FIRM SURVIVAL, LIFE CYCLE AND TECHNOLOGICAL REGIME

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Abstract

New firms run a high risk during their first years of life. This study analyses the life expectancy of the 1994 contingent of Spanish manufacturing firms during the period 1995-2000 or, in other words, during their first six years of life. The life cycle and technological regime of the industries determine different survival environments for new firms. Specifically, the firms enjoy higher rates of survival during the initial phases of the industry life cycle, whereas they find strong barriers to survival in industries with a high level of technology. In addition, the hazard rate varies with the initial size of the firm. We find start-up size to be an important determinant of the chances of survival. Large firms have higher relative survival rates in mature industries, whereas small firms come across more barriers to their continued operation in high technology industries.

Key words: firm survival, hazard rate, life cycle, technological regime, Spanish industries.

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FIRM SURVIVAL, LIFE CYCLE AND TECHNOLOGICAL REGIME

1. -INTRODUCTION.

In 1994, 12,984 Spanish manufacturing firms were created. Six years later 50.3% of them were still in operation[1]. The low survival rate of the 1994 cohort demonstrates the risk run by firms during their infancy or first five years of life.

The trajectory of industrial firms varies according to their size, the stages in the product life cycle and technological level of the industry. Additionally, the hazard rate faced by the entrants during their first years of life decreases as the firm ages. For this reason, the first years of life are a critical period in which the new firm develops its ability to adapt to the conditions of the market (cost structures, competitive strategies, adaptation to changing patterns of demand, development of economies of scale, etc.). This is why we are interested in analysing the life trajectories of the 1994 manufacturing cohort during their infancy.

This study deals with two relevant aspects of industrial dynamics. It analyses firm survival according to the life cycle of the market and according to the technological level of the industry. In view of the lack of studies on firm survival in Spain, we follow the paths of the cohort of manufacturing firms created in 1994 during the first six years of their lives. When we group together the branches of industry according to their life cycle and technological regime, we find that the differences in the hazard rate faced by the new firms give rise to different life trajectories. The results obtained indicate that the life expectancy of firms that take the decision to enter a specific market depends on the characteristics of the industry and the individual factors of newcomers.

In recent years a considerable number of studies, both empirical and theoretical, have been published on the post-entry behaviour of firms and the evolution of markets. Despite being applied to different countries and periods, the results show a series of empirical regularities. In effect, the operation of markets offers a series of “stylised facts” that affect both firm mobility (firm entry, exit, and growth), as well as firm survival[2].

This is the reason for our interest in ascertaining whether the empirical regularities that relate firm survival to the industrial life cycle and technological regime are also valid for Spanish manufacturers. In summary, the initial hypotheses are related to three relevant aspects of the dynamics of industrial markets, that can be defined as follows:

a) Firms entering new and emerging markets are more likely to survive than those entering mature markets.
b) Industries with a high level of technological development offer greater opportunities for the incorporation of new entries, but present high barriers to

[1] Despite the fact that the statistical source used also includes firms with no salaried employees, they are not included in this study, as self-employment strategies tend to predominate in such entrepreneurial units and they are less likely to be the creation of an entrepreneurial project. In the 1994 cohort in Spain, a total of 16,711 industrial firms with no salaried workers were created.
[2] See Gerosky (1995); Audretsch and Mata (1995); Malerba and Orsenigo (1996) and Caves (1998).

the survival of such new firms[3]. Therefore, firms entering high technology industries have a lower than average survival rate for manufacturing industries[4].

c) The survival rate for new firms is directly related to the initial size. During their infancy, firms entering the market with less than the Minimum Efficient Size have greater difficulty in surviving and in reducing the disadvantages associated with their productive scale.

Following this introduction, the text is divided into four sections. The second section highlights the relationship between the industrial dynamics and the life cycle phases of the industry. The third section describes the environment of the new firm according to the technological regime of the industry. The fourth section links the technological regime and the life cycle of industries, and presents the empirical results of a proportional hazard model. The paper ends with a summary of the most relevant contributions of the study. In an additional annexe we present a database produced with information from the National Statistics Institute (INE) *Central Company Directory* (DIRCE), and the criteria that distribute the sectors to two digits of the CNAE-93 in accordance with the life cycle and the level of technology.

2. -FIRM SURVIVAL AND INDUSTRY LIFE CYCLE

The trajectory of a firm can be divided into different phases: a period of gestation or infancy, a period of development and a mature period. The theory of a product life cycle is a suitable instrument for analysing the behaviour of firms from the point of view of the industry dynamics.

The concept of a product life cycle was initially developed by Dean (1950), Levitt (1965), Vernon (1966) and Cox (1967), among others[5]. These authors analysed the performance of firms in achieving a strategic advantage during the development of an industry. The technological evolution of an industry affects the ability of firms to consolidate their position in the market and the incentives to potential competitors to enter the market.

The industries evolve over time. Products, management methods, firm size, market structure, and the role of institutions change during the industry life cycle. Furthermore, firm entry and exit varies over the phases of the industry life cycle. In the initial stages of the life cycle there is a high rate of firm entry and a

[3] See Gerosky (1995) the barriers to firm entry and exit determine the industry entry and exit flows and, on the other hand, the barriers to survival affect the competitive conditions of the firms after they have entered. Moreover, if we take into consideration the fact that the survival rate of new firms is low, the entry barriers often act as barriers to survival.

[4] In industries where innovative activity plays an important role, the likelihood of new entrants surviving over a decade is lower than in industries where innovative activity is less important, but those entrants that are able to survive exhibit higher growth rates. See Audretsch (1995).

[5] The life cycle concept is related to studies on biological systems. In fact, Marshall, in his *Principles of Economics*, defends a greater use of biological concepts: *"The economist's Mecca is found in economic biology rather than in economic dynamics. However, biological concepts are more complex than mechanical ones; therefore, all studies dealing with the fundamentals of the Economy should reserve a relatively large space for mechanical analogies, and for this reason, we frequently use the term balance, which suggests something of static analogy"* (Marshall, 1890, Spanish edition, 1963, p. XXIV).

lower rate of exit. When the industry reaches its mature stage, the trend is reversed and exits exceed entries. Therefore, the stage at which an industry finds itself can be determined by the results of the market turnover.

In recent years, the availability of suitable statistical resources for studying the changing dynamics of industries has aided the appearance of new interpretative models (Abernathy and Utterback, 1978; Klepper and Graddy, 1990; Klepper, 1996). The literature dealing with industry life cycle establishes a connection between the business dynamics (i.e. the factors related to firm entry, exit and growth) and the process of innovation[6]. The business dynamics of an industry depend on the life cycle of the product. When a new product appears in the market, firms entries exceed exits. Later, in the mature stage, exits exceed entries. The innovation process is also affected by the dynamics of the industry, as industries with a high Net Entry Rate tend to maintain a high level of innovation and show important rates of growth in levels of efficiency (Gerosky, 1995).

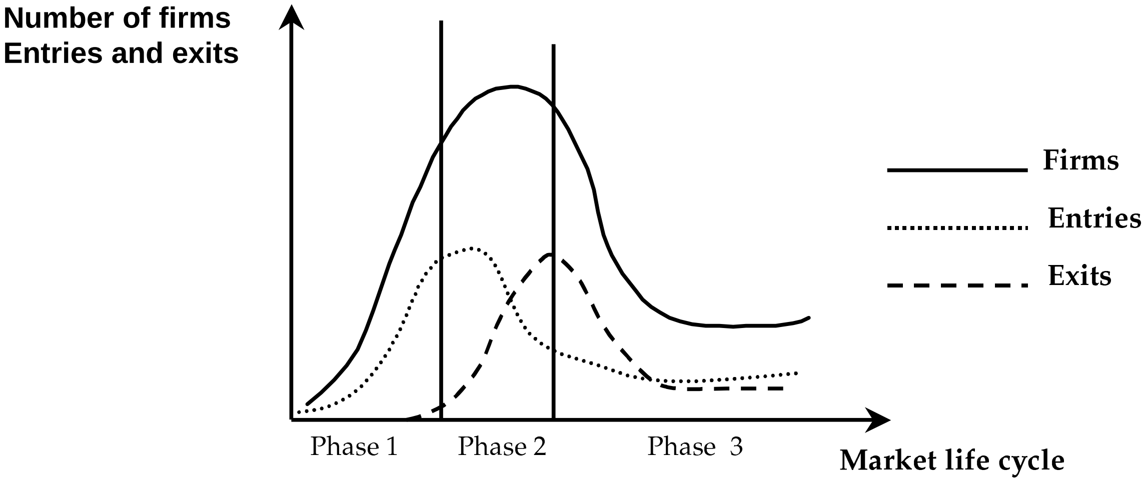
Business dynamics and industry life cycle.

The introduction of a product to the marketplace may be the result of a completely new product or of improvements to an already existing product. In both cases, the firm introducing the innovation is running a high risk since it cannot know to what extent consumers will accept the product or how potential competitors will react. When an innovating company introduces a new product to the market it is ignorant of the degree of acceptation and the *dominant design* that will eventually prevail[7]. The uncertainty entailed in innovation influences the structure of the market. In the initial stages, market competition is intense and firms tend to be small. The absence of substitute goods and the inflexible behaviour of demand mean that the producers holding the patents enjoy considerable power in the marketplace. However, with the passage of time, the entry into the market of new firms that manufacture the dominant design erodes the power of the first entries. The evolution of entries, exits and the number of active firms shows a notable regularity.

[6] The innovation of a product can be divided into two distinct activities: the technical development of the new product and its introduction onto the market. The life cycle stages of the industry deal with this second activity. Therefore they determine the evolution of a product in the market, from its launch until it reaches maturity, in terms of technological development or firm turnover. Schumpeter (1954) made a distinction between 'invention' (a new discovery) and 'innovation' (the commercial development of a discovery). Inventions often derive from basic research, whereas innovations are developed by companies.

[7] The existence of a dominant design has brought about various criticisms. For some writers, specific product characteristics do not undergo substantial changes over long periods of time (Abernathy and Utterback, 1978).

Chart 1.
Entries, exits and market structure



Furthermore, there are other factors that determine the market structure for each phase of the life cycle: changes in the design of the product, the relevance of price as a competitive variable, specific knowledge and the level of suitability. Gort and Klepper (1982) distinguish five phases in the life cycle of a product. A different level of firm turnover is recorded in each phase.

When the product is introduced into the market (first phase), there is a low number of products. Firm entries predominate, as the number of exits is practically zero. The Net Rate of Entry is positive and growing. Subsequently there is a high rate of supply and demand (second phase) and, therefore, the number of producers increases considerably. At the end of this second phase the number of exits increases. The acceptance of the dominant product design and the growing relevance of cost as a competitive market variable affects the dynamics of firm entry and exit in two ways: on the one hand these factors facilitate the exit when the economies of scale play an important role in the industry, and, on the other hand, they raise barriers to the entry of potential competitors. During the third phase, the gross entry rates decrease and the gross exit rates increase. In the fourth phase, exits exceed entries. At this stage the market structure shows major asymmetries with large companies occupying new niches by absorbing producers. Finally, in the fifth phase, entry and exit flows are moderated and the market reaches maturity.

In order to simplify our exposition we have limited ourselves to three phases of the industry life cycle[8]. In the initial exploratory or embryonic stage the market size is small, there is a high level of uncertainty, the design of the product is elementary, and the machinery used in its production is not very specialized. A high number of firms enter the market and, moreover, there is intense competition based on product innovation. In the intermediate or growth stage, there is a high rate of market growth, a stabilization in product design, a lower rate of innovation, and specialized machinery is incorporated into the production process. The number of firm entries is modified and company takeovers are frequent. In the mature stage there is low market growth, the number firm entries falls, the market structure stabilizes, innovations are less

[8] Some writers divide the evolution of markets into five stages (Gort and Klepper, 1982).

significant, and production and sales techniques are more sophisticated (Klepper, 1997).

The empirical evidence of studies that analyse the evolution of specific products or markets indicates that the number firms established in the market, the distribution according to firm size, and the entry and exit flows vary with the life cycle of the product. Gort and Klepper (1982) and Klepper and Graddy (1990) study the evolution of entries and exits during the product life cycle and demonstrate that the reduction in the number of producers is a normal market phenomenon[9].

In general the process of restructuring in an industry (*shakeouts*) is closely linked to changes in technology (Utterback and Suarez, 1993; Jovanovic and MacDonald, 1994; Klepper, 1995). In the initial stages of an industry, the firms are small and the product highly priced. Subsequently, the entry of new firms increases the number of producers and the incumbents increase their scales of production, bringing about an overall increase in the industry's production and a fall in prices. When the growth in demand and the average size of the incumbents begins to level off, the number of exits rises and a process of industrial restructuring begins. In the product consolidation phase the distribution of the size of firms is asymmetrical and the number of exits exceeds the number of entries[10].

Empirical evidence

The cumulative survival rates of the industrial firms show that firm mortality is high during the infancy period. Of the 12,984 firms that make up the cohort of manufacturing firms created in 1994, 1,722 ceased operation during the first year. The likelihood of exiting the market in 1995 was 13.3%, and, therefore the likelihood of remaining in operation at the end of 1995 was 86.7% (1 - 0,133)[11.] After the first three years of the contingent's life, 64.7% of the firms remained in operation. Of the 1994 contingent, only 50.5% of firms surpassed the period of infancy. By the end of 2000, 49.5% of the manufacturing firms had exited.

However, having said that, the companies of the 1994 contingent do not follow identical trajectories. We can see differences in the industrial firm survival rates according to the phase of the industrial life cycle. In order to simplify our exposition, we distinguish between those industries with a predominance of new and emerging markets that are in their formative period and those mature

[9] Gort and Klepper (1982) study the markets for 46 products in the United States throughout their life cycle. Following the commercial presentation of the product, the majority of those markets recorded a rapid growth in entries and a low rate of exits. After this period of about ten years, the reduction in entry flows coincides with an increase in exits. According to these writers, for 19 of the products that reach the phase of maturity, the number of producers that are eliminated from the market rises to an average of 40% of the industry population.

[10] Jovanovic and MacDonald (1994) develop a life cycle model for a competitive industry that is subsequently subjected to an empirical contrast using the evolution of the automobile tire manufacturing industry in the United States between 1906 and 1973.

[11] The failurre rates during the first years of the contingent are high, above those given by other studies -Agarwal and Audretsch (1999) for example. These differences are due in part to the different nature of the statistical sources used. In this respect the DIRCE is exhaustive in the collection of data on small-size firms, which, as we know, have a higher failure rate.

industries with a predominance of less dynamic markets in the intermediate or mature period of the life cycle.

In the initial phase firms enjoy higher levels of survival than those in the mature phase of the industries. After the first six years of the contingent's life, 53.4% of the firms in the initial phase continued in operation, as opposed to 48.1% of firms in mature industries.

Table 1 shows the cumulative survival rate of the firms that start-up in 1994, with a distinction made between industries in the initial phase and those in the mature phase of the life cycle.

The cumulative survival rate is obtained from the data contained in the life table. Thus, the survival rate of an individual firm or a group of firms in year "t" shows the number of firms still active in "t" in relation to the initial number of firms, i.e.:

$$S(t) = \frac{Firms active in "t"}{Initial\, firms start-ups}$$

The likelihood of an individual firm (or group of firms) ending its activity during a specific year "t" will be determined by the hazard rate confronting the firm. We can express the hazard rate for the firms active in "t-1" that managed to survive in "t" as follows:

$$h(t) = 1 - \left[\frac{S(t)}{S(t-1)}\right]$$

This expression shows the likelihood of a firm of "t-1" years exiting the market during the year "t". For the discreet time the hazard rate *h(t)* is the likelihood of a firm that has survived until year "t" will exit the market during the period "t+Δt", as we can see in the following expression:

$$h(t) = \lim_{\Delta t \to 0} \frac{P(t \leq T \leq t + \Delta t \mid T \geq t)}{\Delta t} = \frac{f(t)}{S(t)}$$

where *t = 1,2,...T*, is the discreet time; *f(t)=dF(t)/dt* is the function of density corresponding to the exits with respect to the initial number of firms in the group; *F(t)=Pr(T<t)* is the likelihood of the firms in the group reaching a life period "T" lower than "t"; and, finally, *S(t)=1-F(t)* is the survival function.

Table 1
Survival rates according to the life cycle

Time	Initial Phase	Mature Phase
After 1 year	0.8733	0.8627
After 2 years	0.7609	0.7377
After 3 years	0.6694	0.6302
After 4 years	0.6134	0.5685
After 5 years	0.5721	0.5161
After 6 years	0.5343	0.4808
Firms	5,810	7,179
Homogeneity tests according to start-up firm size classes: χ^2 (Pr > χ^2)		
Log-rank test	31.85 (0.000)	42.71 (0.000)
Wilcoxon test	36.16 (0.000)	56.27 (0.000)
Source: Central Company Directory		

The cumulative survival rates in Table 1 plot the life trajectory of the firms in the industries of the initial and mature phases and, therefore, do not take into consideration the individual variables that affect survival. However, the evidence indicates that firm survival varies positively with firm start-up size. For this reason it is interesting to analyse the survival curves according to the initial size (Table A-1). When we calculate the cumulative firm survival rates according to the start-up size level by the number of workers, the survival curves take on a different meaning[12].

The log-rank and Wilcoxon statistics in Table 1 provide additional information on the survival rates when the units of observation are divided into size strata. In our case, both the log-rank and the Wilcoxon tests show a high level of significance. These results indicate that the survival rates differ according to the size of the firms.

The survival curves indicate that the life expectancy of firms differs according to the industry life cycle phase and also depends on the initial size of the firm. At the same time, these differences in the life trajectories of firms that belong to a specific industry and size range indicate that the hazard rate confronted by new firms varies according to the size of the firm and the phase of the industry.

In Table 2 we show the relative hazard rates for the firms in the 1994 contingent. To do this we estimate the Cox statistics that compare the survival curves of each group of firms[13]. This estimator shows the hazard rate for the firms of each start-up size level in relation to the hazard rate for the cohort.

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[12] The log-rank test and Wilcoxon-Breslow test provide a comparison with the estimated hazard rate and the hypothetical hazard rates between *i* ($i \geq 1$) groups of firms. The null hypothesis is: $H_0 : h_1(t) = h_2(t) = \ldots = h_i(t)$, for all $t \leq T$, and the alternative hypothesis is: H_A: at least on of the $h_i(t)$'s is different for some $t \leq T$. The number of failures in group *i* ($i=1,\ldots,r$) at time *tj* is $w_{ij} = n_{ij}\, d_j / n_j$, where d_j is the number of failures at time *tj* and n_j is the incumbent firms across all groups just before *tj*; d_{ij} and n_{ij} denote the same things for group i. The stadistical test is, $U = \sum_{j=1}^{k} c_j\,(d_{1j} - w_{1j}, \ldots, d_{rj} - w_{rj})$, where $c_j = 1$ in the log-rank test and $c_j = n_j$ in the Wilcoxon-Breslow test. See Klein y Moeschberger (1997: 187:219)).

[13] The relative hazard rates are the exponential coefficients from the Cox regression renormalized. The renormalization is chosen so that the expected number of failures within

Table 2
Relative hazard rates according to the initial size of the company and the life cycle of the industry

Start-up Size Class	Full Sample	Initial Stage	Mature Stage
1-2 employees	1,101	1,149	1,072
3-5 employees	0,920	0,924	0,920
6-9 employees	0,874	0,787	0,936
10-19 employees	1,006	0,888	1,053
20-49 employees	0,937	0,870	0,950
50 or more employees	0,673	0,644	0,683
Total	1,000	1,000	1,000
Cox Estimator			
χ^2 ($Pr > \chi^2$)	62,04 (0,000)	55,36 (0,000)	22,33 (0,000)

Source: Central Company Directory

Firms with 50 or more employees have the greatest advantage in the initial stage. In this group the relative hazard rate is 64.4%. On the other hand, small firms show a relative hazard rate of 114.9%. In industries in the initial stage, 48.8% of firms with less than 3 employees finished their period of gestation or infancy, whereas 67.5% of those with 50 employees or more did so.

Mature industries with 50 or more employees also enjoy moderate risks (68.3%). However, the relative hazard rate among firms with less than three employees is much lower than in first phase industries (107.2%). In mature industries, after six years 46.3% of firms with less than 3 employees survived, whereas 59.3% of large firms did so.

3. -FIRM SURVIVAL AND TECHNOLOGICAL REGIME

In this section we develop the analytical framework that allows us to compare firm survival rates with the process of technological innovation and the nature of knowledge in the industries. As we have seen, the activities of innovation and technological development are relevant factors in the dynamics of the industry. Moreover, the innovation processes take on different dynamics depending on the nature of technological knowledge. For Nelson and Winter (1982) the characteristics of the knowledge generated by firms in R&D activities determine the technological regimes of the industries.

There is a great deal of economic literature that analyses the role played by technological knowledge in the evolution of industries. Nevertheless, there are significant differences between the theories that address technological change from the point of view of the production of knowledge and those based on technological regimes[14]. Let us look at the main aspects that separate each of those perspectives.

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groups weighted of the regression coefficients is 0 (meaning the hazard is 1). Let b_i ($i=1,\dots,r-1$) be the estimated coefficients and define $b_r = 0$, constant K is calculated by $K = \sum_{i=1}^{r} w_i\, b_i \,/\, d$ where $w_i = \sum_j w_{ij}$ is the expected number of failures for group i, d is the total number of failures across all groups, and r is the number of groups. The relative hazard rates are $exp(b_i - K)$.

[14] Nelson and Winter (1974, 1978, 1982); Malerba (1992); Malerba and Orsenigo (1993);

In the innovation theories the agent is the firm[15]. One exponent of this literature is the model developed by Griliches (1979) dealing with the function of knowledge creation. Here, the company is an exogenous agent that generates new economic knowledge from its technological research and development activities. From this point of view, the main input of the firm in the creation of knowledge is the R&D activity.

On the other hand, in the technological regime approach, the actor bringing about the change is the individual agent that has the ability to generate the technological knowledge. Here, the firm becomes an endogenous variable to the model: when an agent has great expectations about the returns of an innovation, he decides to create a new firm. The asymmetries in the expectations for the profitability of technological knowledge explain why many established firms fail to materialize the results obtained from R&D activities. When access to technological knowledge is open to individual agents, these are more able to create a new firm and develop an innovation.

Models based on technological regimes emphasize the public asset nature of the technological knowledge and the low access cost for agents that make use of it[16]. Potential competitors often create far greater expectations of profitability for an innovation than those firms already active in the industry. The effect of technological spillovers and the existence of asymmetric expectations between outsiders and insiders encourage the creation of firms in industries that offer fewer barriers to technological knowledge.

Audrestch (1997) describes the incentives an agent has to create a firm with the following expression:

$$\Pr(e) = f\,(p - w)$$

where the likelihood of materializing the entry is a function of the expected net present discounted value of the profits accruing from starting a new firm (*p*) to the wage he would earn if he remains employed by an incumbent firm (*w*). If the expected profit differs little from the wage, then the entrepreneur has little incentive to create the new firm. On the other hand, if the expected profits are much higher than the current wage, there is a greater probability that the individual agent will start a new enterprise.

However, the ability of the individual agent to gain access to technological knowledge depends on the nature of the knowledge – its degree of suitability, ease of transmission between agents, complementarity with other technological knowledge, etc. In addition, the nature of the knowledge varies from one industry to another. In some industries the new knowledge is of a tacit nature, in other words it is largely generated within the company and is only transferred to the outside with difficulty. In other industries new knowledge is more easily transferred and generates greater technological spillover between agents. Nelson and Winter (1982) distinguish two technological regimes, depending on

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Audretsch (1995, 1997).

[15] Arrow (1962); Scherer (1984); Dosi (1988), Cohen and Levin (1989)

[16] An overview of the literature concerning scientific knowledge, technology and innovation can be consulted in Stephan (1996).

the nature of the knowledge: the *routinized regime* and the *entrepreneurial regime*.

In routinized regime industries, technological information is difficult to transfer between agents as there is a predomination of tacit knowledge that is difficult to appropriate outside the organization that generates it. The *routinized regime* industries have firms with large firms –the market concentration is high- and they are capital and advertising expenditure intensive.

In *entrepreneurial regime* industries, it is easier to transfer information outside the company, there is a predominance of coded knowledge, and new firms undertake technological innovations without great difficulty. *Entrepreneurial regime* industries have a high percentage of small and medium-size firms, an intense innovative activity, and a high incidence of innovation in small firms. In the *routinized regime*, small firms record a lower rate of innovation than the average for the industry, whereas in the entrepreneurial regime, the rate of innovation in small firms is greater than that of the whole industry (Audrestch, 1997).

The nature of the knowledge is a relevant element in the ability of individual agents to check the profitability of a technological innovation. Therefore, when faced with the question "How do firm entries and exits affect the technological regime of the industry?", we have to point out that there is a direct relationship between the technological regime and the turnover of firms in the industries. In effect, industries where the *entrepreneurial regime* predominates, they experience higher turnovers –both in firm entries and exits- than those sectors with *routinized regimes* (Audrestch, 1995). In each technological regime the nature of the technological knowledge determines the flow of information between agents and therefore also determines the ability of entrepreneurs to exploit the ideas developed by incumbents.[17]

However, as Gerosky (1995) points out, the factors that determine the turnover of firms in a market do not have to be identical to those that determine survival. This leaves us with another question to answer, "How does firm survival affect the technological regime?" Bearing in mind that firms operating in innovative environments face great uncertainties, both from a technological and a demand point of view, we should expect the survival rate to be lower. On the other hand, in routinized regime industries, technological conditions and consumer preferences are more stable and defined and, as a consequence, we should expect the survival rate of new firms to be higher.

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[17] The usual concept of knowledge as a public asset, with public access and low transmission costs, has been questioned by studies into the geography of innovation and dissemination of knowledge. These studies indicate that, although the cost of transmitting information may remain the same despite the distance, the cost of disseminating and transmitting knowledge does increase with distance (Audrestch and Feldman, 1996). In this study we do not deal with the geographical aspects of knowledge transmission, but we wish to mention it as a relevant factor.

Empirical evidence

Below we will see if the technological regimes approaches fit the life trajectories of the contingent of industrial firms created in 1994. According to the predictions for the technological regimes in the highly technologically intensive industries, the entry barriers for new firms are low, but the barriers to survival are high. Therefore we should expect firms which decide to enter a high technology industry to face high mortality levels and low survival rates.

Table 3 shows that after the first six years, 49.18% of the high technology sector companies in the 1994 contingent continued in operation. In contrast, 54.54% of firms in the medium and low technology sectors were still operative.

Table 3
Industrial firm survival rates by technological regime

Time	High level of technology	Low and medium level of technology
After 1 year	0,8240	0,8697
After 2 years	0,7274	0,7492
After 3 years	0,5888	0,6508
After 4 years	0,5561	0,5903
After 5 years	0,5187	0,5423
After 6 years	0,4875	0,5056
Firms	642	12.347
Homogeneity tests according to start-up firm size classes: χ^2 (Pr > χ^2)		
Log-rank test	8,62 (0,125)	64,42 (0,000)
Wilcoxon test	9,28 (0,098)	78,92 (0,000)

Source: Central Company Directory

As we would have expected, the survival functions differ depending on the start-up size in which the firm is situated, as can be seen from the log-rank and Wilcoxon estimators. However, the differences in the likelihood of survival according to the firm's start-up size are not statistically significant in the industries with a high level of technology.

Table 4
Relative hazard rates according to the initial start-up firm size and technological regime

Start-up size class	Full Sample	High level of technology	Low and medium level of technology
1-2 employees	1,101	1,162	1,098
3-5 employees	0,920	0,896	0,921
6-9 employees	0,874	0,869	0,875
10-19 employees	1,006	0,894	1,012
20-49 employees	0,937	0,662	0,952
50 or more employees	0,673	1,313	0,634
Total	1,000	1,000	1,000
Cox estimator χ^2 (Pr > χ^2)	62,04 (0,000)	7,49 (0,186)	58,11 (0,000)

Source: Central Company Directory

If we compare the survival curves for the six size ranges included in this study, in the high technology industries the relative hazard rate for firms with less than 3 workers is high (116.2%). The small firms face few barriers to entry but the barriers to their survival are considerable. Intermediate size firms –between 3 and 50 employees- have relatively low failure rates, whereas firms with 50 or more employees have a relatively high hazard rate (131.3%). Nevertheless, the low number of firms in this range means we have to interpret this relatively low hazard rate with caution.

When the entrants reached the age of six in the high-tech industries, the survival rate in firms with less than 3 employees was 43.83%; in firms with between 10 and 19 employees it was 53.8%; and in firms with 50 or more employees it was 33.3% (the low number of companies in this sector means we have to view this survival rate with caution).

In low and medium technology industries, those firms with less than 3 employees have a higher possibility of survival since the relative hazard rate is 109.8%, whereas firms with 50 or more employees show a moderate relative hazard rate of 63.4%. At the end of the year 2000 year 47.7% of firms with less than 3 employees and 64.5% of firms with 50 or more employees were still active.

Barriers to survival are lower in *routinized regime* industries and, in addition, small firms face less unfavourable relative hazard rates. The likelihood of survival of small firms in *routinized regimes* is low, but nevertheless greater than that of small firms in high technology industries.

4.-SIZE, LIFE CYCLE AND TECHNOLOGICAL REGIME.

Up to now we have dealt with the survival trajectories of industrial firms separately according to their life cycles and the technological regimes of the industry. However, the diversity of environments met by new industrial firms combines with both dimensions, so that that the industries in the initial or mature phases have high or low technological intensity. If we proceed to a quadripartite classification, following the criteria put forward in the second epigraph, the explanatory capacity of our exercise is considerably increased.

The industries in the initial cycle with a low technological intensity show the highest survival rates, while the sectors in the initial cycle with a high technological intensity are in the most difficult survival environments (Table 5). In industries in the initial phase, firms with less than 3 employees show relatively high hazard rates. On the other hand, the relative hazard rate for firms with 50 or more employees is very low (53.0%) in the sectors in the initial cycle with low technological intensity (in the initial cycle with a high technological intensity, the relative hazard rate of these firms is very high).

In mature industries the technological intensity has an opposite effect on the survival rate. The survival rate at six years of the cohort in the mature industries with low technological intensity is low (47.92%), while in the high-tech cohort the survival rate is high (53.21%). In the mature industries the small firms show less disadvantages in their relative hazard rates than those in the initial cycle industries. The homogeneity statistics (Wilcoxon y Cox) are insignificant in the high-tech sectors, particularly in the mature sectors. New firms entering mature industries which are intensive in technological resources enjoy a competitive environment that facilitates access to demand niches not covered by active firms[18]. Generally, in mature industries there is a predomination of new firm strategies to cover new market segments, whereas radical innovations designed to improve products or production and distribution processes become less relevant.

Additionally, in Table 5 we examine the effects of size-range of start-up firms and the changes of size-range on the likelihood of survival during the first six years of their lives. We applied a proportional hazard model to determine how the initial size and the changes in the size range have a bearing on the survival probability of the new firms.

[18] The results obtained for mature manufacturing industries in Spain are in keeping with those presented for North American manufacturers by Agarwal y Audretsch (2001).

Table 5
Survival according to life cycle and technological regime

		Survival Rate		**Relative survival rate**		**Proportional hazard model**			**Homogeneity test**	
	Number firms	**3 years**	**6 years**	**1-2 workers**	**50 o more workers**	**Size**	**Mobility**	χ^2	**Wilcoxon**	**Cox**
All firms	12.984	0,6477	0,5047	1,101	0,673	-0,088 (0,011)*	-0,009 (0,005)***	316,34*	85,25 (0,000)	62,04 (0,000)
Initial life cycle	5.810	0,6694	0,5343	1,149	0,644	-0,120 (0,188)*	-0,009 (0,005)***	69,06*	64,39 (0,000)	55,36 (0,000)
Mature life cycle	7.174	0,6302	0,4808	1,072	0,683	-0,070 (0,014)*	-0,002 (0,007)	222,15*	34,51 (0,000)	22,33 (0,000)
Low technological intensity	12.342	0,6508	0,5056	1,098	0,634	-0,088 (0,011)*	-0,015 (0,005)*	300,24*	78,92 (0,000)	58,11 (0,000)
High technological intensity	642	0,5888	0,4875	1,162	1,313	-0,089 (0,051)**	-0,009 (0,005)***	14,59**	9,28 (0,098)	7,49 (0,000)
Initial cycle & low technological intensity	5.386	0,6762	0,5397	1,145	0,530	-0,117 (0,019)*	-0,019 (0,009)**	44,81*	57,57 (0,000)	50,83 (0,000)
Initial cycle & high technological intensity	424	0,5825	0,4646	1,208	2,341	-0,141 (0,066)**	-0,009 (0,005)***	14,62*	13,54 (0,019)	11,81 (0,037)
Mature cycle & low technological intensity	6.956	0,6311	0,4792	1,072	0,687	-0,072 (0,014)*	-0,002 (0,007)	222,56*	33,58 (0,000)	21,62 (0,000)
Mature cycle & high technological intensity	218	0,6009	0,5321	1,045	0,612	-0,104 (0,042)**	-0,054 (0,032)***	8,10**	1,77 (0,880)	0,88 (0,972)

Coefficients statistically significant at the (*)1%, (**)5% and (***)10% level. Standard Error in brackets.
Source: Central Company Directory

The hazard function may be defined as a multivariant model that includes a vector Z of observed independent variables. The link between observed variables and the life duration of firms can be expressed according to the Proportional Hazard Specification (Kiefer, 1988):

$$h(t|z)=h_0(t)\exp(Z\beta)$$

After taking logarithms we obtain the next expression,

$$\ln h(t) = \ln h_0(t) + Z\beta$$

where β is a vector of parameters, Z is a vector of explanatory time-invariant covariates and $h_0(t)$ is an unknown non-negative base line hazard rate.[19] In our estimation we use two explanatory variables. *Size* is the initial range-size of the new firm and *Mobility* is the percentage of survivors in 1998 that changed size-range during the period 1994-1998. This variable reflects the capacity of new firms to discover their relative efficiency levels –*Jovanovic Effect*- and to adopt their optimal size. All Cox regressions have industrial dummies at two-digit standard industrial classification (SIC) level.

The initial size of the firm has a greater bearing on the risk of failure in the sectors in the initial cycle, especially in the high-tech and initial phase of the cycle. In the mature sectors the initial size of new firm has a lesser effect on the likelihood of survival. In mature industries and low-tech industries the market niches give the small firms a greater chance of remaining operative, despite being far from the optimal size for minimizing the average cost in the industry as a whole.

The changes in size-range of the surviving firms during their first four years of life reduces the hazard rate, especially in mature manufacturing industries, where the ability of new firms to reach the optimal size for their market niches is more important.

5. -CONCLUSIONS.

Life expectancy for new firms entering a market differs according to their individual characteristics and the nature of the industry. This study investigates how firm survival is related to the two relevant dimensions of industry: the life cycle and the technological regime. To do this, we first develop the classification criteria for the industry from two sides. First we determine the life cycle phase of the industry according to the firm entry and exit flows; next we establish the technological regime of the industry according to the level of R&D expenditure.

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[19] This procedure has been followed by Dunne and Pakes (1994) in their study for U.K. manufacturing firms; Mahmood (1992), Audretsch (1995) and Audretsch and Mahmood (1995) for U.S. manufacturing firms; Audretsch, Houweling and Thurik (2000) in Netherlands; Fotopoulos and Louri (2000) in Greek; Wagner (1994) in German; and Audretsch, Santarelli and Vivarelli (1999) in Italy.

Companies that decided to enter an industry in the initial phase of its life cycle stood a greater chance of survival those that entered an industry in the mature phase. Nevertheless, firms in industries with a high technological level encountered greater barriers to survival than those companies in medium and low technology industries.

Alongside these sectorial differences in the survival curves for the firm start-ups in 1994, the life trajectory of the entries within the same industry varies according to the initial firm size. Therefore, in addition to the relationship between the life trajectory of the contingent according to the life cycle and the technological regime, this study analyses the survival curves of the six different start-up firm size classes.

A regularity that emerges from the data used in the study indicates that the likelihood of survival is directly related to the start-up firm size. Moreover, the disadvantage in terms of life expectancy of small entries increases when we are dealing with a mature and/or high technology industry.

Medium and large firms enjoy higher survival rates in formative stage industries and low-tech industries. In the mature industries, the relative hazard failure rate associated with the initial size of the firm shows smaller differences: the small firms have relatively moderate disadvantages. In particular, small firms that take the decision to enter into mature, high-tech industries have a greater probability of finding small market niches and, therefore, the barriers to their survival are smaller.

ANEXE 1. -DATA SOURCES AND INDUSTRY CLASSIFICATION CRITERIA

In order to study the likelihood of survival of new entrants over six years, it is essential to have data sources that offer individual information on firm evolution. Access to longitudinal databases with company information opens up considerable possibilities for studying the evolution of markets[20]. Unfortunately, in our case we still do not have access to long series that covers the full history of individual markets. Nevertheless, the use of the *Central Company Directory* (DIRCE) produced by the National Statistics Institute, despite being limited to the period between 1994 and 2000, allows us to work out the most relevant keys to the business demographics of Spanish manufacturing[21].

The DIRCE is a source that covers practically all activity in Spain, with the exception of agricultural and public companies. Its data is highly reliable and the information is up to date. One of the main advantages of the DIRCE is the thoroughness with which data is collected. By using such sources as tax declarations, customs records, and Social Security payment centres, it covers the whole range of business activities in all sectors of the economy, except agriculture.

In order to appreciate the exhaustiveness of its information we can look at the total company population registered by the DIRCE in 2000. During the year the DIRCE registered 2,594,886 active firms, 344,432 new companies and 269,070 closures[22]. In this study we limit our field of analysis to manufacturing industries at two-digit standard industrial classification (SIC) level. The energy industry, construction, services, and publicly owned companies remain outside our area of study. We also exclude firms with no salaried employees, as these correspond more to self-employment strategies than to the creation of new firms.

For the 1994 contingent of industrial firms we have information on the initial size of the company, the sector in which it is active, the changes in size, and the closures that took place during the first five years of the firms' lives.

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[20] Industrial Economy research projects have, in the past, resorted to various statistical sources to study market dynamics. Case studies, cross-section data, data panels with individual and temporal data and, finally, longitudinal data on agents participating in a specific market. The data source used in this study would fall within these latter categories. The availability of individual information over long periods of time, not at the moment the case of the DIRCE, facilitates the study of a complete market history (Gerosky and Mata, 2001).

[21] The DIRCE is the first database of business demography in the Spanish economy that, like the census bureaus available in other countries, keeps an exhaustive record of Spanish companies. The basic unit of the DIRCE is the company, which is defined as an organization subject to a governing authority, which may be, depending on the case, a physical person, a legal entity, or a combination of both, and constituted with the aim of operating in one or several areas of the production of goods and services.

[22] Registrations or de-registrations do not correspond exactly to the creation or dissolution of firms. Registrations record the birth of a new entrepreneurial project, as well as the resumption of an interrupted activity, the merger or takeover of companies, or the registration of companies not detected until that time. De-registrations could correspond to firm closures, but also to changes in activity and the merger or takeover of companies.

We have divided the industrial sectors according to a double criterion. In the first place, we have divided the life cycle into three phases according to the market turnover (entries and exits) in each industry. The identification of each stage in prior studies is basically done by looking at the Net Entry Rate itself[23]. In the second place, we have classified the industries according to their technological level as measured by R&D expenditures. This second classification criterion allows us to identify those high technology industries with the enterprising regime and the rest of the branches of industry with routinized regimes[24].

The classification of the industrial sectors according to the life cycle in which they find themselves follows the proposal put forward by Gort and Klepper (1982) and Agarwal and Gort (1996). These works determine industry life cycles according to the results of Net Entry Rates (Gross Entry Rates less Gross Exit Rates). When the Net Entry Rate is positive, markets in their initial stages predominate, whereas when the Net Entry rate is negative, there is a predomination of mature markets. If we adapt this classification criterion to our data, we can divide the industrial branches into three life cycle stages depending on the levels of entry and exit flows.

Empirical life cycle studies often adopt the market for a specific product as a unit of analysis and not the economic sector, which has a more heterogeneous nature. Such studies gain in precision by circumscribing their analysis to a group of goods and to the behaviour of the firms that produce those goods. However, owing to the nature of our data base, in this study we take as our unit of analysis the economic sector to a considerable level of aggregation, which means we lose in precision but gain in area of study, as we cover all branches of industry.

During the 1994-2000 period, the flow of firm entries and exits shows a trajectory in line with the cyclical profile of the Spanish economy. The entries maintain a stable rate between 1994 and 1998 and the exits decrease during the expansive phase of the cycle, particularly between 1996 and 1999. The Net Entry Rates show a clear negative tendency during 1994 and 1995 and a notable positive trend between 1996 and 1998. In 1999 there is a slight negative result due to the drop in entries.

Table A-1
Manufacturing entry and exit rates

	1994	1995	1996	1997	1998	1999	2000
Gross Entry Rate	8,21	8,96	7,41	7,73	8,15	6,39	5,97
Gross Exit Rate	10,61	9,61	6,5	5,82	6,61	6,5	6,51
Net Entry Rate	-2,39	-0,64	0,91	1,91	1,54	-0,11	-0,55

Note: The gross entry and exit rates are the arithmetical average of the sectorial rates.
Source: Central Company Directory

[23] See Utterback and Suárez (1991).
[24] All firms are classified at two-digit standard industrial classification (SIC) level. The distribution of industries according to the life cycle phase and the technological level is shown in Table A-3.

The life cycle phase of the industrial branches depends on the result of the firm entry and exit flows. Thus, industries in which entries clearly predominate over exits are in the first stage of their life cycle, whereas industries with more exits than entries are in the final or mature stage.

The DIRCE offers seven Net Entry Rates for each sector between 1994 and 2000, i.e. X_{94}, X_{95},…, X_{00}.[25] Between 1994 and 2000 we can distinguish two sub-periods: in the first (1994-1997) there are more exits than entries and in the second (1998-2000) we see a recovery in entries and a drop in exits.

The average Net Entry Rate for each industry in the two sub-periods mentioned is determined by the following expressions. For each j = 1,2,…,n we computed,

$$X_1(j)=\sum_{t=94}^{97}\frac{X_t}{4} \qquad \text{and} \qquad X_2(j)=\sum_{t=98}^{00}\frac{X_t}{3}$$

where $X_1(j)$ and $X_2(j)$ are the mean of the Net Entry Rates for each industry in 1994-1997 and 1998-2000. One industry is classified in the formative stage if,

$$X_1(j) > \mu_1 \qquad \text{and} \qquad X_2(j) > \mu_2$$

where μ_1 y μ_2 are, respectively, the mean Net Entry Rates for the manufacturing group in 1994-1997 and 1998-2000.

One industry is in the intermediate phase of the industrial life cycle if,

$$X_1(j) > \mu_1 \qquad \text{and} \qquad X_2(j) \le \mu_2$$

Finally, an industry is in the mature phase of the industry life cycle when the net entry rate reaches lower values than that of manufacturing in the second or both periods.

Moreover, we classify industries according to their technological level – high, medium or low, according to the R&D spending of the incumbent firms in 1998. The data on R&D spending is taken from the *Technological Innovation Survey* carried out by the National Statistics Institute. In the high technology sectors, spending on R&D is above 3% of the Gross Value Added; for medium technology sectors R&D spending is between 1% and 3% of the Gross Value Added, and finally, for low technology sectors R&D spending is less than 1%[26].

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[25] A greater temporal cover by the database and a greater sectorial disintegration would have allowed the distinguishing of a larger number of phases. See for example Gort and Klepper (1982).

[26] Mature industries (second and third phases of the life cycle) should not be identified with low technology industries. In mature industries there is a predomination of process innovation over product innovation, although there may be an intense amount of innovation. See McGahan and Silverman (2001) for more on innovation in firms in mature industries.

STATISTICAL ANNEXES

Table 1A
Survival rates by start-up size and life cycle

Time	Size (1-2)	Size (3-5)	Size (6-9)	Size (10-19)	Size (20-49)	Size (50 +)	All
	Initial Stage						
After 1 year	0,8397	0,9030	0,9126	0,9249	0,8954	0,9000	0,8733
After 2 years	0,7315	0,7751	0,8109	0,8039	0,8170	0,8500	0,7609
After 3 years	0,6322	0,6888	0,7307	0,7264	0,7255	0,8000	0,6694
After 4 years	0,5749	0,6350	0,6791	0,6659	0,6536	0,7750	0,6134
After 5 years	0,5332	0,5970	0,6461	0,6029	0,6144	0,7000	0,5721
After 6 years	0,4888	0,5649	0,6175	0,5714	0,5817	0,6750	0,5343
Firms	2.950	1.556	698	413	153	40	5.810
	Mature Stage						
Time	**Size (1-2)**	**Size (3-5)**	**Size (6-9)**	**Size (10-19)**	**Size (20-49)**	**Size (50 +)**	**All**
After 1 year	0,8260	0,8822	0,9138	0,9021	0,8805	0,9661	0,8627
After 2 years	0,7065	0,7612	0,7580	0,7706	0,7679	0,8983	0,7377
After 3 years	0,5990	0,6451	0,6773	0,6476	0,6655	0,8136	0,6302
After 4 years	0,5388	0,5883	0,6066	0,5846	0,5939	0,7119	0,5685
After 5 years	0,4975	0,5487	0,5348	0,4769	0,5324	0,6441	0,5161
After 6 years	0,4633	0,5128	0,4972	0,4434	0,4949	0,5932	0,4808
Firms	3.339	1.868	905	715	293	59	7.179

Source: National Statistics Institute Company Directory

Table 2A
Survival rates by start-up size and technological regime

Time	Size (1-2)	Size (3-5)	Size (6-9)	Size (10-19)	Size (20-49)	Size (50 +)	All
	High technological level						
After 1 year	0,7717	0,9042	0,8391	0,8462	0,8421	0,8333	0,8240
After 2 years	0,6881	0,7665	0,7586	0,7308	0,8421	0,8333	0,7274
After 3 years	0,5531	0,5928	0,6667	0,6154	0,7368	0,5000	0,5888
After 4 years	0,5016	0,5868	0,6437	0,5962	0,6842	0,5000	0,5561
After 5 years	0,4630	0,5569	0,5977	0,5577	0,6842	0,3333	0,5187
After 6 years	0,4373	0,5269	0,5402	0,5385	0,6316	0,3333	0,4875
Firms	311	167	87	52	19	6	642
	Low and medium technological level						
Time	**Size (1-2)**	**Size (3-5)**	**Size (6-9)**	**Size (10-19)**	**Size (20-49)**	**Size (50 +)**	**All**
After 1 year	0,8356	0,8910	0,9175	0,9136	0,8876	0,9462	0,8697
After 2 years	0,7198	0,7676	0,7823	0,7853	0,7822	0,8817	0,7492
After 3 years	0,6178	0,6684	0,7025	0,6794	0,6838	0,8280	0,6508
After 4 years	0,5585	0,6107	0,6379	0,6152	0,6112	0,7527	0,5903
After 5 years	0,5169	0,5714	0,5825	0,5214	0,5550	0,6882	0,5423
After 6 years	0,4772	0,5370	0,5501	0,4879	0,5199	0,6452	0,5056
Firms	5.978	3.257	1.516	1.076	427	93	12.347

Source: National Statistics Institute Company Directory

Table A-3
Industry life cycle and technological regimes
CNAE Divisions

CNAE Division	Manufacturing industries	Life -Cycle Phase	Technological Level	1994 Entries
15	Food and drink product industry	third	low	1461
16	Tobacco industry	third	medium	4
17	Textile industry	second	low	564
18	Garment and fur trade industry	third	low	880
19	Leather preparation, tanning & finishing	third	low	701
20	Timber industry, excluding furniture	second	low	1365
21	Paper industry	first	low	120
22	Publishing, graphic arts and reproduction	first	low	1025
23	Coke production, petroleum and nuclear fuels	third	low	1
24	Chemical industry	second	high	216
25	Rubber and plastic products	first	medium	356
26	Other non-metallic mineral products	second	low	702
27	Metallurgy	third	medium	106
28	Metallic products, excluding machinery	first	low	2517
29	Machinery and mechanical equipment	first	medium	633
30	Office machinery and computer equipment	first	high	41
31	Electrical machinery and material	third	medium	323
32	Electronic material; television and communications	first	high	71
33	Medical, optical and watch-making instruments	first	high	165
34	Motor vehicles, trailers and semi-trailers	first	medium	132
35	Other transport material	first	high	140
36	Furniture making and other manufacturing	third	low	1365

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