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What drives business failure? Exploring the role of internal and external knowledge capabilities during the global financial crisis

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ABSTRACT

This paper contributes to the debate on the determinants of business failure and helps to clarify the effect of internal innovation efforts and external knowledge sources in a hazard model of firm exit. Using panel data of manufacturing and service firms in Spain for the period 2009–2015, our findings show that the financial crisis increased the probability of business failure; however, firms with high levels of R&D human capital are better positioned to survive under uncertain financial conditions. In addition, we find evidence that cooperation with vertical partners reduces the effect of business failure in manufacturing sectors. This study provides new insight into the antecedents of business failure and how firms can match their business capabilities to prevailing economic conditions.

1. Introduction

The risk of business failure is significant at any stage of business development (for a recent review of the literature on organisational survival and failure refer to Josefy, Harrison, Sirmon, & Carnes, 2017). New ventures are particularly susceptible; according to Bhattacharjee, Higson, Holly, and Kattuman (2009) between 50% to 90% of new businesses fail as a result of micro and macroeconomic factors in the business environment. Failure by insolvency, liquidation or closure refers to the voluntary 'winding-down' of a business due to poor performance, which is viewed as an efficient reallocation of resources (Siepel, Cowling, & Coad, 2017). The decision to close down a business is jointly influenced by a variety of factors, including firm characteristics (Colombelli, Krafft, & Quatraro, 2013; Spaliara & Tsoukas, 2013), firm-specific capabilities (Cefis & Marsili, 2012), and macroeconomic conditions (Liu, 2004). Bhattacharjee et al. (2009) state that firms' exits are deemed to be cyclical in nature. Bankruptcies in particular are often associated with adverse economic conditions, such as the recent financial crisis, and acquisitions are often associated with economic recoveries (Bachmann, Elstner, & Sims, 2013).

Despite increasing knowledge about the adverse effect of macroeconomic instability on business survival, limited research has considered the role of knowledge in a firm's ability to avoid the risk of failure during an economic downturn (Thornhill & Amit, 2003). Economic recessions present some of the most unpredictable events in the life of a business. Research from the resource-based view emphasises the importance of knowledge in firm survival (e.g., Geroski, Mata, & Portugal, 2010). Further, the dynamic capabilities perspective posits that firms must continuously develop and extend their resources and capabilities to cope with environmental changes (Eisenhardt & Martin, 2000; Teece, 2007; Teece, Pisano, & Shuen, 1997). We argue that internal innovation efforts and external knowledge assets are dynamic capabilities that provide firms with sources of competitive advantage (Zahra & George, 2002) that might enable them to overcome adverse economic conditions. Firms with high levels of knowledge resources are found to have a lower hazard of exit (Aspelund, Berg-Utby, & Skjevdal, 2005). Additionally, we examine the impact of the financial crisis on business failure in manufacturing and service sectors separately. We contend that industry context can influence the effect of the economic downturn on business failure (Kim & Lee, 2016).

This study makes two important contributions to the business failure literature. First, we investigate the impact of macroeconomic instabilities on firm survival in a hazard model of firm exit. Understanding the connection between business failure and fluctuations in the macro-economic factors offers new insights to theories relating to the environmental antecedents of firm survival. The life cycle hypothesis proposed by Bachmann et al. (2013) suggests that business exit rates often rise during economic downturns and the periods which follow them. Second, the paper examines how dynamic capabilities enable firms to avoid the risk of failure during economic downturns.

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These capabilities encompass activities through which managers continuously configure assets into viable resource combinations (Fainshmidt, Nair, & Mallon, 2017), and are likely to influence the incidence of business failure during the global financial crisis (Ahn, Mortara, & Minshall, 2018; Zouaghi, Sánchez, & García Martínez, 2018).

To test these hypotheses, we estimate a parametric hazard model assuming a Weibull distribution. Further, following the methodology proposed by Spaliara and Tsoukas (2013), we interact predictor variables with a variable that captures the financial crisis period (2009–2013). Our objective is to capture the sensitivity of business failure to internal and external knowledge capabilities 'in' and 'post' recession.

The paper is organised as follows. Section 2 provides an overview of the relevant literature and presents the research hypotheses. In Section 3, we discuss our data and estimation methodology. In Section 4, we estimate our model with a Weibull estimator selected using the Cox-Snell residuals and likelihood ratio (LR) test. We conclude by summarising the main findings and suggest directions for future research.

2. Theoretical background and hypotheses

2.1. Internal innovation resources and business failure

The dynamic capabilities view (Teece, 2007) extends our understanding of how firms utilise their resources in volatile conditions (Wu, 2010). Capabilities are often intangible resources that are acquired over time, for which there is no market and relate to a firm's own know-how in the way they combine market derived resources. As such, they offer an internal impediment to business failure, improving resilience in economic downturns (Grewal & Tansuhaj, 2001). A firm's internal capabilities are manifold, ranging from organisational capabilities to innovation resources. These resources fundamentally revolve around knowledge and include investment in R&D and skilled personnel but may also incorporate organisational capital and networking capabilities (Wu, 2010).

2.1.1. R&D intensity

Extant research suggests that investment in R&D improves a firm's learning capabilities, often referred to as absorptive capacity (Cohen & Levinthal, 1990; Zahra & George, 2002), and constitutes an important input to the development of intangible capital (Garcia Martinez, Zouaghi, & Sanchez Garcia, 2017; Gu, Jiang, & Wang, 2016). R&D capabilities enable firms to develop and maintain its broader capabilities to identify, assimilate and exploit knowledge from external sources.

Recent studies support the premise that investment in R&D reduces the risk of business failure (e.g., Cefis & Marsili, 2012; Howell, 2015), enhances firm survival and productivity gains (Ugur, Trushin, & Solomon, 2016). Li, Shang, and Slaughter (2010) report that R&D intensity has long been regarded as a key driver of firm survival in the high-technology software industry. Similarly, Kim and Lee (2016) and Fontana and Nesta (2009) suggest that R&D intensity is a key firm-specific dynamic capability that significantly influences firm survival. In the case of service firms, internal R&D activities contribute to knowledge creation and foster combinations of new and old information necessary for the development of services and quick delivery (Amara, D'Este, Landry, & Doloreux, 2016). We therefore hypothesise that R&D intensity increases a firm's knowledge base and is negatively associated with business failure.

H1. R&D intensity is negatively associated with business failure.

2.1.2. R&D human capital

Ployhart and Moliterno (2011) define human capital as a "unit-level capability that is created from the emergence of individuals' knowledge, skills, abilities, and other characteristics" (p. 127). Resource-based theorists argue that labour can be an important source of competitive advantage because tacit knowledge is uniquely firm-specific (Coff, 1997). R&D human capital is responsible for transforming the idiosyncratic tacit and explicit knowledge, including learning abilities, experience, and abilities that are useful in carrying out firm's activities (Delgado-Verde, Martín-de Castro, & Amores-Salvadó, 2016; D'Este, Rentocchini, & Vega-Jurado, 2014). Goedhuys and Sleuwaegen (2016) state that human capital is a key driver of firm growth, reducing firm failure and the incidence of low growth. Research by Dahl and Klepper (2015) suggests that more productive firms hire more talented employees, which gives rise to enduring firm capabilities and survival over time.

Recent work by Siepel et al. (2017) highlights that both 'general' and 'specific' human capital skills in the workforce are crucial in shaping growth and survival prospects of manufacturing firms. This supports previous work by Cooper, Gimeno-Gascon, and Woo (1994) showing that firms whose founders have lower levels of human capital are more likely to fail. Focussing on German start-ups, Rauch and Rijsdijk (2013) explore the relationship between growth, firm survival and human capital embedded in the entrepreneur and report that growth can hinder firm survival as resources are constrained in growing firms; however, both general and specific human capital can offset the risk of business failure. Thus, we argue that R&D human capital matters for the determination of a firm's absorptive capacity and decreases hazard rates.

H2. R&D human capital is negatively associated with business failure.

2.2. External knowledge sources and firm survival

Firms do not exist in isolation; the benefits of open innovation are increasingly recognised in the innovation management literature as the trend towards innovation collaboration across organisational boundaries intensifies (Podmetina, Teplov, Albats, & Dabrowska, 2016; Schroll & Mild, 2012). Extant literature shows that increasing openness is associated with the development of dynamic capabilities to cope with turbulent environments (Cruz-González, López-Sáez, Navas-López, & Delgado-Verde, 2015; Di Minin, Frattini, & Piccaluga, 2010; Zouaghi et al., 2018). During economic downturns, firms that actively engage in external collaboration exhibit a strong adaptive behaviour to ensure their survival while maintaining internal innovation capabilities for future growth (Chesbrough & Garman, 2009).

Vertical alliances with suppliers and customers enable firms to learn different skills, pool complementary resources, update and modify learning routines, and access market information (Miotti & Sachwald, 2003; Walsh, Lee, & Nagaoka, 2016), which are likely to make them stronger competitors (Silverman & Baum, 2002). Supplier collaboration is found to enhance efficiency and complement the technological-base of the firm (Belderbos, Carree, & Lokshin, 2004; Un & Asakawa, 2015). Scholars have demonstrated the benefits of collaborating with consumers in value creation activities (Garcia Martinez, 2014; Grimpe & Sofka, 2009; Lusch & Vargo, 2006). Cooperating with so-called lead users has been described as an important source of innovation for firms, especially in fast-paced or turbulent markets (von Hippel, 2005).

Universities, along with innovation intermediaries and consultants, government agencies and firms in other industries are all considered to be *horizontal* partners (Belderbos et al., 2004; Stefan & Bengtsson, 2017). Collaboration with universities and research institutes can provide access to tailor-made, cutting-edge technologies (Tether & Tajar, 2008; Tsai, 2009); however, it may require firms to collaborate with other actors in order to implement the technology (Berg-Jensen, Johnson, Lorenz, & Lundvall, 2007). Also alliances with innovation intermediaries are often motivated by the need to achieve novelty goals and reduce development time (Chiaroni, Chiesa, Massis, & Frattini, 2008). Collaboration with competitors offers firms speedy market

penetration (van Beers & Zand, 2014) and access to technological abilities that can be difficult, time-consuming, and costly to develop alone (Chen, Chen, & Vanhaverbeke, 2011). Therefore, we propose that external knowledge assets are more likely to reduce the risk of firm failure by enabling firms to tap into new and relevant knowledge bases and competencies.

H3a. Vertical collaboration is negatively associated with business failure.

H3b. Horizontal collaboration is negatively associated with business failure.

H3c. Competitor collaboration is negatively associated with business failure.

2.3. Moderating effects of the financial crisis

Economic downturns are often associated with high levels of environmental uncertainty and significant downward shifts in demand levels (Cerrato, Alessandri, & Depperu, 2016). Investments in R&D and innovation activities become significantly riskier during periods of recession due to the uncertainties in the commercialisation of new products and services and the generation of sufficiently high payoffs to recoup production costs (Cruz-Castro & Sanz-Menéndez, 2016).

The recent financial crisis has forced many firms to postpone ongoing R&D and innovation projects (Cincera, Cozza, Tübke, & Voigt, 2012; Filippetti & Archibugi, 2011; Paunov, 2012). However, evidence show that firms are able to cope better during recession periods by having invested in R&D activities (Zouaghi et al., 2018). Archibugi, Filippetti, and Frenz (2013), in their analysis of three waves of the UK Community Innovation Survey (CIS), find that the lack of internal financial resources hampered innovation during the economic crisis; however, highly innovative firms increased innovation efforts during the downturn, which helped them to overcome the challenges of operating in a slow economy.

Cruz-Castro and Sanz-Menéndez (2016) show that the Spanish public research sector was poorly equipped to resist the recent crisis, with public R&D budgets decreasing in times of recession. Similarly, Milić (2013) suggests that investment in innovation and future growth are at risk during an economic crisis, when most organizations cut their R&D budgets. Comin and Gertler (2006) provide evidence to support the pro-cyclical argument that R&D investment and the global financial crisis have reduced aggregate private investment in innovation. We therefore hypothesise that:

H4. The effect of R&D intensity on business failure diminishes in crisis periods.

The recent literature highlights the role of human capital during a time of crisis as a valuable resource to foster innovation and creativity. Filippetti and Archibugi (2011), for instance, show the crucial role played by qualified human resources in mitigating the effects of the financial crisis, suggesting that the effects in terms of human capital investments are not the same across all European countries. The underlying argument is that the economic downturn has led to the migration of skilled workers, cuts in public R&D spending and education in some countries.

During periods of recession, innovation requires sufficient capabilities through investment in human capital to find ways to increase production and reduce costs, as well as sufficient financial capital either to bring in outside talent or to introduce new equipment (Bathelt, Munro, & Spigel, 2013). Goedhuys and Sleuwaegen (2016) find that human capital is a key driver of firm growth and reduces firm failure. Recent research by Dahl and Klepper (2015) suggest that more productive firms hire more talented employees, which gives rise to enduring firm capabilities and survival over time. These findings are supported by Day (2016) who predicts that R&D and human capital accumulation will continue to sustain economic growth under uncertain conditions. Thus, we hypothesise that:

H5. The effect of R&D human capital on business failure diminishes in crisis periods.

Cooperation with different partners has become more attractive for firms during uncertain economic conditions to access new knowledge, skills and capabilities leading to long-term survival (Chesbrough & Garman, 2009; Di Minin et al., 2010). Abramovsky, Kremp, Lopez, Schmidt, and Simpson (2005) concluded that firms favour cooperative strategies to overcome the perceived high risks of innovation and financial constraints. Cerrato et al. (2016) report a positive relationship between crossbreed acquisitions and long-term firm performance during a crisis. Partnering with firms that possess complementary assets leads to superior performance and help firms to survive longer (Velu, 2015).

Collaborative approaches, given their double aim of pooling knowledge and sharing costs and risks of R&D activities, should increase in periods of economic downturn in order to support firms' innovation capabilities (Laperche, Lefebvre, & Langlet, 2011). Extant literature on open innovation argues that firms use external collaboration to boost innovative performance and meet new business challenges (Dahlander & Gann, 2010; Huizingh, 2011; Lichtenthaler, 2011). Thus, we hypothesise that a mitigating effect of collaboration on business failure in times of economic crisis.

H6a. The effect of vertical collaboration on business failures diminishes in crisis periods.

H6b. The effect of horizontal collaboration on business failures diminishes in crisis periods.

H6c. The effect of competitor collaboration on business failures diminishes in crisis periods.

3. Methodology

3.1. Data and sample

Data for the quantitative analysis are drawn from the Spanish Technological Innovation Panel (PITEC); a statistical instrument for studying innovation activities of Spanish companies over time. The database is compiled by the Spanish National Statistics Institute (INE), in collaboration with the Spanish Science and Technology Foundation (FECYT) and the Foundation for Technological Innovation (COTEC). The PITEC dataset contains panel data for > 13,000 firms since 2003 and includes both manufacturing and service sector firms. Each firm in the sample has a unique identification code, which allows us to keep track of its entry date and current status. If a firm appears with a new identification code in the database, it is regarded as a new entry (Kim & Lee, 2016). If a code for an existing company disappears from the database due to a business closure, it is regarded as an exit. If the code remains in a given year, the firm is considered to be a surviving firm. In this study, we include firm-level data for the period 2009–2015,[1] for both manufacturing and service firms since we contend that the industry context can influence the effects of the economic downturn on business failure.

3.2. Measures

3.2.1. Dependent variable

The dependent variable is business failure related to the firm time that it has taken the company to reach the risk to go out (situation of failure). We examine the exits of firms between 2009 and 2015. In our

[1] The age of the company is available from 2009.

study, the failure analysis is based on firm exists due to closure (Howell, 2015; Ugur et al., 2016). The data is left censored at 2009 since the entry date is unobserved (because the sample starts in 2009) and right censored at 2015 since we have not observed all potential exits for that year.

3.2.2. Independent variables

R&D intensity is defined as a firm's R&D expenditure as a proportion of the firm's total sales (Kim & Lee, 2016). R&D intensity is extensively used in innovation research as an innovation input measure (Mairesse & Mohnen, 2010). Ugur et al. (2016) report a strong relationship between R&D intensity and firm survival.

R&D human capital is measured as the percentage of highly skilled R &D workers (researchers and technicians) (Vogel, 2013). Highly qualified employees are regarded as a significant factor in innovation performance (Teirlinck, 2017).

3.2.3. External knowledge sources

In line with previous studies (e.g., Ciliberti, Carraresi, & Bröring, 2016; Stefan & Bengtsson, 2017), we distinguish between three types of external collaborations: vertical collaboration (suppliers and consumers), horizontal collaboration (commercial research institutions and consultancy firms, private laboratories and consultants, universities and educational institutions, public and non-profit research institutions) and competitor collaboration. Following Laursen and Salter (2006), *collaboration depth* was defined as the intensity of collaboration with each partner type. In the survey, firms are asked to indicate using a four-point Likert scale the intensity of collaboration with each external knowledge source (ranging from 0 = “not used” to 4 = “highly used”). Each source is then coded as a binary variable in which 1 represents an external knowledge source used to a high degree (4) and 0 when a given source is not used, or only to a low or medium degree (0 to 3).

Financial crisis: we consider two time periods: recession (2009–2013) and post-recession[2] (2014–2015), to better understand the long-term effects of the financial crisis on the likelihood of business failure. We are interested in whether the impact of internal and external knowledge sources on business failure is significantly different between the two time periods. We specify a year dummy to take account of the financial crisis as an indicator of downswings (Ugur et al., 2016) that takes the value 1 in years 2009–2013, and 0 otherwise (2014–2015). Following the methodology proposed by Spaliara and Tsoukas (2013), we interact our independent variables with the financial crisis variable to capture the sensitivity of business failure to internal innovation resources and external knowledge sources ‘in’ and ‘post’ financial crisis.

3.2.4. Control variables

Firm size is measured as a dummy variable that takes the value 1 if the number of employees equals or is > 200, and 0 otherwise. Large firms are at less risk of failure compared to small firms as they have access to alternative sources of finance and are less informationally opaque (Spaliara & Tsoukas, 2013). *Labour productivity* is defined as the natural logarithm of firm sales divided by the total number of employees (Ugur et al., 2016). Finally, we test whether firms' exit behaviour is closely linked to their industry affiliation (Kim & Lee, 2016) by controlling for *industry effects* following the OECD classification of industries in terms of technology and knowledge intensity (OECD, 2005). We create four industry dummies to identify manufacturing firms belonging to high-tech, medium-high, medium-low and low-tech industries; and two dummy variables for service industries: knowledge-intensive business and low knowledge-intensive business services. We use the high-tech industry as the baseline for manufacturing models and the knowledge-intensive services for service models. Table A.1 in Appendix A describes the variables used in this study.

[2] When GDP started to be positive in Spain

3.3. Hazard model

We use survival analysis to examine the impact of internal and external knowledge capabilities on business failure. Hazard models are suitable for disentangling the determinants of firm failure since they account for both the probability of failure and the time-duration until failure (Nilsson, 2016). Standard regression approaches, such as ordinary least square (OLS) are not appropriate for the analysis of survival data because they do not correct for the problem of right censured variables (Talay, Calantone, & Voorhees, 2014; Velu, 2015). In this study, not all firms in the database have failed by the end of our period of analysis. Survival analysis can cope with right censored data which represents situations where a failure event has not yet occurred and with time-series data with different time horizons (Jenkins, 1995).

The cumulative distribution function of the duration time T is denoted as F and defined as:

$$F(t) = P_r(T \leq t) \; with \; t \geq 0 \tag{1}$$

This function gives the probability that the duration T is less than or equal to t.

The survival probability is given by:

$$P_r(T > t) = 1 - F(t) \equiv S(t) \tag{2}$$

which gives the probability of being alive just before period t, or more generally, the probability that the event of interest (in our case, closures) has not occurred by duration t. Then, the hazard function $h(t)$ is the conditional failure rate defined as the probability of exit during a very small time interval assuming the firm has survived to the beginning of that interval. The hazard of exit, the dependent variable in this study, is defined as the instantaneous rate of occurrence of the event (exit) at time t. The hazard function is given by:

$$\lambda(t) = \lim_{dt \to 0} \frac{P_r\{t \leq t + dt \mid T \geq t\}}{dt} \tag{3}$$

where dt is a very small interval, the numerator of this expression is the conditional probability that the event will occur in the interval $[t, t + dt]$ given that it has not occurred before, and the denominator is the width of the interval.

We rejected a Cox proportional hazard model because it failed the Schoenfeld (1982) residuals tests of the proportionality assumption (Ugur et al., 2016). As a result, we estimated five parametric survival models: exponential, lognormal, Weibull, Gompertz, and log-logistic, where survival can be estimated in proportional hazard (PH) or accelerated failure time (AFT) metrics. We selected the optimal model using the fit level in the Cox-Snell residuals plots and the likelihood ratio (LR) test. Both sets of criteria favoured the Weibull distribution.

Therefore, our hypotheses were tested using the Weibull model for the parametric hazard model not only to address the right-censuring problem, but also to analyse the effect of various covariates on a probability of failure model.

The survivor function is then $S(t) = e^{-(\lambda t)^p}$. The model used describes a proportional hazard model which can be formally represented by the following equation:

$$h(t) = h_0(t)\, exp(X\, \beta) \tag{4}$$

where $h(t)$ is the hazard rate at time t and $h_o(t)$ is a baseline hazard rate, which is $h_0(t) = p\lambda^p\, t^{p-1}$ and β corresponds to the estimate coefficients.

All results (descriptive and estimations) are based on weighted data in order to be representative of the population of Spanish firms. The data was weighted back to the total business population reported by the Spanish National Institute of Statistics (INE, DIRCE).[3]

[3] The data is available at this link: http://www.ine.es/dyngs/INEbase/es/operacion.htm?c=Estadistica_C&cid=1254736160707&menu=resultados&idp=1254735576550

Table 1
Summary statistics of the whole sample.

	All firms	Fail = 1	Fail = 0	p-Value	Recession = 1	Recession = 0	p-Value
R&D intensity	0.07 (0.31)	0.10 (0.42)	0.07 (0.32)	0.000	0.07 (0.31)	0.06 (0.27)	0.000
R&D human capital	38.05 (44.53)	25.56 (40.79)	39.67 (44.74)	0.000	37.09 (44.32)	37.94 (44.63)	0.048
Vertical partners	0.75 (0.90)	0.56 (0.83)	0.78 (0.91)	0.000	0.74 (0.90)	0.75 (0.93)	0.106
Horizontal partners	0.25 (0.69)	0.16 (0.55)	0.26 (0.70)	0.000	0.24 (0.69)	0.25 (0.71)	0.251
Competitors partners	0.09 (0.09)	0.07 (0.26)	0.09 (0.00)	0.012	0.08 (0.28)	0.09 (0.28)	0.474
Firm size	0.24 (0.43)	0.10 (0.30)	0.26 (0.00)	0.000	0.24 (0.43)	0.26 (0.43)	0.000
Productivity	11.71 (1.06)	11.26 (1.22)	11.74 (1.05)	0.000	11.69 (1.06)	11.76 (1.10)	0.000

Notes: the table presents sample means. Standard deviations are reported in parentheses. The p-value of a test of the equality of means is reported.

4. Results

Table 1 reports means and standard deviations for the variables used in the empirical study: total sample (column 1), failed and surviving firms (columns 2 and 3) and firms during and after the crisis (columns 5 and 6). Further, the p-values of a test for the equality of means are presented in columns 4 and 7. Looking at columns 2 and 3 we observe that surviving firms are less engaged in R&D activities, although have more skilled workers, are more active in collaborative relationships, more profitable and more larger-sized compared to failing firms.

Table 2 reports the descriptive statistics and the correlation matrix for the variables used in the empirical study (with the exception of sectoral dummies). Correlation values among all variables are generally low to moderate, suggesting there is a low risk of facing collinearity issues with this set of variables.

Fig. 1 shows the plot of estimated hazard functions, for manufacturing and service separately. The hazard experienced by firms increases over time; low-tech manufacturing firms are more likely to fail compared to high-tech industries. Similarly, the hazard rate for low-knowledge intensive service firms is higher than for knowledge intensive firms.

Tables 3 and 4 present the results using the Weibull hazard model with unobserved heterogeneity for manufacturing and service firms, respectively. When the coefficient of the hazard model is larger than 1, it implies that, as the covariate increases, so does the hazard rate (i.e., the time of exit of a firm is advanced). On the other hand, when the coefficient of the hazard model is < 1, as the covariate increases, the hazard rate decreases (i.e., the time of exit of a firm is delayed). Robust standard errors are presented in parentheses (de Figueiredo & Kyle, 2006; Velu, 2015). For both sectors, we estimated six model specifications. Model 1 includes the explanatory variables and control variables. Models 2 to 6 include the interaction terms for the independent variables and the financial crisis covariate.

The coefficient for the direct relationship between the financial crisis and the hazard rate is significant and > 1, showing that the financial crisis is an important factor in explaining business failure (Tables 3 and 4 – Model 1). Hypothesis 1 states that high R&D intensity will decrease the likelihood of firm failure. The coefficient for the direct relationship between R&D intensity and the hazard rate is significant and > 1 for both sectors (Tables 3 and 4 – Model 1), suggesting that R&D intensity reduces the probability of firm survival. Hence, Hypothesis 1 is not supported. Hypothesis 2 states that high levels of human capital will decrease the likelihood of firm failure. The coefficient for the direct relationship between R&D human capital and the hazard rate is significant and < 1 (Tables 3 and 4 – Model 1), showing that R&D human capital is an important factor explaining firm survival in manufacturing and service sectors. Hence, Hypothesis 2 is supported.

Hypotheses 3a–3c state that external knowledge assets will decrease the likelihood of firm failure. Results show differential effects for manufacturing and service sectors, supporting our hypothesising that the determinants of business failure differ across sectors where firms face different technological opportunities. In the case of manufacturing firms, the coefficients for the direct relationship between vertical and horizontal collaboration and the hazard rate are significant and < 1, suggesting the importance of vertical and horizontal collaboration in explaining manufacturing firms' survival. In contrast, the coefficient for the direct relationship between competitor collaboration and the hazard rate is significant but > 1. For service firms, the coefficients for the direct relationship between horizontal collaboration and the hazard rate are significant and < 1, suggesting the importance of horizontal collaboration in explaining service firms survival. However, the coefficients of both vertical and competitor partners are not significant. Hence, Hypotheses 3a–3c is partially supported.

Hypothesis 4 states that the relationship between R&D intensity and business failure diminishes due to the financial crisis. Model 2 (Tables 3 and 4) shows that the coefficient for the direct relationship between the financial crisis and the hazard rate is significant and > 1, suggesting that the financial crisis is an important factor in increasing the likelihood of business failure However, the interaction between R&D intensity and the financial crisis is not significant; hence, H4 is not supported.

Table 2
Descriptive statistics and correlation matrix.

	Mean	SD	Correlation coefficients								
			1	2	3	4	5	6	7	8	9
1. Business failure	0.06	0.23	1								
2. R&D intensity	0.07	0.31	0.02*	1							
3. R&D human capital	38.05	44.53	−0.05*	0.25*	1						
4. Vertical collaboration	0.75	0.90	−0.04*	0.14*	0.48*	1					
5. Horizontal collaboration	0.25	0.69	−0.02*	−0.19*	0.26*	0.26*	1				
6. Competitor collaboration	0.09	0.09	−0.01*	0.08*	0.21*	0.36*	0.19*	1			
7. Financial crisis	0.71	0.45	0.01	0.01*	−0.01*	−0.01	−0.01	−0.01	1		
8. Firm size	0.24	0.43	−0.08*	−0.10*	−0.05*	−0.04	−0.01*	−0.02*	−0.02*	1	
9. Productivity	11.71	1.06	−0.08*	−0.20*	0.11*	0.12*	0.38*	0.04*	−0.03*	0.04*	1

S.D. = standard deviation.
* $p < 0.01$

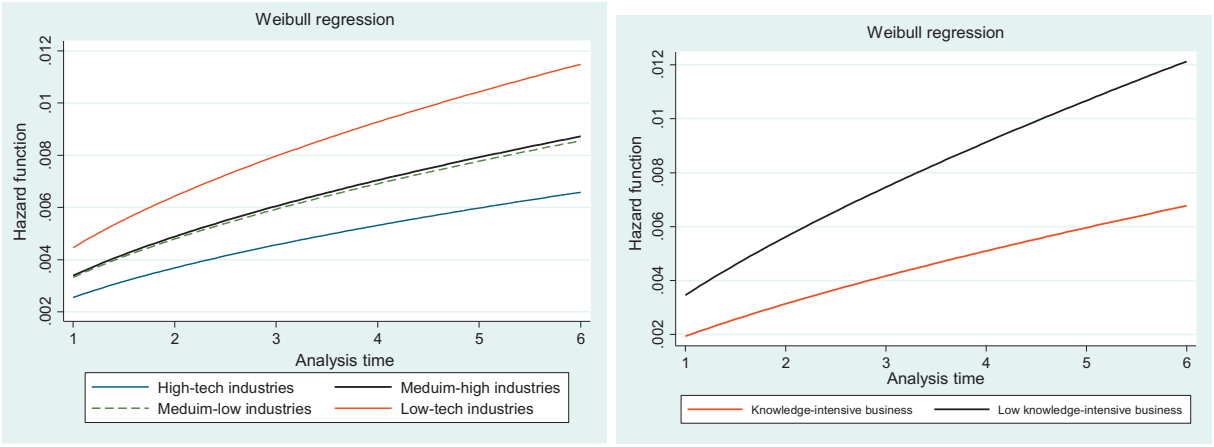

Fig. 1. Hazard functions: (a) manufacturing firms and (b) service firms, 2009–2015.

Hypothesis 5 states that the relationship between R&D human capital and business failure diminishes due to the financial crisis. Model 3 (Tables 2 and 3) shows that the interaction term between R&D human capital and financial crisis is significant and < 1 for service firms only. This suggests that R&D human capital reduces the effect of service firm failure in times of recession compared to a post recession period. In order to understand better how the financial crisis affects the relationship between R&D human capital and firm failure, we conduct an effect size interpretation of the interaction term using the non-exponentiated coefficients of the hazard model (Velu, 2015).

Interpreting interaction coefficients in hazard models is perhaps less graph-friendly; however, the non-exponentiated coefficients provide rich information (Trevor, 2001). Using the unstandardized coefficient of the model with the interaction term, we multiply the raw interaction coefficient by the high and low levels of the moderator (for instance, 1 and −1 to account for a one standard deviation increase or decrease in the variable of interest). Adding the interaction term to the raw main effect coefficient produces two coefficients that, at high and low levels of the moderator represent the total effects of a one-standard-deviation increase in the predictor of interest on the lagged hazard rate (Trevor, 2001). Exponentiating these coefficients produces hazard rate multipliers that are associated with a one-standard-deviation increase in the predictor's effect at high and low levels of the moderator.

According to Table 4 (Model 3), the hazard ratios of R&D human capital and the interaction term between R&D human capital and financial crisis are 0.98 and 0.99, respectively. This gives non-exponentiated coefficients of −0.02 and −0.01, respectively. Therefore, a one standard-deviation increase in R&D human capital results in a 0.97 multiplier (exp [−0.02–0.01]) of the hazard rate, and a 3% ((hazard rate multiplier − 1) × 100) decrease in the failure rate for manufacturing firms at any time *t*, when in a recession period. The same increase in R&D human capital translates to a 0.99 multiplier and a 1% decrease in the failure rate for manufacturing firms at any time t when in a post-recession period. Thus, at the height of recession, the effect of R&D human capital on firm survival is over 2 times larger than in the post-recession period. R&D human capital has a greater impact in reducing service firm failure during recession periods compared to post-recession periods.

Hypotheses 6a–6c state that the relationship between external collaboration and business failure will diminish in times of financial crisis.

Table 3
Hazard rate model for manufacturing firm (weighted results).

	M1 Haz.ratio	M2 Haz.ratio	M3 Haz.ratio	M4 Haz.ratio	M5 Haz.ratio	M6 Haz.ratio
Financial crisis	3.06(0.47)[c]	3.11(0.48)[c]	3.41(0.62)[c]	3.65(0.66)[c]	2.99(0.46)[c]	3.25(0.53)[c]
R&D intensity	1.28(0.12)[c]	1.87(0.55)[b]	1.29(0.12)[c]	1.29(0.12)[c]	1.28(0.12)[c]	1.29(0.12)[c]
R&D human capital	0.99(0.00)[c]	0.99(0.00)[c]	0.99(0.00)[c]	0.99(0.00)[c]	0.99(0.00)[c]	0.99(0.00)[c]
Vertical collaboration	0.82(0.04)[c]	0.82(0.04)[c]	0.82(0.04)[c]	1.02(0.10)[c]	0.82(0.04)[c]	0.82(0.04)[c]
Horizontal collaboration	0.84(0.06)[b]	0.84(0.06)[b]	0.84(0.04)[b]	0.84(0.06)[b]	0.82(0.04)[b]	0.82(0.04)[b]
Competitor collaboration	1.38(0.18)[b]	1.38(0.18)[b]	1.38(0.19)[b]	1.38(0.19)[b]	1.38(0.19)[b]	2.24(0.65)[b]
Firm size	0.37(0.05)[c]	0.37(0.05)[c]	0.37(0.05)[c]	0.37(0.05)[c]	0.37(0.05)[c]	0.37(0.05)[c]
Labour productivity	0.54(0.02)[c]	0.54(0.02)[c]	0.54(0.02)[c]	0.54(0.02)[c]	0.54(0.02)[c]	0.54(0.02)[c]
Medium high-tech	1.30(0.17)[a]	1.30(0.17)[a]	1.30(0.17)[a]	1.30(0.17)[a]	1.30(0.17)[a]	1.30(0.17)[a]
Medium low-tech	1.31(0.16)[b]	1.31(0.16)[b]	1.31(0.16)[b]	1.31(0.16)[b]	1.31(0.16)[b]	1.31(0.16)[b]
Low-tech	1.74(0.23)[c]	1.74(0.24)[c]	1.74(0.24)[c]	1.74(0.24)[c]	1.74(0.24)[c]	1.74(0.24)[c]
Interaction terms						
R&D intensity * Financial crisis		0.68(0.21)				
R&D human capital * Financial crisis			0.99(0.02)			
Vertical collaboration * Financial crisis				0.76(0.08)[b]		
Horizontal collaboration * Financial crisis					1.20(0.24)	
Competitor collaboration * Financial crisis						0.56(0.18)[a]
Vif	1.55	2.10	2	1.94	1.81	1.84
Observations	27,404	27,404	27,404	27,404	27,404	27,404
Log likelihood	−3727.65	−3727.17	−3726.31	−3724.22	−3727.11	−3726.01

Note: standard errors give inside parentheses; Vif = Variance Inflation Factor.
[a] Significance at 1%.
[b] Significance at 5%.
[c] Significance at 10%.

Table 4
Hazard rate model for service firm failure (weighted results).

	M1 Haz.ratio	M2 Haz.ratio	M3 Haz.ratio	M4 Haz.ratio	M5 Haz.ratio	M6 Haz.ratio
Financial crisis	1.81(0.31)[c]	1.86(0.33)[c]	2.07(0.41)[c]	2.21(0.47)[c]	1.79(0.32)[c]	1.91(0.33)[c]
R&D intensity	1.16(0.09)[b]	1.31(0.15)[b]	1.16(0.09)[b]	1.16(0.09)[b]	1.16(0.09)[b]	1.16(0.09)[b]
R&D human capital	0.98(0.00)[c]	0.98(0.00)[c]	0.98(0.00)[c]	0.98(0.00)[c]	0.98(0.00)[c]	0.98(0.00)[c]
Vertical collaboration	0.98(0.07)	0.98(0.07)	0.98(0.07)	1.24(0.13)[b]	0.98(0.07)[b]	0.98(0.07)[b]
Horizontal collaboration	0.88(0.06)[a]	0.88(0.06)[a]	0.88(0.06)[a]	0.88(0.06)[a]	0.88(0.06)[a]	0.88(0.06)[a]
Competitor collaboration	1.26(0.22)	1.26(0.22)	1.26(0.22)	1.24(0.22)	1.26(0.22)	2.02(0.58)
Firm size	0.27(0.3)[c]	0.27(0.3)[c]	0.27(0.3)[c]	0.27(0.3)[c]	0.27(0.3)[c]	0.27(0.02)[c]
Labour productivity	0.75(0.03)[c]	0.75(0.03)[c]	0.75(0.03)[c]	0.75(0.03)[c]	0.75(0.03)[c]	0.75(0.03)[c]
Low knowledge-intensive	1.79(0.29)[c]	1.79(0.29)[c]	1.79(0.29)[c]	1.79(0.29)[c]	1.79(0.29)[c]	1.79(0.29)[c]
Interaction terms						
R&D intensity * Financial crisis		0.85(0.12)				
R&D human capital * Financial crisis			0.99(0.00)[b]			
Vertical collaboration * Financial crisis				0.74(0.09)[c]		
Horizontal collaboration * Financial crisis					1.04(0.17)	
Competitor collaboration * Financial crisis						0.53(0.18)[a]
Vif	1.47	1.89	1.88	1.87	1.78	1.78
Observations	21,002	21,002	21,002	21,002	21,002	21,002
Log likelihood	−3499.15	−3498.47	−3496.53	−3494.41	−3499.11	−3497.05

Note: standard errors give inside parentheses; Vif = Variance Inflation Factor.
[a] Significance at 1%.
[b] significance at 5%.
[c] Significance at 10.

Model 4 (Tables 2 and 3) shows that the interaction term between vertical collaboration and financial crisis is significant and < 1 for manufacturing firms only, suggesting that cooperation with vertical partners reduces the effect of manufacturing firm failure by 23% and service firm failure by 8% in recession period compared to post-recession.

Finally, Model 6 (Tables 2 and 3) shows that the interaction term between competitor collaboration and financial crisis is significant and < 1 for both service and manufacturing firms. Thus, the effect of competitor collaboration on firm failure during the recession is around 11 and 40 times larger compared to post-recession, for manufacturing and service firms, respectively.

5. Discussion and conclusion

The main objective of this paper is to examine the effect of internal and external knowledge sources on business failure, distinguishing between recession and post-recession periods. Using a hazard model, this paper shows the differential effects of internal innovation capabilities and external knowledge sources on business failure. Our results support the view that the financial crisis increases the probability of business failure. During the economic downturn, firms are likely to face more turbulent and uncertain environments, and therefore are more exposed to failure (Colombelli et al., 2013). Bhattacharjee et al. (2009) find that a larger number of firms are more likely to go bankrupt during unstable years characterized by high inflation and unfavourable exchange rate changes. In line with our results, Martin-Rios and Parga-Dans (2016) conclude that the economic crisis resulted in a fall in firm survival. Financial crises are often associated with high levels of environment uncertainty and significant downward shifts in the demand level which result in declining revenues and declining profits (Cerrato et al., 2016). Ugur et al. (2016) report that the macroeconomic environment at times of financial crisis is likely to reduce survival time.

Consistent with the dynamic capability perspective (Teece et al., 1997), our results confirm that R&D human capital, as a dynamic capability, provides firms with sources of competitive advantage. We find that R&D human capital is a valuable internal capability for firm survival. These findings support the extant literature (Pennings, Lee, & Van Witteloostuijn, 1998; Siepel et al., 2017) by demonstrating that investments in human assets help shape the life prospects of a firm. Additionally, results highlight the key importance of human capital resources in mitigating the effects of the financial crisis on firm failure. This effect seems to be more important for service firms, where human capital has a strong and positive association with firm survival. Highly qualified staff plays an important role in service firms to sustain long-standing relationship with their clients and to cope with external environment changes (Martin-Rios & Parga-Dans, 2016; Pennings et al., 1998; Thakur & Hale, 2013). Human capital is a source of sustainability and plays an important role in the success of firms. Investments in R&D human capital are essential for the service sector; this may be due to the survival of those firms under conditions of high competition requiring resources and capabilities to cope with turbulent market conditions. Fainshmidt et al. (2017) also note that a firm's human resources management helps hedge against economic downturns.

This study provides valuable insights into the importance of external knowledge assets in times of crisis for firm survival. Our empirical evidence confirms that manufacturing industries benefit from vertical collaboration which enhances their survival during the recessions. Consistent with our findings, George, Zahra, Wheatley, and Khan (2001) showed that external relationships with clients reduce the risk of organisational failure. Furthermore, access to research and institutional sources from research or intermediary knowledge organizations can be important strategies for mitigating the risks of manufacturing firm failure. Our empirical analysis demonstrates that manufacturing firms that collaborate with horizontal partners are more likely to overcome economic downturns. However, the relationship with competitors can hinder firm survival especially in time of crisis.

5.1. Contributions and managerial implications

Several managerial implications follow from this discussion and offer managers insights into the failure trap. First, firms that understand the factors associated with exit decision are more likely to build capabilities to mitigate the likelihood with failure. Second, policies aiming at promoting firm survival should differ across sectors, given that the degree of effectiveness of the factors influencing firm failure differs across sectors. Explaining the role of internal and external knowledge capabilities as sources of firm survival differentials among different sectors may help managers to take advantage of more efficient bundles of these resources to achieve firm long-term viability.

Manufacturing managers maintain their investment in R&D activities in order to build their internal resources base for enhancing its

efficiency and survive longer. R&D activities as a dynamic capability can help manufacturing firms' survival prospects and better adapt to an economic crisis. Our empirical research has shown the crucial role played by human capital in decreasing the effects of the crisis particularly in service sector firms. Managers in service firms need to invest in building a broad skills base to mitigate firm failure during the crisis period and to ensure long-term survival. Intangible human capital inside a firm is an idiosyncratic resource and difficult to imitate. Third, the analysis of external sources of knowledge enables managers to identify the types of external partner that provide the right knowledge assets to reduce the likelihood of firm failure.

5.2. Limitations and future research

This paper focuses on innovative firms due the particularity of the PITEC database which provides exclusively innovation indicators for innovative firms. A more diverse sample of firms may generate different results, but would not have as detailed information on firm specific capabilities. Second, our dataset is specific to firms in Spain so evidence from other countries on the factors influencing firm failure might help to develop more general empirical evidence in future research. Third, another limitation of our database is the anonymization of some variables in order to avoid disclosure. The anonymization process applied requires the following modifications: a) replacing the firm-level observations of five quantitative variables (Turnover, Investment, Number of employees, Innovation expenditures and Number of R&D employees) with data generated by means of a “hiding” process of the original observations; b) replacing the firm-level observations of the rest of the quantitative variables with the percentage value with respect to the aggregated value (for example, intramural R&D expenditure is replaced by the percentage of intramural R&D expenditure on total innovation expenditure).

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Appendix 1

Table A.1
Variables description.

Variables	Definitions
Dependent variables	
Business Failure	Year of firm exit due to closure
Predictor variables	
R&D intensity	R&D expenditure as a proportion of firm total sales
R&D human capital	Percentage of R&D top skilled workers
Vertical collaboration	The intensity of external knowledge search with vertical partners (customers and suppliers)
Horizontal collaboration	The intensity of external knowledge search with horizontal partners (universities, intermediaries, government agencies and firms in other industries)
Competitor collaboration	The intensity of external knowledge search with competitors
Financial crisis	Takes the value 1 if the observation corresponds to the period of crisis 2009–2013; 0 if the period is 2014–15.
Control variables	
Firm size	Dummy variable that take value 1 if the number of employees equal to or $>$ 200, and 0 otherwise
Labour productivity	Ln (ratio of firm sales to the total firm employees)
Sector dummy	Dummy variables indicating the sector where the firm operates

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