs) that raise revenues without concentrating on profitability exhibit volatile growth, which in turn increases the risk of failure; while only firms with growth in profitability experience effective firm growth, reinforcing firm survival. Similarly, Delmar et al. (2013), using a panel of knowledge-intensive new firms in Sweden (similar to USOs), showed that profitability increases the firms' survival rate.

In the highly dynamic and innovative environments in which USOs are involved, rising profitability provides firms with self-financing capacity, enhancing access to additional resources and improving their survival expectations (Dosi et al., 2017). Nevertheless, it is largely unclear from the empirical literature whether a USO's profitability has a positive effect on firm survival. Indeed, the studies addressing this issue fail to find a significant association between both variables (Rodríguez-Gulías et al., 2016; Fernández-López et al., 2020). This could be partly explained by the financial support sometimes provided by the parent universities, which would help in propping up the economic performance of the USO and reducing the risk of failure (Su and Sohn, 2015; Civera and Meoli, 2018). In other words, low profitability might be mitigated by the assistant role of the parent universities. Drawing on the theoretical arguments, the following is stated:

H7: Firm profitability is positively related to USOs' survival probability.

Organizational and population ecology arguments claim that efficiency sustains firms' performance and survival, while inefficiency increases firm failure (Van Witteloostuijn et al., 2003). Firm efficiency comes to be associated with firm survival in a direct way because firms that are more efficient in the use of their assets are expected to gain market share, improving their possibilities to remain competitive in the market and survive (Gimeno et al., 1997; Zingales, 1998). In addition, firm efficiency is indirectly associated with firm survival through firm profitability. More specifically, changes in asset turnover suggest changes in the firm's productivity, and this is suitable for forecasting forthcoming firm profitability (Novy-Marx, 2013). Further, firms with a superior minimum efficient scale should have superior price–cost margins and, hence, a superior likelihood of firm survival (Basile et al., 2017).

Thus, Rodríguez-Gulías et al. (2016) found that asset efficiency, measured by total asset turnover, is positively related to a USO's survival. This result underlines the "direct effect" of firm efficiency on survival, which is the ability to generate income. Stemming from previous evidence, the following hypothesis is proposed:

H8: Firm efficiency is positively related to USOs' survival probability.

The role of debt in firm survival has been researched and reported in the literature on organizational ecology (Tran and Santarelli, 2018), and usually an inverted U-shaped association between both variables arises (Huynh et al., 2012). In this respect, bank debt is one of the main financing sources of firms; the effective access to this financial resource may improve a firm's survival prospects. At the same time, it may signal the quality of a business project, raising the possibility of attracting additional investors (Bertoni et al., 2011). This aspect is especially relevant for USOs whose innovative investments often lacking collateral value (Fryges et al., 2015), which increases the banks' sensitivity to risk (Colombo and Grilli, 2007; Revest and Sapio, 2012) and makes a some of the USOs credit-constrained (Ayoub et al., 2017). Nevertheless, several problems arise when the level of indebtedness begins to be excessive. The financial costs of debt consume part of the funds otherwise destined to finance the USO's growth and innovative activities. In addition, insolvency costs and agency costs increase significantly, which also raises the probability of firm bankruptcy (Jensen, 1986; Admati et al., 2018). In this respect, it is noteworthy that a firm's access to debt may be conditioned by the value of its assets, since they can act as collateral for debt (Booth et al., 2001; Rajan and Zingales, 1995). Then, a potential correlation between a firm's assets (Hypothesis 1) and leverage (Hypothesis 9) might emerge.

From an empirical view, the effect of leverage on a USO's survival has been scarcely investigated. Thus, Fernández-López et al. (2020) found that the higher the leverage ratio of USOs, the higher the probability of failure. In spite of this evidence, a quadratic relationship is proposed by drawing on the theoretical arguments:

H9: Leverage related to USOs' survival probability is an inverted U-shaped curve.

3 Methodology

This section describes the sample, the variables, and the model used in the analysis of a USO's propensity for failure (or survival).

3.1 The sample

The dataset originally constructed by Corsi et al. (2017) was used in the empirical study. It included 952 Italian and 531 Spanish USOs whose information referred to the period 2005-2013 and was obtained from different databases. Particularly, Aida BdV and SABI databases, both of them provided by Bureau Van Dijk, were employed to obtain accounting information on Italian and Spanish firms, respectively. In addition, information about patenting activity performed by USOs had been manually extracted from the ESPACENET database. Furthermore, for the purpose of this study, it was necessary to update Corsi et al.'s dataset by including the survival data required to perform the analysis. Specifically, those data were the following: the firm's legal status, the dates of change in legal status, the dates of the last year available, and birth dates.

After discarding some USOs due to lack of survival data, the final dataset was an unbalanced panel consisting of 1,275 USOs observed between 2005 and 2013. Out of these firms, 498 (39.06%) are located in Spain and 777 (60.94%) in Italy.

3.2 Definitions and measurement of the variables

No further outcomes can be achieved if the firm fails and no longer exists, so firm survival can be considered as the essential indicator of firm success. Besides, survival reflects a firm's capability to adapt to environmental turbulences ("evolutionary fitness") (Yagüe and March, 2011). Thus, the dependent variable was the survival time of the USOs in years (_t), calculated as the time elapsed between the firm birth date[1] and the moment in which the firm failed, nuanced by a dummy variable that indicates whether the event (failure) has taken place (_d)[2]. The firms' legal status, available in SABI and Aida databases, are used to define the USOs as failed (event). For Spanish firms, 9 SABI categories are considered to be firm failure: bankruptcy, state of insolvency, extinct, dissolved, closing of the register, provisional closing of the register, inactive, probably inactive, and untraceable according to sources. For Italian ones, 4 Aida categories are considered to be firm failure: closed, closed (in liquidation), closed (closure due to bankruptcy), and in liquidation. The opposite group, the reference group, are active firms which included merged firms (fusion), following Zhang (2009). The survival time is censored to the right on December 2013 because an exit event is not observed for all USOs (i.e., for continuing firms).

In order to test the hypotheses, we defined a set of explanatory variables that are widely used in the literature on firm survival (Table 1). In addition, a country dummy variable was included in order to capture institutional factors that may influence a USO's survival.

INSERT Table 1 Definitions of independent variables and predictions HERE

3.3 Estimation and model specification

Since firm failure is the result of strategies over time, it should be considered to be a continuous process, even though the appraisal of failure occurs at a certain time (Dimitras

[1] For 54 Italian USOs the exact birth date was not available, while their birth year is available. Hence, we decided to approximate their birth date as July 1 for all of them in order to avoid discarding these firms.

[2] In this work, the data is in the form of a panel, therefore, each company presents a set of records, specifically one for each period of time (t_0, t_1]. At the end of each time period (t_1), the event variable (_d), dummy variable censored, will take the value 1 if the company has experienced a failure and 0 otherwise. Thus, each company will show a vector of zeros that can end in a 1 if the company finally fails, or 0 if it has not failed in the study period (censorship on the right). In our case, the failure event is exclusive, that is, once the company presents the event, it leaves the sample and ceases to be observed (absorbing or culminating event).

et al., 1996). An appropriate approach to analyse the dynamics of firm failure is the use of event analysis techniques. These techniques consider "time to failure" as an integral factor in firm failure analysis (Kleinbaum and Klein, 2005; Chancharat et al., 2007). Therefore, event models study the effect of a set of covariates on the time elapsed before the event (failure).

The choice of this methodology is based on two issues. First, event models are adequate to cope with censured samples, which is the case of our right-censored sample since some firms were still active in 2013. Second, they allow including time-varying covariates which not only overcome the limitation of considering characteristics previous to the time of a firm's entry in the dataset as the unique determinants of its survival probability (Esteve and Mañez, 2008) but also deal with the deterioration in those variables which involves different effects during the firm's failure process (Luoma and Laitinen, 1991).

Following Conceiçao and Faria (2014), Rodríguez-Gulías et al. (2016), and Fernández-López et al. (2020), we apply the semiparametric Cox proportional hazards model specification (Cox, 1972):

$$h\left(t|x_j\right) = h_0(t)\; e^{(\beta_x\, x_j)}$$

where $h_0(t)$ is the baseline hazard, x_j is a vector of covariates, and β_x is the vector of their coefficients.

Under this specification, the effect of a unit of change of the explanatory covariates is a constant parallel shift of the baseline function. The statistic based on the Schoenfeld residuals (Schoenfeld, 1982; Grambsch and Therneau, 1994) is used to test this proportionality assumption.

Therefore, the following equation gives the basic specification of our model:

$$h(t|x_j) = h_0(t)\exp(\beta_1 LN\_ASSETS_{ij} + \beta_2 LN\_AGE_{ij} + \beta_3 PAT_{ij} + \beta_4 HIGH\_TECH_i + \beta_5 VENT\_CAP_i + \beta_6 IND\_SHAR_i + \beta_7 ROA_{ij} + \beta_8 TOT\_TUR_{ij} + \beta_9 LEV\_R_{ij} + \beta_{10} LEV\_RSQUAR_{ij} + \beta_{11} SPAIN_i)$$

There are two main advantages of the Cox proportional hazards model (Wennberg et al., 2011). Firstly, any assumption regarding the duration dependence is required. Secondly, the Cox model allows flexible handling of the non-linear relations and the time-varying covariates. Since no assumption of the baseline hazard function is required, the semi-parametric Cox model is less efficient than the correct parametric specification. Nevertheless, misspecification of the hazard rate $h_0(t)$ may lead to inconsistent estimates (Cleves et al., 2008).

4 Results

4.1 Non-parametric and descriptive analysis

Of the 1,275 USOs analysed, 1,046 survived for the period 2005–2013. Thus, the survival rate is 82.04% (or the failure rate is about 17.96%).

By using the Kaplan-Meier estimate procedure, Figure 1 depicts the non-parametric estimate of the survival function. Accordingly, the estimate of the survival functions indicates that 25% of the USOs did not survive after 9.027 years; while the estimated median, the time beyond which 50% of USOs are expected to survive, is 14.81 years.

INSERT Figure 1 Kaplan-Meier estimate of the survival function HERE

The smoothed hazard rates are shown in Figure 2. The failure hazard of USOs increases at a steady pace with age during the first 12 years of activity, but after then, failure rates increase more rapidly. This shape may reflect that the effect of the parent university's support received by USOs during their early stages is exhausted as time goes by, suggesting that the failure risk of the USOs is not at its peak during the initial years of activity, as it could be expected.

INSERT Figure 2 Smoothed hazard estimates HERE

Table 2 shows the descriptive statistics of the explanatory variables.

INSERT Table 2 Descriptive statistics of independent variables HERE

The average total assets of the sampled USOs are 835 thousand euros. The firms have an average annual age of 5.18 years. The percentage of observations with patent activity is 6.8%, and 57.3% of the USOs operate in the medium- and high-tech industries. The percentage of observations of venture-backed USOs is 9.1% and with industry shareholders is 31.4%. The mean of the returns on assets (ROA) is negative (−3.3%), the average total asset turnover is 0.911, and the mean leverage ratio is about 61.7%.

Finally, Table 3 shows the correlation matrix of independent continuous variables. The correlation matrix shows that there are no critical correlations which we have to hold in account. Thus, the firm's age is positively associated with ROA, total asset turnover, and leverage ratio. Whereas firm profitability (ROA) is negatively correlated to total asset turnover and the firm's indebtedness (LEV_R). Firm size also shows a positive correlation with firm age and a negative one with total asset turnover. Surprisingly, no significant correlation is found between firm size and indebtedness. In this regard, the literature observes that firms with a high value of assets also have improved borrowing capability, suggesting a positive relationship between firm asset and leverage (Booth et al., 2001; Rajan and Zingales, 1995). This is especially the case when a significant part of such assets are tangible assets and can act as collateral for debt. In contrast, USOs generally exhibit a low asset tangibility due to their technology transfer activity (Greco et al., 2013), which may partly explain the lack of a significant correlation between USOs' assets and leverage.

INSERT Table 3 Correlation matrix HERE

4.2 Semiparametric analysis: the Cox model

The results of estimating the proportional hazards Cox models are shown in Table 4. In order to test the hypotheses, different empirical models were estimated. Model 1 included the most widely used independent variables in the literature (LN_ASSETS, LN_AGE) as well as the control variable (SPAIN). Model 2 added the variables related to patent activity and the technological level of industry (PAT and HIG-TECH). In Model 3 and Model 4, variables referring to the strategic partners (VENT_CAP and IND_SHAR) and financial performance (ROA, TOT_TUR, LEV_R and LEV_RSQUAR) were included, respectively. Finally, all of the variables in Model 5 were considered simultaneously.

In order to test the assumption of proportionality, a test based on Schoenfeld residuals was performed for each model. In all of them, the null hypothesis that the hazard rate is proportional is not rejected, suggesting that the models are correctly specified.

INSERT Table 4 Cox estimation HERE

The results of the Cox estimations show a significant inverse effect of both the firm size (LNASSETS), more smoothly, and the firm age (LN_AGE) on failure hazard. Thus, firm size and firm age have a positive effect on USOs' survival, and the failure hazard is reduced as firm size or firm age increase. These findings are consistent with those by Conceiçao and Faria (2014) and Fernández-López et al. (2020). Hence, Hypothesis 1 and 2 are validated.

Contrary to expectations, patent activity (PAT) shows a significant positive relationship with failure hazard, that is, it reduces the survival probability. Although this finding does not validate Hypothesis 3, it is similar to that of Fernández-López et al. (2020). Similar to Rodríguez-Gulías et al. (2016) and Fernández-López et al. (2020), operating in high-tech sectors (HIGH_TECH) seems to have no effect on a USO's failure propensity. Hypothesis 4 is not validated.

No effect of the presence of venture capital partners (VENT_CAP) on failure hazard was found. Hence, the Hypothesis 5 cannot be validated. Having industrial partners (IND_SHAR) seems to be negatively related to failure hazard, validating Hypothesis 6. This result is consistent with that by Prokop et al. (2019).

Concerning the financial ratios, the results do not indicate any effect of return on assets (ROA) on failure hazard, similar to Rodríguez-Gulías et al. (2016) and Fernández-López et al. (2020). In this way, the Hypothesis 7 is not validated. Meanwhile, asset efficiency (TOT_TUR) seems to be negatively related to firm hazard failure in USOs, supporting the Hypothesis 8. This result is consistent with that by Rodríguez-Gulías et al. (2016). In turn, the leverage ratio (LEV_R) has an inverted U-shaped relationship with the failure hazard, contrary to the results expected in Hypothesis 9 as well as the findings of Fernández-López et al. (2020).

Finally, the country' institutional factors also matter in determining a USO's chances to survive; being located in Spain (SPAIN) significantly increases the failure hazard of USOs.

5 Result Discussion

From the empirical findings of this study, it emerges that old and large USOs survive more than their smaller and younger counterparts. This is in line with the organizational population perspectives and resource-based view arguments, remarking that the well-established set of resources and expertise of large and old USOs helps them in achieving a competitive advantage position for surviving the difficulties related to the development of innovation and its commercialization, allowing a more resilient organizational advance. From the organizational ecology perspective, the concepts of the "liability of smallness" and "liability of newness" also support the superior organizational processes and routines of larger and older USOs that let them efficiently conduct their business, decreasing the firm failure rate.

The findings also reveal that patenting USOs face lower chances of survival. This unexpected result might be partly explained by the type of technology developed by USOs. Thus, USOs tend to patent radical technology to a greater extent than other firms (De Coster and Butler, 2005; Stephan, 2014). However, radical innovation is characterized by high risks of failure (Scaringella et al., 2017; Bock et al., 2018) and requires prior generation of valuable organizational resources (Nerkar and Shane, 2003). Without this "cushion" of resources, radical technology may decrease the firm's chances to survive. Further, given that USOs are formed by researchers and other academics, they are usually focused on the technology development rather than on its effective translation into marketable and profitable products. As previously remarked, USOs lack managerial capabilities and prior expertise in industry, which leads them to undervalue the entrepreneurial orientation and economic returns needed for firms (Neves and Franco, 2018; Prokop et al., 2019). This creates an emphasis on patenting that is not counterbalanced with clear business planning and product development.

High-tech USOs do not exhibit superior chances to survive compared to non-high-tech USOs, suggesting that the technological level of the industries where USOs operate is not relevant in determining their survival chances. In this respect, other industry's features, such as the degree of industry concentration (Nerkar and Shane, 2003), may have more relevance for firm survival. Nevertheless, this requires further research.

Similarly, venture-backed USOs have no higher chances to survive compared to non-venture-backed ones. The evidence does not support the existence of screening, signalling or monitoring effects of venture capitalists on USOs' survival. This counterintuitive result may be related to the low maturity of the venture capital industry in Continental European countries compared to Anglo-Saxon ones. Indeed, significant differences in the institutional contexts may lead the former to underperform in terms of firm growth and survival compared to the later (Pommet, 2017; Bruton et al., 2010). Again, this issue requires further study.

Industrial partners increase a USO's chances to survive. This evidence is in line with the arguments which claim that industrial links improve access to critical skills and resources, helping newcomers to overcome the so-called liability of "newness in the sector". In this respect, industrial partnerships may help academic founders in developing managerial capabilities and networking, contributing to firm survival.

Firm profitability seems to have no effect on a USO's survival prospects, suggesting the irrelevance of this economic indicator in predicting a USO's survival. This result, although theoretically counterintuitive, is partly consistent with the empirical studies that report the low financial performance reached by USOs, which does not prevent them from having higher survival rates than non-USOs (Cantner and Goethner, 2011; Criaco et al., 2014; Rodríguez-Gulías et al., 2016). This can be partly explained by the support provided by parent universities that keeps USOs alive (Su and Sohn, 2015; Civera and Meoli, 2018), sometimes in an artificial way.

In contrast, asset efficiency increases a USO's survival prospects. This finding, together with that referred to firm profitability, suggests that the direct way in which firm efficiency may influence firm survival is more important than the indirect one (i.e., through firm profitability). In other words, USOs that are more efficient in the use of their assets to generate income are expected to increase their survival prospects.

Contrary to expectations, the findings reveal a U-shaped relationship between USOs' survival and their indebtedness. Thus, the estimated coefficients indicate that, initially, financial leverage decreases a USO's chances to survive, however there is a turning point after which the leverage enables the firms' survival prospects. This finding speaks in favour of a signalling effect of financial leverage about the quality of the business; if the USO is able to support a certain level of indebtedness, it may gain access to additional resources for organizational development.

Also, the findings show that USOs located in Italy survive more than those located in Spain, suggesting that country-level institutional factors play an important role in a USO's survival.

6 Policy and managerial implications

The findings of this study have some implications for policy makers and management practice. First, given the difficulties that small and young USOs must overcome to survive, policy makers need to better design acceleration programs to effectively boost the USO's development until it reaches a certain firm size and maturity. In this regard, improvement of the existing business incubation programs and science parks is required. They should offer services that are tailored to significantly enable USOs' growth rather than focus on supporting business modelling and exploitation of technology (Soetanto and Jack, 2016).

Second, the negative effect of patent activity on USOs' survival concerns the type of technologies patented. Not all patents are easily transformed into successful entrepreneurial opportunities. Particularly, radical innovation, even when protected, requires a long time-to-market as well as slack resources, putting a major constraint on firm survival. This constitutes important challenges for academic entrepreneurs, who need to assess *a priori* the feasibility of the nascent business against realizing the patent's value by licensing or selling it to external investors.

Third, the non-effect of venture capital calls for reflection on the potential drawbacks of the venture capital industry in contexts where it is still not well-developed, as in the case of Spain and Italy (Acevedo et al., 2016). In this regard, policy schemes targeted to stimulate both the national market and to attract global venture capitalists are required. Yozma, the Israeli venture capital program requiring the co-investment of university and industry, has proved to be a good practice in generating resilient incentives to invest in talented innovative high-tech start-ups, improving their growth and survival prospects (Avnimelech and Teubal, 2006)

Fourth, the positive effect of industrial partners calls policy makers to actively take part in building innovative networks involving both public and private actors with the aim of effectively performing the technology transfer process from university to industry. Sharing resources, knowledge, expertise, and risks between universities, start-up firms, industry, and governmental agencies would allow increasing the competitive advantage, growth, and the chances of survival for all of the actors involved. Additionally, the findings speak in favour of embedding managerial practices in USOs. In this regard, it is possible to alleviate the frequent lack of managerial skills of academic entrepreneurs through (1) the appointment of surrogate entrepreneurs and (2) the involvement of professional investors.

Fifth, USOs may be competitive in using investment assets to generate income. It is worth noting that the asset turnover ratio tends to vary among sectors. Thus, USOs in technology-based and hard science sectors (such as biotech) are characterized by large asset bases but relative limited sales, due to the usually long time-to-market, yielding low asset turnover ratios. On the contrary, USOs in knowledge-based and social science sectors (especially business advisory) usually have small asset bases, which frequently yield high asset turnover ratios. Thus, policy makers need to tailor supporting policies differently to foster the asset efficiency of each type of USOs.

Finally, an active involvement of external providers of finance, not only in the form of debt but especially in the form of equity, is required to provide USOs the critical base of financial resources. In this respect, to counterbalance the information asymmetries expected between USOs and potential investors due to the intangible nature and the lack of collateral value of the firms' assets, a regulatory framework facilitating the participation of private equity investors as well as incentivizing it (for example, by allowing investors to fiscally recover part of their investment in case of losses) is required.

7 Conclusions and limitations

Gaining an understanding about the dynamics related to USOs' survival is a critical point for many scholars and policy makers, because universities have become a significant source of innovative and high-tech firms in some countries. To this end, using a sample of 1,275 Italian and Spanish USOs, this paper has tested a set of potential firm-level survival determinants mainly drawn from the resource-based theory of the firm and the population and organizational ecology perspectives.

Our findings confirm, in part, the proposed hypotheses since a USO's resources and strategies, such as firm size and age, industrial partners, firm efficiency and financial resources, arise as positive determinants of a USO's survival. Conversely, patenting activity increases a USO's chances of failure, whereas venture capitalists, operating in high-tech sectors, and firm profitability do not seem to have a central role in a USO's survival prospects. These findings may help policy makers and practitioners in designing more appropriate strategies to overcome or alleviate the shadow of the "Valley of Death" in USOs, since the above-mentioned factors constitute key elements of the technology transfer process from university to industry.

Additionally, the limitations inherent in this study present opportunities for future research. First, the variables venture capital and industrial partner were considered constant for each USO throughout the analysed period because SABI and Aida BdV databases show the latest updated information. In the future, getting annually updated information regarding partners (i.e., venture capitalist and industrial partners) could be useful for analysing the effect of the entry or exit of these partners on a USO's survival.

Second, the individual characteristics of the academic entrepreneurs may have a central role in determining a USO's survival. Future research may benefit from considering the potential effects of the entrepreneurial team's characteristics on a USO's survival.

Third, external factors related to parent universities and the macroeconomic settings may exert significant effects in determining USOs' survival prospects. Future studies should better investigate these external dynamics in order to gain an understanding of USOs' survival. In this regard, the use of multilevel methodology by hierarchically testing contextual-level and firm-level factors of USOs' survival may be useful. Along this line of reasoning, a study of the effect of the expected economic crisis derived from the COVID-19 pandemic on the survival rates of USOs opens an interesting future research direction about how external economic shocks can affect typically resource-constrained firms. For this purpose, future studies would benefit from expanding the sample period.

Finally, the obtained findings refer to Italian and Spanish USOs, which limit the generalizability of the result to other countries. Future studies are clearly needed to expand this analysis to other geographic regions and perform comparisons among different contexts (e.g., European versus American contexts, Anglo-Saxon versus Continental European contexts).

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Table 1 Definitions of independent variables and predictions

HYPOTHESIS	VARIABLE		MEASURES
H1	*Size*	LN_ASSETS (+)	Natural logarithm of the firm's assets[1]
H2	*Age*	LN_AGE (+)	Natural logarithm of the firm's age
H3	*Patent activity*	PAT (+)	1 if the firm had patent applications filed annually at the country's patent office, the European Patent Office (EPO), the US Patent and Trademark Office (USPTO) or submitted to a Patent Cooperation Treaty
H4	*Industry*	HIGH_TECH (+)	1 for firms in medium- and high-tech industries according to the Eurostat classification and 0 otherwise[2]
H5	*Venture capital*	VENT_CAP (+)	1 if the firm had venture capital funding and 0 otherwise
H6	*Industrial shareholders*	IND_SHAR (+)	1 if the firm had industrial shareholders and 0 otherwise
H7	*Return on assets*	ROA (+)	Net income divided by total assets
H8	*Total asset turnover*	TOT_TUR (+)	Sales divided by total assets
H9	*Leverage ratio*	LEV_R (+) / LEV_RSQUAR (-)	Total debt divided by total assets and its square
Control variable	*Country*	SPAIN ( )	1 if the firm is located in Spain and 0 otherwise

Notes: The sign of the hypothesis is referred to firm survival.[1] Defined following the previous work of Conceiçao and Faria (2014) and Rodríguez-Gulías et al. (2016). The firm's assets is also one of the three criteria considered by the European Commission to classify a company as micro, small or medium-sized enterprise (https://ec.europa.eu/growth/smes/business-friendly-environment/sme-definition_en). [2] Eurostat uses the aggregation of the manufacturing industry according to technological intensity and based on the NACE Rev.2 at the two-digit level.

Table 2 Descriptive statistics of independent variables

Variable	Obs	Mean	Std. Dev.	Min	Max
ASSETS[ab]	6039	835.54	3973.38	0.25	135260
AGE[a]	6039	5.183	3.071	1	15
PAT	6039	0.068	0.252	0	1
HIGH_TECH	6028	0.573	0.495	0	1
VENT_CAP	6039	0.091	0.288	0	1
IND_SHAR	6039	0.314	0.464	0	1
ROA	6013	-0.033	0.524	-19.16	7.02
TOT_TUR	5829	0.911	1.550	0	94.13
LEV_R	6039	0.617	0.809	-0.16	23.10

Notes: [a] Variables are not in logs. [b] Variable is in thousands of euros.

Table 3 Correlation matrix

	ASSETS	AGE	ROA	TOT_TUR	LEV_R	LEV_RSQUAR
ASSETS	1					
AGE	0.1450*	1				
ROA	0.0025	0.0396*	1			
TOT_TUR	-0.0474*	0.0420*	-0.3772*	1		
LEV_R	-0.0037	0.0970*	-0.4085*	0.1948*	1	
LEV_RSQUAR	-0.0092	0.0521*	-0.2865*	0.1048*	0.8675*	1

Notes: This table shows the Pearson correlation coefficients for the continuous variables considered in the empirical analysis.
*p < 0.05, **p < 0.01, ***p < 0.001.

Table 4 Cox estimation

	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
LN_ASSETS	-0.053	-0.073	-0.038	-0.148**	-0.136*
	(0.046)	(0.047)	(0.051)	(0.053)	(0.059)
LN_AGE	-2.586***	-2.597***	-2.602***	-3.180***	-3.198***
	(0.264)	(0.265)	(0.266)	(0.294)	(0.296)
PAT		0.625**			0.435+
		(0.235)			(0.261)
HIGH_TECH		-0.108			-0.114
		(0.135)			(0.144)
VENT_CAP			0.252		0.113
			(0.219)		(0.238)
IND_SHAR			-0.380*		-0.327+
			(0.186)		(0.190)
ROA				-0.021	-0.005
				(0.120)	(0.124)
TOT_TUR				-0.669***	-0.652***
				(0.114)	(0.115)
LEV_R				0.320**	0.344**
				(0.123)	(0.126)
LEV_RSQUAR				-0.016+	-0.017+
				(0.009)	(0.009)
SPAIN	0.732***	0.738***	0.608***	0.767***	0.656***
	(0.146)	(0.149)	(0.155)	(0.160)	(0.174)
Firm-year obs.	6039	6028	6039	5829	5818
Unique firms	1275	1273	1275	1256	1254
Failures	229	228	229	212	211
Log-likelihood	-1351.9	-1341.4	-1349.2	-1208.4	-1198.7
Schoenfeld residuals test	2.15	3.40	5.31	5.73	8.38

Notes: Standard errors in parentheses. + p < 0.10, * p < 0.05, ** p < 0.01, *** p < 0.001

Figure 1 Kaplan-Meier estimate of the survival function

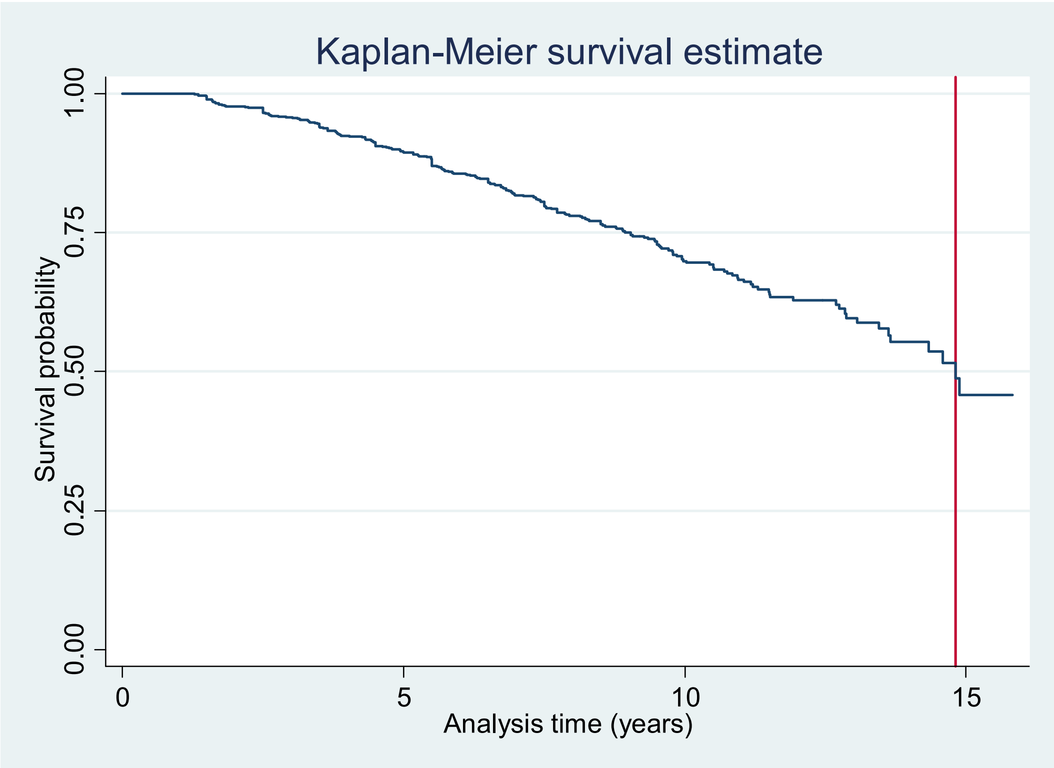

Figure 2 Smoothed hazard estimates