Review of Industrial Organization **25:** 251–273, 2004.

The Determinants of Survival of Spanish Manufacturing Firms

SILVIANO ESTEVE PÉREZ*, AMPARO SANCHIS LLOPIS and JUAN ALBERTO SANCHIS LLOPIS
Universidad de Valencia

Abstract. This paper analyses the factors determining Spanish manufacturing firms' survival – and exit. The data are drawn from the survey *Encuesta sobre Estrategias Empresariales* for the period 1990–1999. The methodology includes both non-parametric techniques and the estimation of a Cox proportional hazards model (CPHM). Our results suggest that the probability of exit is higher for small firms and also for young and mature firms. Furthermore, exporting firms and firms performing R&D activities enjoy better survival prospects.

Key words: Exit, survival analysis.

I. Introduction

Firms' entry into and exit from a market are important processes shaping toughness of competition and the evolution of industries. Both phenomena have important implications on resource allocation, productivity improvements and the rate of innovation and renewal of industries. An increasing number of papers within the literature of industrial organization have been devoting attention to the analysis of firms' entry and their survival (see Sutton, 1997; Caves, 1998; and the special issue of the *International Journal of Industrial Organization* on *Post Entry Performance of Firms*, 1995).[1] However, less attention has been devoted to the study of the determinants of the risk of exit (or, alternatively survival), despite the important economic and social effects of firms' exit.

* Author for correspondence: Facultad de Economía. Departamento de Economía Aplicada II, Edificio Departamental Oriental, Avenida de los Naranjos, s/n, 46022 Valencia, Spain. Tel: 00-34-963828852; Fax: 00-34-963928354; E-mail: sesteve@uv.es

[1] See also Baldwin (1995), Evans (1987), Hall (1987) and Dunne et al. (1988), among others.

Empirical evidence on entry and exit in the case of Spanish manufacturing firms is scarce. Two main contributions are those by Fariñas and Moreno (2000) and Segarra and Callejón (2002). Using firm data on a sample of firms from the survey *Encuesta sobre Estrategias Empresariales* for the period 1990–1995, Fariñas and Moreno (2000) presented an empirical model based on the passive learning model by Jovanovic (1982). They applied non-parametric techniques and found that both exit probabilities and the mean growth rate of successful firms declined with size and age. However, the empirical work was carried out for a pool of firms for the period 1990–1995 so that they did not take into account the evolution of the hazard or the mean growth over time. They also confined all firms' heterogeneity to differences in size and age.

Segarra and Callejón (2002) analyzed the survival patterns by 1998 of the cohort of Spanish manufacturing firms born in 1994. Using data from the Spanish *Directorio Central de Empresas* (DIRCE), gathered by the *Instituto Nacional de Estadística* (INE), they estimated a proportional hazards model. They found that hazard rates were inversely related to firm size and were higher in R&D intensive industries. They also obtained that exit probabilities differed across industries. The main caveats of this work are that it only analyses survival for a single cohort of firms and that the follow-up period is short. Therefore, the robustness of their results critically relies on how representative this particular cohort is. In addition, they do not control for a number of factors affecting a firm's competitive position over time such as entry and exit within the *observation window*. Furthermore, firm heterogeneity within industries is restricted to size.[2]

The aim of this paper is to analyze the determinants of the survival of Spanish manufacturing firms (or, alternatively, the factors affecting their probability of failure) devoting special attention to strategic variables. To this end, we apply non-parametric survival methods and estimate a Cox Proportional Hazards model (CPHM hereafter) (Cox, 1972) using a panel of Spanish manufacturing firms. Survival methods allow accounting both for whether and when an event (e.g. exit) occurs, thus controlling for the evolution of the risk over time. To the best of our knowledge, these techniques have not been applied yet to a panel made up by a representative sample of all Spanish manufacturing (existing) firms and this is the

[2] Segarra (2002) extended the analysis by enlarging the follow-up period to 2000, reaching similar conclusions. Moreover, Segarra and Callejón (1999) examined the effect of business dynamics (that is, business entry and exit) in manufacturing on the growth of total factor productivity in different Spanish industries and regions for the period 1980–1992. They found that entry and exit both differ by industries and regions and lead to increases in total factor productivity.

main contribution of this paper to the existing literature.[3] In addition, unlike most previous studies that analyze the determinants of survival of a reduced number of cohorts of new entrants over a relatively short follow-up period, we focus on a sample of existing firms, including both young and mature firms operating in all manufacturing industries. Moreover, we explicitly consider the influence on the probability of exit of a number of strategic factors such as export or R&D activities. These factors have been relatively less explored in the literature as determinants of firms' survival.

The data we use are drawn from the *Encuesta sobre Estrategias Empresariales* (ESEE hereafter), for the period 1990–1999, which is representative of the Spanish manufacturing firms classified by industrial sectors and size categories. We build a panel of firms, identify their entry and exit dates, and use the exhaustive information at the firm level provided by the data in order to determine the key factors driving survival probabilities.

To anticipate the results, we find that small firms face a higher exit probability than large firms. Moreover, firm's age has a non-linear effect on its survival probability, so that both younger and older firms face a higher hazard of exit. More interestingly, our results also suggest that exporting firms and firms involved in R&D activities enjoy better survival prospects. These results suggest that those factors which are likely to improve firms' efficiency are important drivers of survival. Therefore, our findings make an important contribution to the understanding of the determinants of firms' survival and suggest a number of policy implications. In order to raise the probability of survival, policy makers should promote both exports and R&D activities by firms. Among the policies that could be implemented, one may include measures directed at providing information and access to foreign markets or providing exports infrastructures, together with policies aimed at promoting R&D investments.

The rest of the paper is organized as follows. Section II reviews the main determinants of firms' survival as suggested in the related literature. In Section III we describe the data and use non-parametric survival methods to account for different survival patterns across firms. In Section IV an overview of the methodology applied in the empirical analysis is introduced. The main results are presented and discussed in Section V, and Section VI concludes.

---

[3] Empirical evidence on survival of new firms/plants based on the estimation of hazard rates for other countries are Disney et al. (2003) for the UK, Dunne et al. (1988) and Audretsch and Mahmood (1995) for the US, Mata et al. (1995) and Mata and Portugal (2002) for Portugal, Harhoff et al. (1998) and Boeri and Bellman (1995) for Germany, Audretsch et al. (1999) for Italy, Tveteras and Eide (2000) for Norway, and Honjo (2000) and Kimura and Fujii (2003) for Japan, among others.

II. The Determinants of Firm Survival

The factors determining survival of new entrants have been extensively analyzed in the Industrial Organization literature. The work by Dunne et al. (1988) and Geroski and Schwalbach (1991), the especial issue of *The International Journal of Industrial Organization* on "The post-entry performance of the firms" (1995), and Caves (1998) summarize the main findings.

According to Geroski (1995), one *stylized fact* about entry is that *age* and *size* are positively related to the probability of firms' survival. As first argued by Stinchcombe (1965), new entrants face a "liability of newness" effect, that is, a greater risk of failure as compared to older firms. During their *infancy*, firms have to face the problems of achieving both an organizational structure and an efficiency level to keep pace with competitors. This includes acquiring suitable capital and workforce, establishing business relations with suppliers and getting customers for their products. According to selection models (Jovanovic, 1982; Ericson and Pakes, 1995) new entrants do not know their efficiency levels before entering the market. Recent entrants do not know yet if they have some of the characteristics necessary to adapt themselves to the competitive environment and survive. As time goes by (that is, with age), firms go through a process of learning about their relative efficiency and market competitiveness. Less efficient firms learn about their relative inefficiency and exit the market and surviving firms accumulate experience and information so that learning reduces the risk of exit.

However, a number of studies have found that the probability of exit may increase with age. This relationship is explained by the "liability of adolescence" effect (Fichman and Levinthal, 1991) and the "liability of senescence" effect (Hannah, 1998). According to the liability of adolescence effect, entrant firms are "protected" from failure by initial resource endowments and strategic choices made by firms to compete in the market. This determines low failure rates for young firms. However, as firms age, their endowments and initial choices become less adequate to new environments so that firm exit risk rises during the period of adolescence. After that period, the failure rate decreases as firms consolidate their position in the market. Regarding the liability of senescence effect, some authors have argued that older firms face a relatively high likelihood of exiting the market due to the erosion of technology, products, business concepts and management strategies over time (*liability of obsolescence*) or, in particular in the case of owner-managed firms, difficulties in finding a successor for the business.[4]

[4] The notion of liability of senescence is not contrary to the liability of newness because both phenomena relate to two different development stages of a firm, i.e. early "youth" and "maturity".

Regarding firms' size, larger firms are expected to enjoy better survival prospects (see Dunne et al., 1988; Mata and Portugal, 1994; among others). Because new entrants tend to start at a relatively small size, the liability of newness may also be a *liability of smallness* (Aldrich and Auster, 1986). Firms enter the market at a relatively small scale so that they may face cost disadvantages with respect to well-established firms operating at a minimum efficient scale. Compared to small firms, large firms may also have better access to capital or labor markets which in turn improve their chances of survival. Accordingly, we expect the probability of survival to rise with size. Most previous studies consider start-up size to be positively related with a firm's survival prospects. However, Mata et al. (1995) argue that current size is a better predictor or a firm's survival chances because captures a firm's ability to adapt to changing competitive environment.

In relation to firms' relative efficiency and competitiveness in the market, there are two factors that may be considered to be important determinants of survival: export activities and investment in R&D activities. Competition in international markets is probably tougher as compared to domestic markets so exporting firms will probably be associated with higher efficiency and higher survival probabilities. Recent models of international trade and firms productivity argue that exporting firms are less likely to fail as compared to non-exporters due to the higher productivity of the former (Bernard et al., 2000; Melitz, 2002). Furthermore, undertaking R&D activities is assumed to be positively related to the competitive advantage of the firm and so to its survival prospects. According to the resource-based view of the firm (Wernerfelt, 1984; Barney, 1991), the chances of survival greatly depend on the ability of firms to develop specific capabilities, which in turn may be improved by investing in R&D. Within the literature of the industry shakeout (Klepper, 1996; Klepper and Simons, 2000), a key factor driving industry evolution is innovation. Cumulative economies of scale in R&D confer an advantage on early entrants over later entrants. Therefore, firms undertaking R&D activities are probably more efficient, which improves their competitiveness and survival chances. This is also in line with the predictions of the selection models of active learning (Ericson and Pakes, 1995) in that, by investing in R&D, firms may improve their ability to survive. However, R&D activities are usually associated with uncertainty and so those firms may suffer a higher risk of failure. Previous work examining survival conditions of new entrants at the industry level (Audretsch and Mahmood, 1995; Audretsch et al., 2000; Segarra and Callejón, 2002) have found exit rates to be greater in R&D intensive industries given that competition environment is tougher. However, Audretsch (1995) finds that even in these industries, innovative firms enjoy better survival prospects. Kimura and Fujii (2003) have also found that R&D activities raise firms' survival probabilities.

In addition, the risk of exit may be associated with the firm foreign capital participation. Firms may have inherent disadvantages in doing business abroad, as compared to local firms, in terms of coordinating businesses across distance or learning about the *modus operandi* of the market (Hymer, 1976). These factors may decrease the survival prospects of new foreign firms. By contrast, foreign capital participation could mean access to foreign technologies, which in turn could improve the efficiency of the participated firm and so raise its survival probability. The scarce empirical evidence on the impact of foreign ownership on survival is mixed. Görg and Strobl (2003) and Bernard and Sjöholm (2003) found greater probabilities of exit for foreign-owned plants compared to domestically-owned ones. By contrast, both Li and Guisinger (1991) and Mata and Portugal (2002, 2003), found that domestic entrants are much more likely to exit than foreign ones. However, the empirical findings of both Mata and Portugal (2002) and Bernard and Sjöholm (2003) suggest that the different survival rate among foreign and domestic owned firms is caused by firm and industry characteristics rather than ownership per se.

The effect of the legal structure of the firm on its survival prospects has also been investigated in the literature on exit (Brüdel et al., 1992; Harhoff et al., 1998; Mata and Portugal, 2002). The theoretical prediction is that limited liability corporations face a higher probability of exiting the market than firms with other legal structures. According to Stiglitz and Weiss (1981), in firms with limited liability, entrepreneurs undertake projects with relatively higher expected returns and higher risk of failure. Mata and Portugal (2002), for a sample of Portuguese firms, found that limited liability corporations were significantly less likely to exit than firms with other legal structures.

Finally, the probability of exit is likely to be related to the economic activity performed by firms. We expect firms whose main activity is the production of final goods to endure a higher risk of failure, as compared to firms producing intermediate and capital goods. Final goods producers are supposed to face higher market competition and higher degree of demand uncertainty which in turn may be associated with higher failure rates.

In next section we present the data and provide detailed information on the variables used to capture the determinants of survival.

III. The Data

The data used in this paper are drawn from the ESEE, an annual survey of Spanish manufacturing firms sponsored by the Ministry of Industry since 1990. The ESEE is representative of the population of Spanish manufacturing firms classified by industry and size categories.[5] It provides information on the dates at which firms entered both the industry (that is, the firm's date of birth) and the survey (when a firm first comes under observation). Likewise, this survey allows identifying whether a firm stays in business, exits or leaves the survey.

A firm is computed to exit in year *t* when this is the last year of independent operation by the firm. Therefore exit includes permanent closure, firm in liquidation, shift to non-manufacturing activities and being acquired by another firm. When two firms merge, we do not compute it as two firms exiting and one "*de novo*" entering, but consider the bigger one in the merger as a continuing firm and the smaller firm as an exiting one.[6]

Tables I and II show the main characteristics of our dataset. Firstly, Table I displays the evolution of the sample of firms. Given the sampling procedure of the ESEE and our definition of exit, information in 1999 is only used to identify the firms exiting in 1999. Hence, the sample is made up of a total of 16356 observations, corresponding to 2912 different firms, with 408 of them exiting. The panel of firms is unbalanced given that there is entry and exit of firms. Last column in Table I provides information on the evolution of the sample due to reasons other than firm exit.

Secondly, given the different sampling procedure for *small* (those with 10–200 employees) and *large* firms (those with more than 200 employees), the evolution of firms by size is reported in Table II. Thus, the sample includes 11439 observations of *small firms*, corresponding to 2330 different firms, and 4917 observations of *large firms*, corresponding to 803 different firms. By inspection, the last two columns suggest that the incidence of exit (both annually and globally) is sharply higher for small firms.

[5] The sampling procedure of the ESEE is the following. Firms with less than 10 employees are excluded from the survey. Firms with 10–200 employees were randomly sampled by industry and size strata (according to 21 different productive activities and 4 size intervals), holding around a 4% of the population in 1990. All firms with more than 200 employees were requested to participate, obtaining a participation rate around 60% in 1990. Important efforts have been made to minimise attrition and annually incorporate new firms with the same sampling criteria as in the base year so that the sample of firms is representative of the Spanish manufacturing sector over time (see http://www.funep.es for further details).

[6] It should be noticed that the ESEE does not allow distinguishing between the situation when a sampled firm acquires or (being the larger firm) merges with other firms in the sample or outside the sample from the situation where a non-sampled firm acquires a company within the sample. However, as long as the ESEE is a representative sample, by size and industry, of the Spanish manufacturing firms over time, not considering firms' entry or exit in the latter case does not represent a serious limitation. Indeed, it does not affect either the number of firms in the sector or the concentration in the industry. Furthermore, the former possibility (and also other forms of firm restructuring) is controlled for by the explanatory variables.

Table I. Evolution of the sample of firms analyzed

Year	All firms	Exiting firms	"Net lost"
1990	2053	61	25
1991	1967	52	−10
1992	1925	72	−8
1993	1861	53	39
1994	1769	49	112
1995	1608	28	−48
1996	1628	31	−243
1997	1840	17	118
1998	1705	45	1660
Number of observations	16356		
Number of firms	2912	408	

Notes: "Net lost" = Number of firms censured in t (i.e. firms leaving the survey for reasons other than failure) minus the number of firms entering the sample in $t + 1$.

Table II. Evolution of the sample of firms by size

Year	All firms[a]		Exiting firms[b]	
	Small firms	Large firms	Small firms	Large firms
1990	1452	601	53 (3.65%)	8 (1.33%)
1991	1289	678	45 (3.49%)	7 (1.03%)
1992	1294	631	56 (4.33%)	16 (2.54%)
1993	1298	563	42 (3.24%)	11 (1.95%)
1994	1226	543	43 (3.51%)	6 (1.10%)
1995	1112	496	25 (2.25%)	3 (0.60%)
1996	1165	463	27 (2.32%)	4 (0.86%)
1997	1366	474	13 (0.95%)	4 (0.84%)
1998	1237	468	39 (3.15%)	6 (1.28%)
Number of observations	11439	4917	343 (3.00%)	65 (1.32%)
Number of firms	2330	803	343 (14.72%)	65 (8.09%)

[a] *Small firms* are firms with 10–200 employees and *large firms* are firms with more than 200 employees.

[b] In parenthesis, percentage of firms exiting each year over the total number of firms "at risk" (for each category). The last two rows correspond to the overall "incidence rate" by size category, that is, the number of exits over the total time at risk of suffering the event; and to the overall "exit rate," that is, the number of events over the number of firms by size category.

Finally, the ESEE also provides broad information at the firm level that will be used to carry out the empirical analysis. Table III describes the explanatory variables (or covariates) used in our analysis in order to proxy the effect of the determinants of firms' survival discussed in Section II. The table provides descriptive statistics for each variable, comparing between all firms and those firms exiting, and also distinguishing by firm size.

IV. Empirical Methodology

The empirical analysis is carried out using survival methods.[7] These methods allow to control both for the occurrence of an event (i.e. whether a firm exits, either temporarily or permanently) and the timing of the event (that is, when the exit takes place). Therefore, these methods take into account the evolution of the exit risk and its determinants over time.[8] Moreover, survival methods are appropriate to account for right censoring (when we only know that the firm has survived at least up to a given period t),[9] and easily handle time-varying covariates. The latter allows overcoming the limitation arising from considering firms' characteristics previous to the sample period or at the time of entry as the unique determinant of firm survival over time. Furthermore, the specification of these models may be made flexible enough so as to allow testing the different predictions derived from the theory.

The central concept in survival analysis is the *hazard rat*e. Following Kalbfleisch and Prentice (1980), this is defined as the probability that a firm exits the market in a moment t given that it has survived until this period t and conditional on a vector of covariates X_{it}, which may include both time varying and time-constant variables,

$$\lambda(t; X_{it}) = \lim_{dt \to 0} \frac{Pr\,(t \leq T < t + \mathrm{d}t \setminus T \geq t, X_{it})}{\mathrm{d}t}, \tag{1}$$

where T is a non-negative random variable (duration), which we assume continuous, so that $\lambda\,(t)$ is an instantaneous exit rate.

7 See Kiefer (1988) for a survey on the application of these methods to economic studies.

8 This contrasts with traditional cross-section techniques that examine the unconditional average probability of occurrence of an event during the sample period (e.g. logit and probit) or the average duration (OLS).

9 Using OLS in the presence of censored observations leads to inconsistent and biased estimates. Furthermore, the presence of left censored observations, i.e. firms that started production some time before the beginning of the sample period, is not a problem given that our interest lies on the study of the conditional probability of exit.

Table III. Definition of explanatory variables and mean values (standard deviation in parenthesis)

		All firms			Firms that exit the market		
		All	Small	Large	All	Small	Large
Age variables:							
Age	Difference between current year (*t*) and the constituent year reported by the firm.	23.83 (22.83)	18.06 (17.53)	37.23 (27.62)	22.40 (24.39)	18.18 (21.54)	37.07 (27.84)
Age_group	Variable classifying firms into 5 categories: 1. firms younger than 6 years, 2. firms between 6 and 10 years, 3. firms between 11 and 25 years, 4. firms between 26 and 50 years, and 5. firms older than 50 years. In the regression analysis, we define five dummy variables capturing this classification.	2.98 (1.20)	2.68 (1.11)	3.69 (1.07)	2.78 (1.32)	2.54 (1.22)	3.62 (1.21)
Size variables:							
Size	Number of employees.	260.03 (859.55)	42.41 (46.49)	766.32 (1444.42)	153.16 (405.62)	35.95 (43.14)	560.80 (719.27)
Size_group	Dummy variable taking value one if the firm is *large* (more than 200 employees), and zero if the firm is *small* (from 10 to 200 employees).	0.30 (0.46)			0.22 (0.42)		

Table III. continued

		All firms			Firms that exit the market		
		All	Small	Large	All	Small	Large
Exports	Dummy variable taking value one when the firm exports (any percentage of sales) and zero otherwise.	0.55 (0.50)	0.40 (0.49)	0.88 (0.32)	0.41 (0.49)	0.30 (0.46)	0.78 (0.42)
R&D	Dummy variable taking value one if the firm performs R&D activities, and zero otherwise.	0.35 (0.48)	0.20 (0.40)	0.70 (0.46)	0.21 (0.40)	0.11 (0.31)	0.55 (0.50)
Foreign capital participation	Dummy variable taking value one when the firm is participated by foreign capital (any percentage), and zero otherwise.	0.21 (0.41)	0.09 (0.28)	0.49 (0.50)	0.20 (0.40)	0.10 (0.30)	0.55 (0.50)
Ltd	Dummy variable taking value one if the firm is a limited liability company, and zero if it has any other legal structure.	0.68 (0.47)	0.56 (0.50)	0.94 (0.23)	0.61 (0.49)	0.53 (0.50)	0.90 (0.30)

Table III. continued

		All firms			Firms that exit the market		
		All	Small	Large	All	Small	Large
Final goods	Dummy variable that takes the value of one if the firm produces final goods, and zero if it produces either intermediate or equipment goods (see Table A.1).	0.42 (0.49)	0.45 (0.50)	0.37 (0.48)	0.54 (0.50)	0.59 (0.49)	0.38 (0.49)
Number of observations		16356	11439	4917	1518	1179	339

Note: *Small* firms are firms with 10–200 employees and *large* firms are firms with more than 200 employees. All explanatory variables are time-varying covariates.

In order to examine the effect of the explanatory variables on the risk of firm exit we follow two approaches. Firstly, we carry out three univariate non-parametric tests of equality of hazard (or survival) functions across the r-groups of firms obtained according to the values of each explanatory variable (Cleves et al., 2004). These tests are extensions for censored data of non-parametric rank tests used to compare two or more distributions. Under the null hypothesis, there is no difference in the hazard rate for each of the r groups at any of the failure times and this statistic distributes as a χ^2 with $r-1$ degrees of freedom.[10] Furthermore, given that the sampling procedure differs for large and small firms, we also undertake stratified Log-rank tests for the equality of hazard functions controlling for firms' size.

Secondly, a multivariate analysis is undertaken estimating a semi-parametric survival model in order to unravel the effect of each of the explanatory variables on the risk of exit (alternatively, the probability of survival) controlling simultaneously for the effect of the other variables considered. The estimation is performed using the semi-parametric CPHM, Cox (1972):

$$\lambda\,(t;\,X_{it}) = \lambda_0\,(t)\cdot\exp\,(X_{it}\beta)\,, \tag{2}$$

where $\lambda_0\,(t)$ represents the *baseline function* obtained for values of covariates equal to 0 ($X_{it}=0$). In this specification, the effect of the independent variables is a parallel shift of the baseline function, which is estimated for all those firms that survive up to a particular period.[11] The baseline function is left unspecified and the model is estimated maximizing a partial likelihood function with respect to the vector of coefficients β without the need to estimate the *baseline function* (although it may be recovered non-parametrically).

The CPHM has some desirable properties that make it suitable for our analysis. First, the baseline function is left unspecified. Hence, the potential problem of unobserved heterogeneity that may rise when the baseline

[10] At any failure time, the contribution to the t-statistic is obtained as a weighted standardized sum of the difference between the actual and expected number of exits for each of the r-groups. The three tests applied differ on the weights used and are the following: the *Log rank test*, which is more appropriate when the survival functions for the different groups are proportional; the *Wilcoxon–Breslow–Gehan test*, which is more suitable when the survival functions are not proportional and the censoring patterns are similar across groups; and the *Peto–Peto–Prentice test* that is adequate when the survival function varies non-proportionally among groups and it also controls for different censoring patterns for each group.

[11] Nonetheless, it is possible to test the proportionality assumption and if rejected, more flexible models could be estimated allowing for the effect of explanatory variables to change over time.

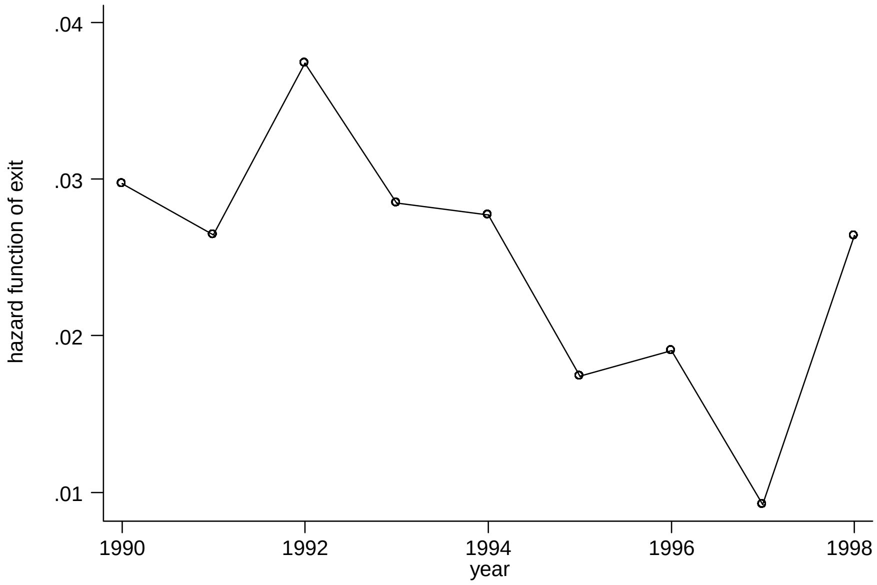

Figure I. Non-parametric hazard function.

function is not properly specified is overcome (Dolton and Van-der-Klauw, 1995). This problem worsens in presence of time-varying covariates.[12] Second, it is only the ordering of the exit times what matters for the estimation of the CPHM, and not the actual times by themselves. The latter is an important property since our analysis is based on calendar time (whereas most previous survival analyses use age as the time dimension in the survival analysis).

V. Results

Before focusing on the effect of the explanatory variables on the risk of exit, we present a non-parametric estimate of the hazard rate, that is, the probability that a firm exits at a particular period given that it has survived until the beginning of that period (Figure I).[13] This graph illustrates the evolution of the overall risk of exit over time, showing the relationship between the risk of failure and the macroeconomic business cycle. We

[12] However, the CPHM involves a loss of efficiency when compared to the right parametric model, if known.

[13] This is estimated as the hazard contribution to the cumulative hazard function between two failure times. This hazard contribution is recorded at all periods at which exit occurs and is obtained as $\hat{\lambda}(t) = d_j/n_j$, where d_j is the number of failures at time j and j is the number at risk at this time, before the occurrence of the event.

Table IV. Non-parametric tests for the equality of survival functions (by explanatory variables)

	Log-rank		Wilcoxon–Breslow–Gehan		Peto-Peto		Higher surviving probability
Age_group	32.03	(0.000)	31.60	(0.000)	31.61	(0.000)	(see note c)
Size_group	42.34	(0.000)	41.86	(0.000)	42.45	(0.000)	Size = 1
Exports	44.22	(0.000)	43.22	(0.000)	44.01	(0.000)	Exports = 1
R&D	71.57	(0.000)	70.31	(0.000)	70.58	(0.000)	R&D = 1
Foreign capital participation	1.86	(0.173)	1.91	(0.167)	2.02	(0.155)	–
Ltd	19.65	(0.000)	18.25	(0.000)	18.66	(0.000)	Ltd = 1
Final goods	15.57	(0.0001)	14.28	(0.0002)	14.71	(0.0001)	Final goods = 0

Notes: (a) 16356 observations, 2912 firms, and 408 exits for the whole period; (b) P-values in parenthesis; (c) The survival probabilities of the five groups by age, from lower to higher, are: firms younger than 5 years, firms between 6 and 10 years, firms older than 50 years, firms between 11 and 25 years, and firms between 26 and 50 years.

observe that the exit risk rises up to 1992, and then decreases until 1997 to later increase in 1998. This evolution of the exit risk seems to be in accordance with the business cycle.[14] However, the decline in the exit rate might also be reflecting the presence of unobserved heterogeneity. As time goes by, the less efficient firms exit the market so the sample may include an increasing proportion of those firms more able to survive. If these abilities were not explicitly included in the model, we would get a decreasing exit rate over time. As discussed in the previous section, the CPHM would be more appropriate in the presence of unobserved heterogeneity.

To understand the effects of the explanatory variables on the exit rate, we first carry out the three non-parametric tests of equality of hazard functions across groups of firms, as discussed in the previous section. The results, reported in Table IV, unequivocally indicate the existence of stringent differences in survival between groups for each of the variables considered (except for "foreign capital participation"). Larger, exporting firms, performing innovative activities, producers of intermediate and capital goods, and with a limited liability legal structure, endure better survival prospects. In addition, both the youngest and very old firms face a higher risk of failure.

Furthermore, since the sampling procedure differs by size, we also carry out stratified Log-rank tests of the equality of survival functions (see Table V). These tests provide an overall test after controlling for the

[14] This result is in line with Gras and Teruel (2002) using census Spanish manufacturing data.

Table V. Non-parametric tests of equality of survival function by explanatory variables, controlling for firms' size (size_group)

	Log-rank						Higher survival probability
	Small firms		Large firms		All firms		
Age_group	16.57	(0.0023)	10.59	(0.0316)	23.55	(0.0001)	(see note c)
Exports	9.33	(0.0022)	13.02	(0.0003)	15.58	(0.0001)	Exports = 1
R&D	19.42	(0.0000)	25.17	(0.0000)	38.48	(0.0000)	R&D = 1
Foreign capital participation	2.38	(0.1229)	1.67	(0.1961)	4.05	(0.0442)	Foreign capital participation = 0
Ltd	3.29	(0.0695)	1.87	(0.1711)	4.20	(0.0404)	Ltd = 1
Final goods	13.74	(0.0002)	0.00	(0.9619)	11.76	(0.0006)	Final goods = 0

Notes: (a) 16356 observations, 2912 firms, and 408 exits for the whole period, (b) P-values in parenthesis, (c) The survival probabilities of the five groups by age, from lower to higher, are: firms with more than 50 years, firms with less than 6 years, firms from 6 to 10 years, firms from 26 to 50 years and firms from 11 to 25 years.

effect of the variable used for the stratification (see column *All firms* in Table V) and separate tests for each of the values of the variable (columns *Small firms* and *Large firms*). After controlling for the effect of size, the results for small firms and for all firms are similar to those obtained with non-stratified tests. However, for large firms we find no significant differences in survival patterns between groups according to sector, legal form and foreign capital participation.

In Table VI we report the main results obtained from the estimation of the reduced-form CPHM model given by (2).[15] A unit change in an explanatory variable leads to a proportional shift, constant across time, in the conditional probability of suffering the event. The effect of the covariates is given by the *hazard ratios*. A value for the hazard ratio smaller (greater) than one implies a negative (positive) effect on the hazard rate.

We have tested for specification errors obtaining that we cannot reject the null hypothesis that the model is correctly specified. Moreover, the tests proposed by Grambsch and Therneau (1994) in order to test the proportionality assumption both for all variables and for each variable individually have been carried out. The null hypothesis that the hazard rates are proportional cannot be rejected at a 5% significance level.

[15] We use standard errors robust to autocorrelation and heteroscedasticity, given that we deal with multiple records per firm.

Table VI. Analysis of the risk of exit of Spanish manufacturing firms, 1990–99. CPHM

	Exit risk	
	Hazard Ratio	*P*-value
Age: (< 6 years omitted)	–	–
6–10 years	1.0378	0.805
11–25 years	0.7078**	0.019
26–50 years	0.7508*	0.098
> 50 years	1.4575**	0.050
Size_group	0.5740***	0.002
Exports	0.7220***	0.010
R&D	0.4257***	0.000
Foreign capital participation	1.8089***	0.000
Ltd	0.9311	0.534
Final goods	1.3072***	0.007
Log-likelihood	−2993.3023	
Wald test (d.f.) (chi-squared)	122.67 (10)	0.000
N. observations	16356	
N. firms	2912	
N. events	408	

Notes: (a) The coefficients indicate the effect on the hazard rate of a standard increase in a continuous variable or a change from 0 to 1 in a dummy variable; (b) The estimation has been carried out using the method of Efron (1977) to deal with "ties" (when there is more than a firm exiting within a year); (c) *P*-values in brackets, and calculated from robust standard errors. *P*-values correspond to two-tails tests of significance of each variables (Ho: the multiplier is equal to 1) and also a global test of joint significance; (d) * significant at 10% level; ** significant at 5 % level; ***significant at 1% level.

The regression results reported in Table VI are discussed below. First of all, relating to firms' age and taking as reference firms younger than six-years of age, we find a non-linear effect of age on the exit probability. Firms between 11 and 25 years old and firms between 26 and 50 years of age endure a significant lower exit risk (29% and 25% lower, respectively) than the risk suffered by the youngest firms. This result is consistent with existing empirical evidence on new firm survival (Dunne et al., 1989; Mata and Portugal, 1994; Mitchell, 1994, among others). In addition, we find that firms older than 50 face worse surviving conditions than younger firms, in line with the pattern of the "liability of senescence" (Hannah, 1998).

Secondly, in relation to firm size, after controlling for other variables, small firms are found to suffer a significantly higher risk of exit than large firms. In particular, the instantaneous probability of exit for large firms is 42.5% lower than that for small firms. These results are consistent with the predictions of the Industrial Organization selection models literature (Jovanovic, 1982; Ericson and Pakes, 1995) and with most of the empirical evidence obtained by the literature on entry and post-entry performance (Dunne et al., 1988; *Special Issue of International Journal of Industrial Organization, 1995*).[16] These findings are robust to grouping firms into five size categories according to the number of employees (<21, 21–50, 51–200, 201–500, >500 employees), as the firms' survival expectations significantly improve with size without exception.[17]

When we consider jointly the effects of size and age on the probability of exit we have that large firms aged between 11 and 25 are the ones with better surviving prospects (they face a 59% lower probability of exit) than small and aged below six.

Thirdly, after controlling for other characteristics, two factors noticeably improve the survival performance of the Spanish manufacturing firms: exports and investment in R&D activities. Exporting firms endure a 28% lower probability of exit than non-exporting firms. This result is in line with the findings of Bernard and Jensen (2002) and Kimura and Fujii (2003). Regarding investment in R&D, we find that the probability of exit for firms involved in R&D activities is a 57% lower than that of firms that do not invest in R&D. This result is consistent with Audretsch (1995) and Kimura and Fujii (2003) who found that innovative firms enjoy better survival prospects.

Taken together, exports and R&D improve notably the chances of firms' survival. Being an exporter and undertaking R&D activities jointly reduces the exit risk to 69%. Moreover, if the firm is also a large firm the failure rate is reduced in 82.5% (when compared to non-exporting, no R&D-performing and small firms).

[16] Agarwal and Audretsch (1999) suggest that small firms in mature phases of the industry life cycle may enjoy better survival conditions. Ghemawat and Nalebuff (1985) also find a strategic advantage for small firms in declining industries. Our results are not incompatible with this since the ESEE excludes very small firms (those with less than 10 employees) and we do not control for the stage of the industry life cycle.

[17] Indeed, if we group size in five categories we get that the probability of exit for the largest firms (those with more than 500 employees) is a 60% lower than that for the smallest firms (those with less than 21 employees).

Fourthly, our results indicate that those firms with foreign capital participation bear a notorious higher risk of exit.[18] The scarce empirical evidence on the impact of foreign ownership on survival is mixed. However, our result is consistent with Görg and Strobl (2003), who found increased probabilities of exit for Irish majority foreign-owned plants, and with Bernard and Sjöholm (2003) who obtained, for a sample of Indonesian firms, that after controlling for plant size and productivity, foreign-owned plants are far more likely to close down compared to domestically-owned ones.[19]

In relation to the legal structure of the firm, we do not find that, once we control for other factors, limited liability corporations have a lower exit probability as compared to firms with other legal forms.[20] This result is in contrast with the findings of Mata and Portugal (2002) who, using a sample of Portuguese firms, found that limited liability corporations were significantly less likely to exit the market as compared to firms with other legal structures.

Finally, regarding the economic activity performed by firms, our results show that those firms whose main activity is the production of final goods endure a 31% higher risk of failure than firms producing intermediate or equipment goods. This is probably due to the higher degree of uncertainty and competition faced by final goods producers as compared to intermediate or equipment goods producers, which in turn increases their chances to exit the market.

V. Conclusions

This paper has empirically analyzed the key factors explaining the survival of Spanish manufacturing firms. We have applied non-parametric and semi-parametric survival methods to a representative sample of Spanish manufacturing firms. Our study differs from most previous studies on survival in that it is based on a sample of all existing manufacturing firms, including young and mature, rather than examining the life patterns of a single cohort of new entrants over a short follow-up period.

Our main results are the following. First, regarding firms' age, we have obtained a non-linear effect of age on survival probability. Both the

[18] This result differs from the one obtained in the non-parametric analysis where we could not reject the null hypothesis of equality of survival functions for domestic firms and foreign capital participated ones.

[19] We have further investigated the effect on survival of alternative definitions of foreign capital participation. In particular, our results do not change when we consider that the firm foreign capital participation reaches 10 and 25 per cent level.

[20] This result differs from the result obtained using the non-parametric tests where we rejected the null hypothesis of the equality of the survival functions for limited liability firms as compared to other legal forms.

youngest and the oldest firms bear a significantly higher failure risk. Second, the risk of failure is significantly higher for small firms than for large firms. This result is consistent with the predictions postulated by the selection models literature and the results obtained by the empirical work on entry and post entry performance. Third, our results have also indicated that survival probability is higher for exporting firms and firms performing R&D activities. These results suggest that those factors that are likely to improve firms' efficiency and competitiveness are important drivers of firms' survival.

Our findings make a significant contribution to the understanding of the determinants of firms' survival and have important policy implications. Although rather tentatively, our results suggest that public policy should promote the participation of firms in export and R&D activities as these two factors have shown to be crucial elements of firm survival. In this line, public policy directed towards the creation of new firms without taking into account these competitiveness factors may be inadequate. If new firms fail shortly after their creation, economic and social costs may be very high. Therefore, policy makers should devote resources to launch programs providing information and access to foreign markets and developing export infrastructures, together with policies aimed at promoting R&D investments.

Acknowledgements

We appreciate comments and suggestions from the editor, two anonymous referees and participants at the *VI Encuentro de Economía Aplicada* (Granada, 2003), the EARIE Conference (Helsinki, 2003) and XXVII *Jornadas de Economía Industrial* (Castellón, 2003). Financial support from the IVIE (*Instituto Valenciano de Investigaciones Económicas*) and from the Ministry of Science and Technology in Spain, project number SEC2002-03812, is gratefully acknowledged.

Appendix. Industry classification

Table A.1. Sector classification (NACE-74)

Code	Sectors	Final goods	Intermediate goods	Equipment goods
1	Ferrous and non-ferrous metals		X	
2	Non metallic miner products		X	
3	Chemical products		X	
4	Metallic products		X	

Table A.1. continued

Code	Sectors	Final goods	Intermediate goods	Equipment goods
5	Industry and agriculture machines			X
6	Office machines			X
7	Electrical material and other electrical goods			X
8	Motors and cars	X		
9	Other transport material		X	
10	Meat, and preserved meta	X		
11	Food and tobacco	X		
12	Beverages	X		
13	Textiles and clothing	X		
14	Leather and shoes	X		
15	Wood and wood furniture	X		
16	Paper, and paper and printing stuff		X	
17	Rubber and plastic products		X	
18	Other manufacturing goods	X		

References

Agarwal, R., and D. B. Audretsch (1999) ‘The Two Views of Small Firms in Industry Dynamics: A Reconciliation’, *Economics Letters*, **62**, 245–251.

Aldrich, H. E., and E. Auster (1986) ‘Even Dwarfs Started Small: Liabilities of Size and Age and their Strategic Implications’, *Research in Organizational Behavior*, **8**, 165–198.

Audretsch, D. B. (1995) *Innovation and Industry Evolution*. Cambridge, MA: MIT Press.

Audretsch, D. B., and T. Mahmood (1995) ‘New Firm Survival: New Results Using a Hazard Function’, *Review of Economics and Statistics*, **77**, 97–103.

Audretsch, D. B., P. Houweling, and A. R. Thurick (2000) ‘Firm Survival in the Netherlands’, *Review of Industrial Organization*, **16**, 1–11.

Audretsch, D. B., E. Santarelli, and M. Vivarelli (1999) ‘Start-Up Size and Industrial Dynamics: Some Evidence from Italian Manufacturing’, *International Journal of industrial Organization*, **17**, 965–983.

Baldwin, J. R. (1995) *The Dynamics of Industrial Competition. A North American Perspective*. Cambridge: Cambridge University Press.

Barney, J. (1991) ‘Firms Resources and Sustained Competitive Advantage’, *Journal of Management*, **17**, 34–56.

Bernard, A. B., and J. B. Jensen (2002) ‘The Deaths of Manufacturing Plants’, *NBER Working Papers Series* number 9026, Cambridge.

Bernard, A. B., and F. Sjöholm (2003) ‘Foreign Owners and Plant Survival’, *NBER Working Paper Series* number 10039, Cambridge.

Bernard, A. B., J. Eaton, J. B. Jensen, and S. S. Kortum (2000) ‘Plants and Productivity in International Trade’, *NBER Working Papers Series* number 5958, Cambridge.

Boeri, T., and L. Bellman (1995) 'Post-Entry Behaviour and the Cycle: Evidence from Germany', *International Journal of Industrial Organization*, **13**, 483–500.

Brüdel, J., P. Preisendörfer, and R. Ziegler (1992) 'Survival Chances of Newly Founded Organizations', *American Sociological Review*, **57**, 227–242.

Caves, R. E. (1998) 'Industrial Organization and New Findings on the Turnover and Mobility of Firms', *Journal of Economic Literature*, **36**, 1947–1982.

Cleves, M. A., W. W. Gould, and R. G. Gutierrez (2004) *An Introduction to Survival Analysis Using Stata*. College Station, TX: Stata Corporation.

Cox, D. R. (1972) 'Regression Models and Life Tables', *Journal of the Royal Statistical Society*, **34**, 187–220.

Disney, R., J. Haskel, and Y. Heden (2003) 'Entry, Exit and Establishment Survival in UK Manufacturing', *Journal of Industrial Economics*, **51**, 91–112.

Dolton, P. J., and W. van-der-Klauw (1995) 'Leaving Teaching in the UK: A Duration Analysis', *Economic Journal*, **105**, 431–444.

Dunne, T., M. J. Roberts, and L. Samuelson (1988) 'Patterns of Firm Entry and Exit in US Manufacturing Industries', *Rand Journal of Economics*, **19**, 495–515.

Dunne, T., M. J. Roberts, and L. Samuelson (1989) 'The Growth and Failure of US Manufacturing Plants', *Quarterly Journal of Economics*, **104**, 671–698.

Efron, B. (1977) 'The Efficiency of Cox's Likelihood Function for Censored Data', *Journal of the American Statistical Association*, **72**, 557–565.

Ericson, R., and A. Pakes (1995) 'Markov-Perfect Industry Dynamics: A Framework for Empirical Work', *Review of Economic Studies*, **62**, 53–82.

Evans, D. S. (1987) 'The Relationship between Firm Growth, Size and Age: Estimates for 100 Manufacturing Industries', *Journal of Industrial Economics*, **35**, 567–581.

Fariñas, J. C., and L. Moreno (2000) 'Firms Growth, Size and Age: A Non-Parametric Approach', *Review of Industrial Organization*, **17**, 249–265.

Fichman, M., and D. Levinthal (1991) 'Honeymoons and the Liability of Adolescence: A New Perspective on Duration Dependence in Social and Organisational Relationships', *Academy of Management Review*, **16**, 442–468.

Geroski, P. (1995) 'What Do We Know about Entry?', *International Journal of Industrial Organisation*, **13**, 421–440.

Geroski, P., and J. Schwalbach (1991) *Entry and Market Contestability: An International Comparison*. Oxford: Basil Blackwell.

Ghemawat, P., and B. Nalebuff (1985) 'Exit', *RAND Journal of Economics*, **16**, 184–194.

Görg, H., and E. Strobl (2003) 'Footlose Multinationals?', *The Manchester School*, **71**, 1–19.

Grambsch, P. M., and T. M. Therneau (1994) 'Proportional Hazards Tests and Diagnostics Based on Weighted Residuals', *Biometrika*, **81**, 515–526.

Gras, N., and M. Teruel (2002) 'Entradas, Salidas y Supervivencia de Empresas: Evidencia Empírica', in A. Segarra (dir.): *La creación y la supervivencia de las empresas industriales*. Madrid: Civitas Ediciones.

Hall, B. H. (1987) 'The Relationship between Firm Size and Firm Growth in the US Manufacturing Sector', *Journal of Industrial Economics*, **35**, 583–605.

Hannah, M. (1998) 'Rethinking Age Dependence in Organizational Mortality: Logical Formalizations', *American Journal of Sociology*, **104**, 126–164.

Harhoff, D., K. Stahl, and M. Woywode (1998) 'Legal Form, Growth and Exit of West German Firms', *Journal of Industrial Economics*, **46**, 453–488.

Honjo, Y. (2000) 'Business Failure of New Firms: An Empirical Analysis Using Multiplicative Hazards Model', *International Journal of Industrial Organization*, **18**, 557–574.

Hymer, S. (1976) *The International Operations of National Firms*. Cambridge, MA: MIT Press.

International Journal of Industrial Organization (1995), **13**, *Special Issue on Post-Entry Performance of Firms*.

Jovanovic, B. (1982) 'Selection and the Evolution of Industry', *Econometrica*, **50**, 649–670.

Kalbfleisch, J. D., and R. L. Prentice (1980) *The Statistical Analysis of Failure Time Data*. John Wiley and Sons.

Kiefer, N. M. (1988) 'Economic Duration Data and Hazard Functions', *Journal of Economic Literature*, **6**, 646–670.

Kimura, F., and T. Fujii (2003) 'Globalizing Activities and the Rate of Survival: Panel Data Analysis on Japanese Firms', *NBER Working Paper Series*, no. 10067, Cambridge.

Klepper, S. (1996) 'Entry, Exit, Growth, and Innovation over the Product Life Cycle', *American Economic Review*, **86**, 562–583.

Klepper, S., and K. L. Simons (2000) 'The Making of an Oligopoly: Firm Survival and Technological Change in the Evolution of the US Tire Industry', *Journal of Political Economy*, **108**, 728–760.

Li, J., and S. Guisinguer (1991) 'Comparative Business Failures of Foreign-Controlled Firms in the United States', *Journal of International Business Studies*, 2nd quarter, 209–224.

Mata, J., and P. Portugal (1994) 'Life Duration of New Firms', *Journal of Industrial Economics*, **42**, 227–246.

Mata, J., and P. Portugal (2002) 'The Survival of New Domestic and Foreign-Owned Firms', *Strategic Management Journal*, **23**, 323–343.

Mata, J., and P. Portugal (2003) 'Patterns of Entry, Post-Entry Growth and Survival: A Comparison between Domestic and Foreign Owned Firms', *Small Business Economics*, forthcoming.

Mata, J., P. Portugal, and P. Guimaraes (1995) 'The Survival of New Plants: Start-Up Conditions and Post-Entry Evolution', *International Journal of Industrial Organization*, **13**, 459–481.

Melitz, M. J. (2002) 'The Impact of Trade in Intra-Industry Reallocations and Aggregate Industry Productivity', *NBER Working Papers Series*, number 8881, Cambridge.

Mitchell, W. (1994) 'The Dynamics of Evolving Markets: The Effects of Business Sales and Age on Dissolutions and Divestitures', *Administrative Science Quarterly*, **39**, 575–602.

Segarra, A. (dir.) (2002) *La creación y la supervivencia de las empresas industriales*. Madrid: Civitas Ediciones.

Segarra, A., and M. Callejón (1999) 'Business Dynamics and Efficiency in Industries and Regions. The Case of Spain', *Small Business Economics*, **13**, 253–271.

Segarra, A., and M. Callejón (2002) 'New Firms Survival and Market Turbulence: New Evidence from Spain', *Review of Industrial Organization*, **20**, 1–14.

Stiglitz, J., and A. Weiss (1981) 'Credit Rationing in Markets with Imperfect Information', *American Economic Review*, **71**, 393–410.

Stinchcombe, F. (1965) 'Social Structure and Organizations', in J. March, ed., *Handbook of Organizations*. Chicago: Rand McNally.

Sutton, J. (1997) 'Gibrat's Legacy', *Journal of Economic Literature*, **25**, 40–59.

Tveteras, R., and G. E. Eide (2000) 'Survival of New Plants in Different Industry Environment in Norwegian Manufacturing: A Semi-Proportional Cox Model Approach', *Small Business Economics*, **14**, 65–82.

Wernerfelt, B. (1984) 'A Resource-Based View of the Firm', *Strategic Management Journal*, **5**, 171–180.