1. R&D investments and firm survival across regions

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1. INTRODUCTION

Expenditure on R&D has been gaining increasing attention over recent decades (Jaffe, 1986; Cohen and Levinthal, 1989; Griliches, 1998; and Lee, 2002). This has been reinforced by the rise of the ‘knowledge society’,¹ which has positioned R&D expenditure as a positive externality requiring government support. Given the current crisis, the OECD (2010) has stressed that innovation – and R&D – is essential for countries and firms to recover from the economic downturn and thrive in today’s highly competitive and connected global economy.

In parallel, there has been a growing interest in the development of entrepreneurship and business dynamics through the behaviour of firms in different sectors and regional environments (Kirzner, 1973; Schultz, 1979; Audretsch and Thurik, 2004; Lazear, 2005; Parker, 2005; Klein and Cook, 2006; and Johannisson, 2009). The entrepreneurial activity has emerged as a key element in economic development (Acs et al., 2004; Thurik and Wennekers, 2004; Stel et al., 2005; Braunerhjelm, 2007; and Audretsch, 2007). Braunerhjelm (2011) has highlighted that there is an intricate nexus of interacting forces on four variables: entrepreneurship, knowledge, innovation and economic growth. Thus a large number of public programmes has tried to boost entrepreneurial development as a response to the economic crisis.

Therefore the set of policies simultaneously encouraging R&D and entrepreneurship raises the question of how they both relate and whether it is possible to find synergies between them, and also the extent to which R&D strengthens the likelihood of firm survival. A review of the literature on entrepreneurship demonstrates that there is a concern for finding its determining factors (Acs and Armington, 2004; Audretsch and

Callejón, 2007). Moreover, the theory of knowledge spillovers explains how knowledge (mainly measured as R&D expenditure and patents registered) is a driving force for entrepreneurship (Acs et al., 2005). This theory also explains how the creation of a company is an endogenous response to investment in knowledge, which is not entirely appropriate for incumbent firms (Audretsch and Keilbach, 2011). Also, Carlsson (2011) has shown in a range of national innovation systems that 'new knowledge' is the driving force of innovation, entrepreneurship and economic development.

Referring to the case of the Spanish economy, the current crisis has significantly worsened these indicators of investment in knowledge. Until 2008, R&D rates continued to rise in line with the acceleration since 2004, with figures pointing to a certain convergence with European and other advanced countries of the OECD. In that year, this expenditure continued to increase by 7.6 per cent (in constant euros), while from 2009 it has decreased markedly. According to the National Statistics Institute (INE, 2012), in 2011, domestic expenditure on R&D recorded a decrease of 4.1 per cent compared to the previous year: business spending shrank by 5.4 per cent, while spending on public administration and higher education fell by 3.3 per cent. Also, staff dedicated to R&D recorded a significant decline. It is anticipated that this recent spending contraction in the Spanish economy will continue in coming years, resulting in a continuous deterioration (COTEC, 2012, p. 11).

In the field of patents registered, we can see an improvement in the Spanish economy, although the crisis has had negative impacts. However, providing a comparable measure should make the data accord with international scales. Concerning triadic patents (Europe, Japan and the USA), Spain shows limited ability to protect its innovative efforts. In 2009, the USA, Japan and the EU-27 accounted for 87.5 per cent of the global total. Within the EU, triadic protection is concentrated in Germany (12 per cent worldwide), France (5.1 per cent) and the UK (3.4 per cent), while in Spain it represented only 0.47 per cent worldwide.

The analysis of this drop in spending on innovation in the Spanish economy during the crisis has served as a stimulus to develop this study. A decline of innovation expenditure over several years would mean closures and increased fragility of the productive sector. This is why studying R&D and its relationship to the probability of business survival becomes important compared with other economic indicators.

The study has not referred to a patents indicator for two reasons: first, due to its small weight in the Spanish economy, where the number of applications is low (preference for trade secrets over patents) and concentrated in a few sectors (Hernández-Cerdán, 2002; Gámir and Durá,

2010); and second, because, for technical reasons, not all innovations can be registered for patents.

Several surveys on entrepreneurship in Spain explain the strong relationship between R&D and entrepreneurial activity (García-Tabuenca et al., 2008, p. 145; 2012, p. 117 and 183). Specifically, a positive relationship between knowledge stock (total domestic expenditure on R&D accumulated from one period to the next, with an annual depreciation rate of 10 per cent, divided by GDP) and entrepreneurship has been found (Abellán-Madrid et al., 2011). However, on closer inspection, we find that, while R&D and entrepreneurship are clearly related, the relationship between R&D and the creation of companies is more erratic. Thus those regions with above average R&D/GDP expenditure may or may not register a higher creation of companies (birth rate), but they always have an above-average entrepreneurship level (number of companies/labour force).

This allows us to state our main study hypothesis: R&D is a key factor for entrepreneurial survival. This has been contested using data on the Spanish economy by Esteve-Pérez et al. (2004), although they work with R&D investment only as a dummy variable and do not carry out any regional analyses. This work aims for a more comprehensive insight, completing the evidence obtained in the previous work by carrying out a regional and sectoral analysis, distinguishing between technological and non-technological companies.

The analysis is therefore conditioned by four different technological environments that combine both regions and sectors where companies operate. This is because a technological company in a technological region faces competition that forces it to spend more on R&D. But, at the same time, being in such a region may have some advantages in terms of knowledge spillovers, making investment more profitable.

Thus our hypotheses are that a negative relationship between the level of R&D expenditure and exit probability can be expected, and that the level of that probability and the slope of the relationship will depend on the environment in which the firms operate.

The rest of the chapter is organized as follows. Section 2 presents a review of the literature, Section 3 is dedicated to data and methodology, Section 4 presents the results, and finally Section 5 contains conclusions and some suggestions regarding economic policy aimed at promoting R&D and therefore improving firm survival.

2. LITERATURE

R&D expenditure is a positive externality that needs government support to achieve a level in accordance with the social optimum. Therefore the market does not provide incentives for firms to allocate the right amount of resources to R&D (Arrow, 1962; Nelson, 1959), so public programmes arise with financial support for ensuring the right level of R&D and, at the same time, helping companies with costs, risks and uncertainties (Dasgupta and Maskin, 1987; Bloom, 2007) associated with innovation.

Achieving the social optimum level of R&D expenditure is therefore a generally accepted goal. Nevertheless, increasing R&D expenditure is not an end in itself but a way of obtaining positive effects for the economy as a whole. This takes us to the question of which are the expected results of the innovation effort and how they can be measured. The results traditionally expected are basically two: increase in productivity and sustainable economic growth.

Companies use R&D as an input in their productive process to obtain technological innovations. These innovations are intended to make the firm more competitive by improving its products or processes. Thus the firm can obtain a new or differentiated product or develop processes with lower costs. All those achievements can increase its productivity, improving its performance in the market.

A wide range of economic literature is devoted to the study of the impact of R&D on productivity and growth. Most of the studies use data at firm and industry level, but there are also works using data at the aggregate national level. Mansfield (1972), Nadiri (1993) and Link and Siegel (2003) use data from several industries in developed countries (the USA, Japan, France, among others) to show the increase in productivity due to R&D investment. This kind of studies follows the usual approach of estimating a production function (Griliches, 1979), where knowledge (proxied by the accumulation of private R&D investment) is one of the productive inputs.

The results are positive in general, but with variations depending on the industry, the period or the country. Thus, in the work by García-Manjón and Romero-Merino (2010) the authors provide a summary of studies with different results. For instance, the relationship can depend on the industry, being positive (the higher the R&D investments, the higher the production) in high-technology sectors (Chan et al., 1990; Coad and Rao, 2008) and negative in low-technology industries (Yu et al., 2008).

On the other hand, the studies by Lichtenberg (1992) or Birdsall and Rhee (1993), among others, use aggregate data from different OECD countries. The results are specific in every study, but R&D is always

significant for explaining economic growth. In this field, there are also some works that conduct growth accounting methods for measuring the impact of accumulated investment in R&D (knowledge stock) on the economic growth of a given country. Fraumeni and Okubo (2005), for instance, in a study for the USA, obtain a contribution of 0.38 percentage points to the GDP average annual growth rate for the period 1961–2000. Jones (2002) obtains a contribution for the same country of 1.4 percentage points in the period 1950–93. In Spain, Borondo (2008) finds a contribution of 1.0 percentage points to the growth of productivity (2.3 per cent) between 1968 and 2004.

Despite the positive effects of R&D, the effect of public programmes on R&D is not exempt from controversy, and numerous studies focus on determining if public support generates an increase in private expenditure on R&D or if, otherwise, it generates a crowding-out effect of this type of expenditure. Among others, David et al. (2000) and David and Hall (2000) have referred to confusing and frequently contradictory estimates of the response of company-financed R&D to changes in the level and nature of public R&D expenditure. Or, referring to the Spanish economy, Callejón and García-Quevedo (2002) and Aerts et al. (2007) have assessed the role of public policies in R&D and complementary effects on private investment, but also on the existence of substitution effects between tax incentives and direct support for R&D. The latter has been specifically mentioned to studies based on information from many OECD countries (Guellec and Pottelsberghe, 2001).

The patent races models introduce a new complexity factor (Loury, 1979; Lee and Wilde, 1980; Kwon, 2012, among others). Thus, in a scenario of patent competition, the situation is the opposite of the one described earlier: companies enter an expenditure race in R&D to achieve a patent. Finally, the winning firm obtains a return on the expenditure, while the expenditure made by the other companies can be seen as an inefficient overinvestment that exceeds the social optimum.

To sum up, R&D expenditure is a question of economic and social interest that usually implies government support for assuring the right level of expenditure and, therefore, a positive impact on entrepreneurship, productivity and economic growth. In this context, the study of the hypotheses of the present work contributes to finding out in detail how R&D expenditure generates economic growth: the improvement of firm survival.

There is a wide range of economic literature about firm survival. The works by Congregado et al. (2010 and 2011) have studied, from an aggregate viewpoint, the determinants of self-employment survival in the countries of the EU-15, and the role of innovation and knowledge in business

survival and success in these countries. Other works in this area have focused mainly on analysing, in the context of industrial organization, the processes of entry and exit of firms (Geroski, 1995; Segarra and Callejón, 2002). Nevertheless, plenty of works are focused on finding the factors that determine firm survival. Among these works should be mentioned the papers by Taffler (1982), Cuthbertson and Hudson (1996) and Lennox (1999), dedicated to studying financial ratios of companies as determining factors for exit, or the papers by Jovanovic (1982), Dunne et al. (1989) and Hopenhayn (1992), studying the influence of size and age of firms, or the one by Bhattacharjee et al. (2009) analysing the economic cycle as a determining factor of survival.

Among the works on firm survival in Spain are Fariñas and Moreno (2000), in which the authors find evidence about decreasing exit probability with size and age of firms. In the same line and for manufacturing firms in Portugal, Mata et al. (1995) show evidence of the importance of current size and post-entry growth on survival. However, the results of a survey conducted by Siegfried and Evans (1994) of over 70 empirical studies concerning entry and firm survival show that the influence of R&D and its intensity is confusing. Another survey on entry and survival literature can be found in Caves (1998).

Therefore survival depends on macroeconomic factors, such as the economic cycle, and microeconomic factors, internal to companies. Among these factors is R&D expenditure, which is, therefore, the hypothesis of the present work. As has been pointed out, R&D allows companies to obtain improvements in their products and processes that increase their productivity. These more productive firms have better tools for competing in the market and, ultimately, for surviving. Therefore R&D would become a key element for companies and governments, as firms committed to these activities are not only more productive, but also become stronger and have guarantees of long-run performance. This has consequences for the economy as a whole, which would benefit from a more productive entrepreneurship that generates economic growth, avoiding at the same time the social and economic costs associated with the death of firms.

The relationship between R&D expenditure and firm survival has been studied specifically in the work by Sharapov et al. (2011). The aim of their paper is to study the impact of R&D on survival, but conditioned to different technological environments. These environments are combinations of regions and sectors in which companies operate, generating four environments through the combination of technological regions and sectors with non-technological regions and sectors.

Thus the authors find that the technological intensity of the sector in which a company operates determines the amount of R&D expenditure

required for building and maintaining the absorptive capacity needed for competing in an effective way and, therefore, for survival.

On the other hand, the technological intensity of the region in which a company operates determines, because of the existence of knowledge spillovers, cost in terms of the R&D of generating innovations.

Thus a technological company established in a technological region faces sectoral competence that forces it to a higher level of R&D investment before reaching the point (T) at which the relationship between that investment and the probability of exit becomes negative. But, on the other hand, being in a technological region can mean that the company benefits from knowledge spillovers from other firms in the area, which means that R&D investment has higher returns once point T is reached.

Therefore an inverted-U-shaped relationship between R&D expenditure and the probability of exit is expected. The declining part of the U confirms that R&D investment helps in survival since it reduces the probability of exit. But that declining part will be reached earlier (in terms of R&D expenditure), depending on the sector (technological or not), and will have a different slope (R&D returns), depending on the region (technological or not). Nevertheless, the U-shaped relationship raises some questions, because it implies that the first investments in R&D are increasing the exit probability of firms, especially in those environments in which the inflexion point is reached very late.

The authors test this hypothesis using microdata on UK manufacturing companies' R&D expenditure and survival between 1998 and 2005, finding significant evidence supporting the hypothesis.

In the case of Spain, the relationship between R&D expenditure and firm survival has been studied by Esteve-Pérez et al. (2004). In this work the authors work with a representative sample of manufacturing companies from the Encuesta sobre Estrategias Empresariales (ESEE – Business Strategies Survey) in the period 1990–99, using both non-parametric and semi-parametric survival methods. The results show that age of companies is significant in terms of firm survival, increasing the exit probability among younger and older firms in the sample. Another significant variable is size; thus the risk of exit is higher in small firms. The authors also find that survival probability is higher for exporting firms and for firms involved in R&D activities. They find that exporting firms have an exit probability 28 per cent lower than non-exporting companies. In the case of R&D, the results show that exit probability for innovative firms reduces by 57 per cent. These results, as the authors point out, are in line with the works by Audretsch (1995) and by Kimura and Fujii (2003).

Nevertheless, this work has some limitations. Thus both exporting and R&D activities enter the model as dummy variables, so the

model distinguishes only between doing R&D or not, not taking into account differences between levels of investment and between technological and non-technological sectors. On the other hand, the authors study the behaviour of firm survival at national level, without any regional disaggregation.

3. DATA AND METHODOLOGY

The work uses data from the survey Encuesta Sobre Estrategias Empresariales (ESEE) for the period 1991–2010. The survey is carried out annually by the SEPI Foundation, and is a panel survey of manufacturing firms located in Spain. The survey started in 1990 and, since that time, about 1800 firms have been surveyed each year (see Table 1.1).

As the SEPI Foundation points out,

one feature that makes ESEE different from other statistics is its provision of information based on panel data, which has implied the systematic tracking of changes in the firms' legal status. The ESEE covers a wide range of decisions that imply extraordinary changes in the firms' life cycle (mergers, absorptions, splitting, adjustment plans for employees, segregation of assets, and so on) that must be controlled to ensure time comparisons. (<https://www.fundacionsepi.es/esee/en/epresentacion.asp>)

The study is therefore focused on manufacturing companies. The fact that innovation in services remains beyond the scope of many studies is a relatively common issue. Many works are focused on manufacturing firms, and in a study by Gómez Uranga et al. (2009), the authors refer to that point in these terms: 'At the beginning, R&D activity was thought to be for industrial activities, with the purpose of generating new knowledge from it'; they also point out that 'the identification of R&D expenditures has more complexities in services than in manufacturing industry'. Meanwhile, Gallego and Rubalcaba (2008), within the EU context, have referred to the particular features of innovation in services, emphasizing those features in comparison with profiles of innovation in goods.

Data from ESEE are used to estimate a Cox proportional hazard regression. This kind of regression is very common in works on firm survival. The goal is to assess the effect of covariates (a set of independent variables) on the hazard rate and on the probability of firm survival.

The hazard rate is the probability that failure (a firm exits the market) occurs in a moment t given that the firm has survived until that moment and conditional on a vector of covariates. The hazard rate can be expressed as follows (Kalbfleisch and Prentice, 1980), where $F(t)$ is the probability

Table 1.1 SEE sample and exits (deaths)

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Sample	2188	2059	1977	1869	1876	1703	1716	1920	1776	1754	1870	1724	1708	1380	1374	1911	2023	2013	2009	2015
Number of exits	62	54	72	53	51	28	35	18	45	38	20	18	51	4	17	35	30	57	127	67

that duration (T) is less than or equal to t . $S(t)$ is the survival function and gives the probability that a firm survives t periods from 1991.

$$\lambda(t) = \lim_{\Delta t \rightarrow 0} \frac{\Pr(t + \Delta t > T > t | T > t)}{\Delta t} = \frac{\partial F(t)/\partial(t)}{S(t)}$$

To assess the effect of the explanatory variables on the risk of exit (controlling for the effect of other variables considered), we estimate the semi-parametric Cox proportional hazard model (Cox, 1972):

$$\lambda(t; X_{it}) = \lambda_0(t) \cdot \exp(X_{it}\beta)$$

In these kinds of model, any given firm faces a hazard rate that is a function of a baseline hazard rate $\lambda_0(t)$ that all firms face, transformed by a set of explanatory variables X_{it} (covariates). Thus the hazard for one firm is proportional to the hazard for any other firm and the proportionality constant is independent of time.

The model is semi-parametric because the baseline hazard is an unspecified function, while the covariates enter the model linearly. The model is estimated maximizing a partial likelihood function with respect to the vector of coefficients.

The dependent variable in this kind of models is always a dummy variable that takes the value 1 if the firm exists. In the estimated model we have 4543 subjects with 671 failures.

The covariates are the following variables:

- *Log (Average Labour Productivity)* – a control variable defined as a ratio of total output in real terms to total number of employees.
- *Foreign Capital Investment* – a control variable that takes the value 1 if the share of foreign capital is more than 50 per cent and 0 otherwise.
- *Log (Age)* – consists of the data on the constitution date of every company and is a classic control variable in survival analysis.
- *Log (Total Number of Employees)* – a common control variable in works on firm survival. It is a proxy for size.
- *Enterprise Group* – a dummy variable that takes the value 1 if the firm belongs to an enterprise group and 0 otherwise.
- *Concentration Rate* – the market share of the four largest companies in the market.
- *Product Standardization* – a dummy variable that takes the value 1 if the product is standardized.

Table 1.2 Descriptive statistics

	Mean	Std dev.	Dummy variables	
			% 1	% 0
<i>Average Labour Productivity</i>	97175.47	182656.70		
<i>Foreign Capital Investment</i>			6.2	93.8
<i>Age</i>	25.03	21.45		
<i>Total Number of Employees</i>	247.24	768.70		
<i>Enterprise Group</i>			30.7	69.3
<i>Concentration Rate</i>	38.25	27.76		
<i>Product Standardization</i>			60.5	39.5
<i>RDT1</i>	11.35	80.65		
<i>RDT2</i>	35.66	174.24		
<i>RDT3</i>	12.55	122.94		
<i>RDT4</i>	12.93	81.62		
<i>Environment1</i>			39.1	60.9
<i>Environment2</i>			18.6	81.4
<i>Environment3</i>			9.2	90.8
<i>Environment4</i>			32.4	67.6
<i>Average Age</i>	25.03	17.10		

- Log(RDT1–4)_1 – multiplicative variables. They use the logarithm of the ratio between expenditure in R&D and sales, multiplied by the environments (1 to 4). These variables enter the model with a lag of one period, reflecting the possible delay in the effect of R&D on firm survival. The ratio is expressed in *given per 10000*. The environments are combinations of regions and sectors. Definitions are as follows:
 - Environment1 – a dummy variable that takes the value 1 if the firm operates in a non-technological region and in a non-technological sector. As can be seen in Table 1.2, this environment represents 39.4 per cent of the sample of firms.
 - Environment2 – a dummy variable that takes the value 1 if the firm operates in a technological region and in a technological sector. This environment represents 18.7 per cent of the sample of firms.
 - Environment3 – a dummy variable that takes the value 1 if the firm operates in a non-technological region and in a technological sector. This environment represents 9.2 per cent of the sample of firms.
 - Environment4 – a dummy variable that takes the value 1 if the firm operates in a technological region and in a non-technological

sector. This environment represents 32.7 per cent of the sample of firms.

- Log (*Average Age*) – calculated from variable age and takes the average age of the firms of the sector in which every company operates. The variable is intended to be a proxy for industry turbulence, meaning that turbulent industries have a lower average age of companies.

Technological regions are considered to be Madrid, Cataluña, País Vasco and Navarra, according to the results presented in several works, for example Calderero and Kuittinen (2009), Reig (2007), López-García et al. (2009) or N-Economía (2012, pp.29–30), and according to various regional technological measures and indicators, among which are investment in R&D, articles published in international journals, use of technology, telecommunications and internet access, e-commerce and so on by businesses, households and governments.

Technological sectors are considered to be, according to the classification of sectors included in the ESEE survey, the following: 9 (pharmaceutical and chemical industry), 14 (industrial machinery), 15 (computer system, electronic and optical products), 16 (electric material), 17 (motor vehicles) and 18 (other transport materials). Figure 1.1 shows the percentage of firms in technological sectors by regions. In general, technological regions

Figure 1.1 Percentage of firms in technological sectors by regions (NUTS-2)

have a greater percentage of firms in technological sectors, with the exception of Aragon, which has a greater percentage (43.9 per cent) in a non-technological region. This particularity might be due to the presence of technological spillovers from the neighbouring regions. In fact, the region of Aragon (NUTS-2) is successful in entrepreneurial activity, and together with Basque Country (36.4 per cent), La Rioja (10.3 per cent) and Navarre (34.3 per cent), forms the 'Northeast' (NUTS-1) region. This, along with 'Madrid' and 'East', are the three NUTS-1 regions, more advanced in terms of entrepreneurial dynamism and entrepreneurial creativity (García-Tabuenca et al., 2011).

4. RESULTS

Results were obtained using a robust estimation for the errors and the Effron method for ties (when two or more firms exit at the same time). A proportionality test was implemented, and the assumption of proportional hazard can be accepted.

In Table 1.3 we present the results of the coefficients estimated for the covariates of the Cox model. Productivity is significant and negative, meaning that an increase in productivity, as expected, reduces exit probability (Carreira and Teixeira, 2011). The presence of foreign capital is significant but positive, and the same occurs with membership of an enterprise group. This is in line with Esteve-Pérez et al.'s (2004) results for Spain: 'those firms with foreign capital participation bear a notorious higher risk of exit'.

Following with the control variables, variable *Age* is significant and positive, meaning that an increase in age increases exit probability; that is, older firms are more likely to exit. This is partly in line with the results of Esteve-Pérez et al. (2004), where the authors find that younger firms are more likely to exit, but also mature firms. *Size (Total Number of Employees)* is significant and negative, so the larger firms are less likely to exit. This is a classic result in the literature on firm survival (Esteve-Pérez et al., 2004; Carreira and Teixeira, 2011, among others). *Concentration Rate* is not significant, which is in line with the results of Sharapov et al. (2011). *Product Standardization* is strongly significant and positive, as can be expected: companies with more differentiated products (low standardization) are less likely to exit. This is pointed out in Holcombe (2009, p. 33): 'The optimal competitive strategy is to seek ways of differentiating the firm's output from that of other firms by creating a product that is more desirable to consumers. Indeed, this strategy is necessary for the survival of a competitive firm . . . '.

Table 1.3 Cox proportional hazard model results

Covariates	Coefficients	Hazard ratio
log(<i>Average Labour Productivity</i>)	-0.2493 (0.0605)***	0.7792 (0.0471)***
<i>Foreign Capital Investment</i>	0.458 (0.1533)***	1.5809 (0.2423)***
log(<i>Age</i>)	0.5934 (0.0450)***	1.8101 (0.0814)***
log(<i>Total Number of Employees</i>)	-0.2701 (0.0474)***	0.7632 (0.0362)***
<i>Enterprise Group</i>	0.4263 (0.1467)***	1.5316 (0.2247)***
<i>Concentration Rate</i>	0.001 (0.0015)	1.001 (0.0015)
<i>Product Standardization</i>	0.3138 (0.0824)***	1.3687 (0.1129)***
log(RDT1)_1	-0.070 (0.0430)	0.9318 (0.0400)
log(RDT2)_1	-0.0754 (0.0372)**	0.9273 (0.0345)**
log(RDT3)_1	-0.1213 (0.0620)*	0.8857 (0.0549)*
log(RDT4)_1	-0.1305 (0.0449)***	0.8776 (0.0394)***
Environment2	0.5952 (0.1539)***	1.8135 (0.2791)***
Environment3	0.537 (0.1871)***	1.7109 (0.3201)***
Environment4	0.1627 (0.1002)	1.1767 (0.1179)
log(<i>Average Age</i>)	-2.7053 (0.1155)***	0.0668 (0.0077)***
Observations	31237	

Notes:

Log-pseudolikelihood = -4384.4479.

Wald Chi² (15) = 754.36; *p*-value (0.000).

Standard errors in parentheses.

* Significant at 10%; ** significant at 5%; *** significant at 1%.

The last control variable is *Average Age* of the sector, which is used as a proxy for turbulence. The variable is highly significant and the coefficient presents a negative sign, so the lower the average age (more turbulence), the higher the exit probability. The variable would be a good proxy for

turbulence. Following Konings et al. (1996), ‘Firms operating in turbulent sectors experience a higher exit probability than firms operating in sectors with low turbulence . . .’.

The effect of R&D on firm survival can be observed through the variables RDT1 to RDT4, with a lag of one period. These variables are all significant (except for environment 1) and present a negative sign, showing that an increase in R&D expenditure generates a lower exit probability. This result confirms the main hypothesis of the chapter, showing how involvement in R&D activities lowers exit probability. Moreover, if we focus on the coefficients of the environments, they are all positive, so it is the effect of incorporating the R&D ratio that turns those signs into a negative impact on exit.

This can be also observed in the second column of Table 1.3, which shows the results of the estimation of the hazard ratios of the Cox models. These ratios are lower than 1 if the covariate contributes to reduce exit probability, and the opposite if the ratio is higher than 1. As can be seen, all the coefficients for the log(RDT) variables are under 1, showing that the effect of R&D is a reduction in exit probability between 8 and 11 per cent.

Figure 1.2 confirms again the main hypothesis of the present work, that is, the existence of a negative relationship between R&D ratio and exit probability in every environment, although this is not significant in environment 1. In addition, it shows the existence of two groups of environments with differentiated behaviours. Thus, in the upper part of the figure, with higher exit probabilities, there are two environments (2 and 3), both with technological sectors. In the lower part we have environments 1 and 4, with non-technological sectors and lower exit probabilities.

This result can be interpreted as a consequence of the more intensive competition and the uncertainties that are inherent in technological sectors, making them more turbulent and, therefore, having higher exit probabilities.

Another interesting result from Figure 1.2 is the big difference in returns between the first R&D investments and later ones. As can be seen, from a certain level of the R&D ratio, increasing it has almost no effect in terms of reducing exit probability. A kind of steady-state level is reached in every environment. Differences between environments are then found at lower levels of investment. At those levels, increasing the rate has different effects, depending on the environment.

In fact, increasing the R&D ratio from 1 per cent to 20 per cent results in the following reductions (Table 1.4) of the estimated exit probability in each environment.

Figure 1.2 R&D rate and exit probability

Table 1.4 Decrease in estimated exit probabilities

Env1	Env2	Env3	Env4
-8.78%	-9.35%	-14.60%	-15.62%

As mentioned above, the ‘sector effect’ predominates, meaning that high-tech environments have higher exit probabilities, independent of region. The situation is the opposite for low-tech environments. It is therefore the risk associated with high-tech sectors that determines the level of exit probabilities.

Among the low-tech sectors (environments 1 and 4), it is in the low-tech regions (environment 1) where there are lower exit probabilities, making investment in R&D less relevant, as shown in the regression results. This can be also seen in Table 1.4, where this environment presents the lower effect when increasing the R&D ratio.

In the case of high-tech sectors (environments 2 and 3), there are two scenarios, before and after the intersection point. For our analysis, we can consider as relevant only the part before the intersection, given that

97.5 per cent of the observations for the ratio R&D/Sales in the sample are lower than 6 per cent (intersection point).

Given the above, in the technological sector companies should be interested in being located in high-tech regions because of the lower exit probability. Behind this could be the existence in such regions of spill-overs and synergies than could be useful for a tech company investing in R&D.

5. FINAL REMARKS

In the current context of economic crisis, it is necessary to find mechanisms that guarantee economic growth and long-term stability. Therefore knowing the factors that influence entrepreneurial activity and, mainly, the survival of those companies, is an ineluctable task.

The present work focuses on one of these factors, showing how innovative activity of companies not only makes them more productive and competitive, but represents a guarantee of survival. Assuring survival is a source of economic stability since social and economic costs associated with exit of firms are avoided.

As shown above, investment in R&D is always a way of reducing exit probability, with the exception of firms operating in non-technological sectors and in non-technological regions. In addition, this effect is stronger at the first level of investment, so it is critical to boost those companies that still have not initiated the investment process.

On the other hand, the need to rank equally with other developed countries, together with the current context of budget restrictions in the public sector, makes it advisable that this boost should be mainly based on private funds. The role of the public sector should therefore be focused on supervising and watching over companies that undertake these investments, building the right incentives and guaranteeing that scarce resources reach the companies that can obtain higher returns on them – those companies that are beginning their innovative processes.

In short, our empirical work has focused on the impact that technological effort (measured in R&D) of Spanish manufacturing firms has had on their survival. The period studied, between 1991 and 2010, has been used to collect in the aggregate analysis the effects of the economic cycle, less mortality of companies in the expansionary period (1995–2007) and more in recessions (1992–94 and 2008–10). It has proved the primary hypothesis, so that business survival is directly related to R&D effort. However, the sectors in which companies operate and the regional environment in which they are located (more or less technological intensity)

have significant influence on the magnitude of investment in R&D, which ensures survival. Thus R&D activities have no effect on survival of non-tech companies in non-tech regions, while they have a big impact for tech companies, mainly for those located in non-tech regions: they can improve their survival probabilities significantly through these activities, achieving the level of exit probability of the tech companies located in tech regions, that is, those with advantages associated with synergies and spillovers.

Our work has therefore two differentiating factors with respect to similar studies using Spanish economy data: R&D is not introduced as a dummy variable, and sectoral and regional segmentation is used. The first factor allows us to conclude that the main impact on survival is associated with the first stages of investment. The second one identifies the key role of R&D for tech companies operating in non-tech regions.

Both findings generate economic policy recommendations, as they provide evidence that suggests where to allocate R&D resources: firms that are at the beginning of their innovation process, rather than ‘innovation-mature’ firms, and tech firms in non-tech regions. This could act as a guide for project assessment, mainly in the actual context of budget constraints, where having rules for allocating scarce resources is highly valuable.

Finally, the work has some limitations that should be the object of further research. First of all, since the ESEE is a survey of manufacturing firms, the innovations of services companies are not taken into account. This is a relatively common limitation, as pointed by Gómez Uranga et al. (2009), because R&D was initially developed for industrial activities and because, in addition, identifying R&D expenses is a more complex task in services companies than in manufacturing firms.

Another limitation may lie in the variable used to proxy innovation, since the use of R&D implies focusing on technological innovations, omitting marketing or organizational innovations. It would be desirable, therefore, that further research on services companies take into account both technological and non-technological innovations.

NOTE

1. Following Toh and Choo (2002), a knowledge society or economy is one in which the generation and use of knowledge can be a source of economic growth, wealth and employment.

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