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**JUAN A. MAÑEZ**
**MARÍA E. ROCHINA-BARRACHINA**
**AMPARO SANCHIS-LLOPIS**
**JUAN A. SANCHIS-LLOPIS**

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# THE ROLE OF LEARNING IN FIRM R&D PERSISTENCE

Juan A. Mañez*
María E. Rochina-Barrachina*
Amparo Sanchis-Llopis*
Juan A. Sanchis-Llopis*

## Abstract

This paper analyses the role of learning in the persistence of the firms' decision to perform R&D activities using firm level panel data. We estimate discrete time proportional hazard models accounting both for firm observed and unobserved heterogeneity. The data used is a panel of Spanish manufacturing firms drawn from the *Encuesta sobre Estrategias Empresariales*, for the period 1990-2000. After controlling for other firm and industry characteristics that might have an effect on firm persistence in R&D activities, we find that learning from R&D performance affects persistence in R&D activities.

*Key words:* R&D activities; persistence; learning, discrete time survival models.
*JEL classification:* C41, L60, O31.

Corresponding author: Juan A. Máñez-Castillejo, Universitat de València and *ERI-CES*, Departamento de Economía Aplicada II, Avda. dels Tarongers s/n, 46022 Valencia, Spain. Telephone: 00 34 963828356; fax: 00 34 963828354.
E-mail address: jamc@uv.es

* Universitat de València and *ERI-CES*

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## 1. INTRODUCTION.

There is a growing literature on the analysis of innovation persistence at the firm level. However, most of these studies focus on the output side of innovation, that is, on the persistence in the achievement of innovation results, such as patents or product innovations (see, among others, Geroski *et al*., 1997; Crepón and Duguet, 1997; Malerba and Orsenigo, 1999; Cefis and Orsenigo, 2001; Raymond *et al*., 2006; or Roper and Hewitt-Dundas, 2008). The analysis of innovation persistence from an input point of view is still scarce. To the best of our knowledge, only Mañez *et al*. (2009), for Spanish manufacturing, and Peters (2009) for German firms, analyse persistence in the realization of R&D activities. However, they do not explicitly analyse how learning from R&D performance may affect firms R&D persistence.

Therefore, in this paper we attempt to fill this gap by testing the role of learning in explaining the persistence of firms in the performance of R&D activities. For this purpose, we use duration model techniques to analyze the determinants of the length of a period of uninterrupted realization of R&D activities (which we will call *R&D spell*, henceforth), focusing on the role of learning. We use a representative sample of Spanish manufacturing firms for the period 1990 to 2000. The dataset is drawn from the *Encuesta sobre Estrategias Empresariales* (ESEE, henceforth), a survey carried out annually since 1990 that provides detailed information at the firm level.

In our empirical analysis we implement discrete time proportional hazard models that aim at capturing the particular nature of the dataset. The estimation method allows for a fully non-parametric specification of the baseline hazard function, permitting a full identification of the effect of survival time (number of years of R&D performance) on the duration of R&D spells. In addition, the estimation method allows controlling for R&D spell heterogeneity (both parametrically and non-parametrically), which contributes to a robust test for the presence of unobserved individual heterogeneity.

The contribution of this paper to the literature on innovation persistence is that this is the first attempt to disentangle how learning from R&D performance may affect firms R&D persistence using survival methods. To the best of our knowledge, both Geroski *et al*. (1997), and Le Bas *et al*. (2003) use survival analysis to investigate innovation persistence, but their focus is on the persistence in obtaining patents and/or major innovations. By contrast, our paper investigates innovation persistence from an input point of view using survival methods, and in particular, the role of learning in the firms' persistence to invest in R&D activities. Both Mañez *et al*. (2009) and Peters (2009) use dynamic discrete choice models to analyse persistence in the performance of R&D activities, but they are not focused on the effects of learning in firm R&D persistence.

To anticipate our results, our findings give support to the existence of a learning effect in the performance of R&D activities. In particular, we obtain that firms with high R&D capital enjoy longer R&D spells (periods of uninterrupted performance of R&D activities), which may be considered as a learning effect, and also that this learning effect only emerges beyond a threshold level of R&D capital accumulation. Further, we also find evidence that the probability that the R&D spell comes to an end decreases with the duration of the spell, that is, our data exhibit *negative duration dependence*. These results could be capturing dynamic effects (a sort of learning innovation curve) within the R&D spell, and they could also be considered as providing evidence of learning-by-doing and learning-to learn effects in R&D activities (Rosenberg, 1976, Nelson and Winter, 1982). They may also be considered as giving support to industry dynamic models where the main source of dynamics arises from firm *active learning* (e.g. Ericson and Pakes, 1995). Finally, we obtain that unobserved heterogeneity is important, probably indicating that persistence is also linked to firm unobserved heterogeneity. This result is consistent with industry dynamic models of *passive learning* (Jovanovic, 1982), in which dynamics is driven by inherent and fairly constant characteristics of the firm (natural endowments, managerial abilities, etc.).

Our findings also contribute to the understanding of the nature and determinants of firms' persistence in the performance on innovative activities. By identifying those factors that increase the propensity of firms to perform R&D activities over a long period of time, we may suggest policy measures to strength firm incentives to undertake innovation activities in a continuous way. From a policy point of view, if persistence in R&D activities is desirable given that it renders higher innovation returns (see, for instance, Beneito *et al*., 2007), policy makers should devote resources to those firms with a higher probability to continue performing R&D, rather than to merely reduce entry costs in these activities indiscriminately. Making public policy more effective is at least in part a matter of targeting activities that may display "dynamic economies of scale", such as R&D activities. To initiate R&D activities is costly and a portion of the investment is irrecoverable in the event of exit. Given that resources are scarce, it is important to make sure that resources are efficiently allocated to "survival-winners". These are relevant considerations to inform R&D-led policies. Thus, non-selective policies aimed at either fostering firms' efforts to start investing in R&D or reducing entry barriers into this activity may be a waste of resources, as some entrants could turn out to be ill-suited to survive in the performance of these activities.

The rest of the paper is organised as follows. Section 2 briefly describes the theoretical framework to explain persistence in innovation activities and establishes our working hypothesis. Section 3 presents the data and section 4 is devoted to the description of the methodology used. Section 5 reports the results, and finally, section 6 concludes.

## 2. THEORETICAL FRAMEWORK AND WORKING HYPOTHESIS.

From a theoretical point of view, there are three approaches suggesting why firm R&D behaviour should exhibit persistence. In what follows we describe these approaches and discuss those factors related to firm and industry characteristics which are likely to affect firms R&D persistence, that is, the duration of firms R&D spells, and establish a number of hypotheses about their expected effects.

### *a) Learning effects.*

The first approach to innovation persistence considers that the cumulative nature of the learning process (Rosenberg, 1976; Nelson and Winter, 1982) may cause persistence: the generation of knowledge is based on previous knowledge and affects future research. Learning-by-doing and learning-to-learn effects may derive from the accumulation of innovation effort and knowledge, so that research today generates new opportunities to research tomorrow. The importance of knowledge accumulation in explaining innovation has been developed by the evolutionary theory approach (Nelson and Winter, 1982). This stream of literature considers that innovations are the result of a process of accumulation of firms' specific competencies (Rosenberg, 1976). In particular, by investing in R&D, firms develop abilities in the form of knowledge, both scientific and informal know how, that may be used to develop further innovations at consecutive times. According to this view, firms benefit from dynamic increasing returns in the form of learning-by-doing, learning-to-learn or scope economies in the production of innovations (Cohen and Levinthal, 1989). The existence of dynamic economies of scale is also consistent with industry dynamic models of active learning (Ericson and Pakes, 1995; Pakes and Ericson, 1998). According to these models, firms learn from their experience and knowledge accumulation and so their abilities to survive in a market (in our case, to perform R&D activities) improve as both time and investments go by.

In order to account for the existence of a learning effect in the performance of R&D activities we follow two approaches. First, the cumulative process of R&D knowledge is usually measured by the effect of the R&D capital stock, which captures technical skills and learning-by-doing accumulated through past R&D investments. The usual approach followed in the literature has been the “knowledge capital” model of Grilliches (1979). According to this model, we may expect that firms with high R&D capital will experience longer periods of uninterrupted performance of R&D activities. Thus, we can use the effect of R&D capital on the R&D spell length as a way to test for the existence of a learning effect in the performance of R&D activities.

Secondly, we may also consider the existence of a learning effect by analysing the relationship between the duration of the R&D spell and the probability that the R&D spell will end at time *j*, that is, by measuring the pattern of "duration dependence" in the performance of R&D activities. Since firms perform R&D activities during the spell, "negative duration dependence" captures dynamic effects generated within the R&D spell (a sort of innovation learning curve). Thus, we expect that the probability that the R&D spell will end at some given time falls as the length of the spell raises. In order to control for this effect, we use survival methods allowing for the estimation of the patterns of duration dependence.

In light of the above discussion, we test for the presence of a learning effect in the performance of R&D activities using the following two hypotheses:

*Hypothesis 1: Firms with high R&D capital endure longer R&D spells, that is, longer periods of uninterrupted performance of R&D activities.*[1]

*Hypothesis 2: R&D spells exhibit "negative duration dependence", that is, the probability that the R&D spell ends decreases with the duration of the spell.*

*b) Success-breeds-success.*

The second approach to innovation persistence argues that R&D persistence is the result of a "success-breeds-success" process: innovative success generates profits that may be reinvested in future R&D activities (Mansfield, 1968, Stoneman, 1983). According to this theory, firm innovation success raises firms' internal funds that can be used to finance further innovations, enhancing firms' incentives to invest in R&D activities. Alternatively, innovation success may be considered as broadening firm technological opportunities of innovations and so inducing more innovation activities in the future (Flaig and Stadler, 1994, 1998). In order to capture firm innovation success we use firm innovation results. Thus, we hypothesize that

*Hypothesis 3: Previous innovation success enhances the duration of R&D spells.*

Furthermore, the ability of firms to convert innovation results into new funds depends on the extent to which the results from R&D activities can be appropriated by the firm or easily diffused within or across industries. Thus, we will control for firm appropriability conditions in our empirical specification. The higher the degree of appropriability of the innovation output, the higher will be the incentives to invest in R&D (Levin *et al*., 1987; and Levin, 1988). Therefore, we formulate our next hypothesis as

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[1] We calculate R&D capital from firms R&D investments following the historical or perpetual inventory method (Griliches, 1979). See Table A1 in the Appendix for a definition of the variables used in our empirical analysis.

*Hypothesis 4: The better the appropriability conditions of the innovation results, the longer the expected duration of the R&D spell.*

*c) Sunk R&D costs.*

Thirdly, R&D persistence may also result from the existence of sunk costs associated with the performance of R&D activities (Sutton, 1991, Máñez *et al*., 2009). When firms decide to perform R&D activities, they have to incur set up costs related to the establishment of an R&D department, the purchasing of specific assets, and/or the hiring and training of specialized workforce. These fixed costs may be considered sunk since they are usually not recoverable, and represent a barrier to both entry into and exit from R&D activities, causing persistence. On the one hand, sunk costs may prevent some firms from starting to perform R&D activities since, unlike firms already performing R&D activities, they have to consider these costs when determining their prices. On the other hand, sunk costs are a barrier to exit from R&D activities because they are not recovered should the firm decide to end the performance of these activities.

In order to control for the role of sunk costs in R&D persistence we use a number of variables relating to the technological regime of the industry where the firm operates, firm size, number of R&D employees, and nature of the R&D activities undertaken by the firm. Sunk R&D costs are expected to be industry dependent. On the one hand, they are determined by the complexity of the production processes, product characteristics, and the nature of the underlying technology (Sutton, 1991; Åstebro, 2002, 2004). On the other hand, they are also expected to be higher in high-tech industries, as in these industries the evolution of market structure depends, to a greater extent, on the pattern of technological change (Sutton, 1991). To account for the technological regime of the industry in which the firm operates we classify industries as Low-tech, Med-tech and High-tech.[2] This industry classification may also capture differences in technological opportunities for converting research resources into new products or better production techniques.

Furthermore, in industries where there is competition through escalation in R&D investments, small firms need to sustain high R&D intensity ratios (R&D expenditures over sales) to cope with high levels of R&D expenditures by large competitors. When this escalation mechanism is intense, small firms might be unable to maintain high enough R&D investments due to eroded profits. Accordingly, sunk R&D costs within a given industry might be higher for large firms as these firms incur high R&D expenditures.

Máñez *et al.* (2009) find that large firms and/or firms operating in high-tech industries have significantly higher sunk R&D costs as compared to small firms and/or firms in low and med-tech industries.

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[2] The technological intensity classification is presented in Table A2 in the Appendix.

Both the previous considerations and the empirical results in Máñez *et al.* (2009) lead us to the next two hypotheses:

*Hypothesis 5: To the extent that R&D sunk costs are higher in high-tech industries, we expect firms operating in these industries to exhibit longer R&D spells.*

*Hypothesis 6: As large firms incur larger sunk R&D costs, as compared to small ones, they should show higher persistence in R&D activities.*

Finally, we also consider two other factors that may be capturing the extent of sunk costs incurred by firms when undertaking R&D (Cohen and Klepper, 1996). The first captures the way in which the firm organizes its R&D activities. Firms may perform R&D activities internally within the firm, or they may contract these activities externally. Since internal R&D activities involve both higher set up costs and effort than contracting them externally, we expect internal R&D activities (as compared to external R&D) to affect positively to the duration of the R&D spell. The second factor accounts for the number of R&D employees in the firm, which is also expected to be positively related to R&D sunk costs. Thus, we hypothesize that

*Hypothesis 7: Those firms performing internal R&D activities endure longer R&D spells.*

*Hypothesis 8: Those firms with high R&D employment show higher persistence in R&D activities.*

### *d) Other controls.*

Finally, we include some controls that could have an impact on the duration of R&D spells. They relate to market competition, business cycle and firm unobservable characteristics.

### *Market competition.*

Regarding market competition conditions, the literature on industrial organization remains controversial on whether market power encourages or inhibits firms from undertaking R&D activities. According to Schumpeter (1942), *ex ante* market power generates financial means to innovate and reduces risk levels. However, following Arrow (1962), the incentives to innovate are higher in competitive markets because the expected incremental rents from innovating are higher as compared to monopoly conditions.

There is empirical evidence on the existence of an inverted U-shaped relationship between competition and innovation, so that the incentives to innovate are higher when market competition is neither too low nor too high (see, e.g. Scherer, 1967; or more recently, Aghion *et al.,* 2004, and references therein). In order to capture the degree of product market competition, we use two variables, namely, a variable capturing whether the firm enjoys a significant market share, and a variable indicating whether the firm exports. We consider that exporting firms may need to innovate to face a higher competitive pressure in international markets (Kleinschmidt and Cooper, 1990; Kotable, 1990). In addition, according to Cohen and Levinnthal (1989), foreign markets may facilitate the transfer of technology and so stimulate firms R&D activities.

*Business cycle.*

We include time-specific effects in order to capture macro-level changes in R&D conditions and institutional factors that are common across firms, such as R&D policy variations, the business cycle, credit-market conditions, etc.

*Firm individual unobserved heterogeneity.*

The decision to persistently undertake R&D activities is also associated with unobservable firm internal capabilities. To account for unobservable characteristics, in our estimation model we control for unobserved heterogeneity, which is expected to be caused by factors such as firm organisational capabilities or managerial ability.

## 3. THE DATA.

The data have been drawn from the ESEE, an annual survey of Spanish manufacturing firms sponsored by the Ministry of Industry and carried out since 1990. The ESEE is a representative sample of the population of Spanish manufacturing firms classified by industry and size that provides information at the firm level.[3]

The unit of observation in this study is the R&D spell. We define an R&D spell as the uninterrupted realization of R&D activities for a given number of consecutive years. A spell is considered as starting in year *j* if the firm did not undertake any R&D activity in year *j-1* but it undertakes R&D activities in year *j*. Analogously, a spell is computed to end in year *T* when this is the first year in which the firm declares not carrying out R&D activities after one or more consecutive years of R&D activities performance. Thus, in this paper, persistence in innovative behaviour is measured by the extent firms are continuously engaged in R&D activities, so that the length of the R&D spell captures the persistence in R&D activities.

Some features of this dataset make it suitable to examine the factors driving firms' persistence in the performance of R&D activities using survival methods. First, it is comprised by a representative sample of the population of Spanish manufacturing firms classified by industry and size categories. Some of the firms in the sample declare to undertake R&D activities the first year they are sampled, so that we do not know whether this year is the starting year of their R&D spell, or whether this spell started some previous

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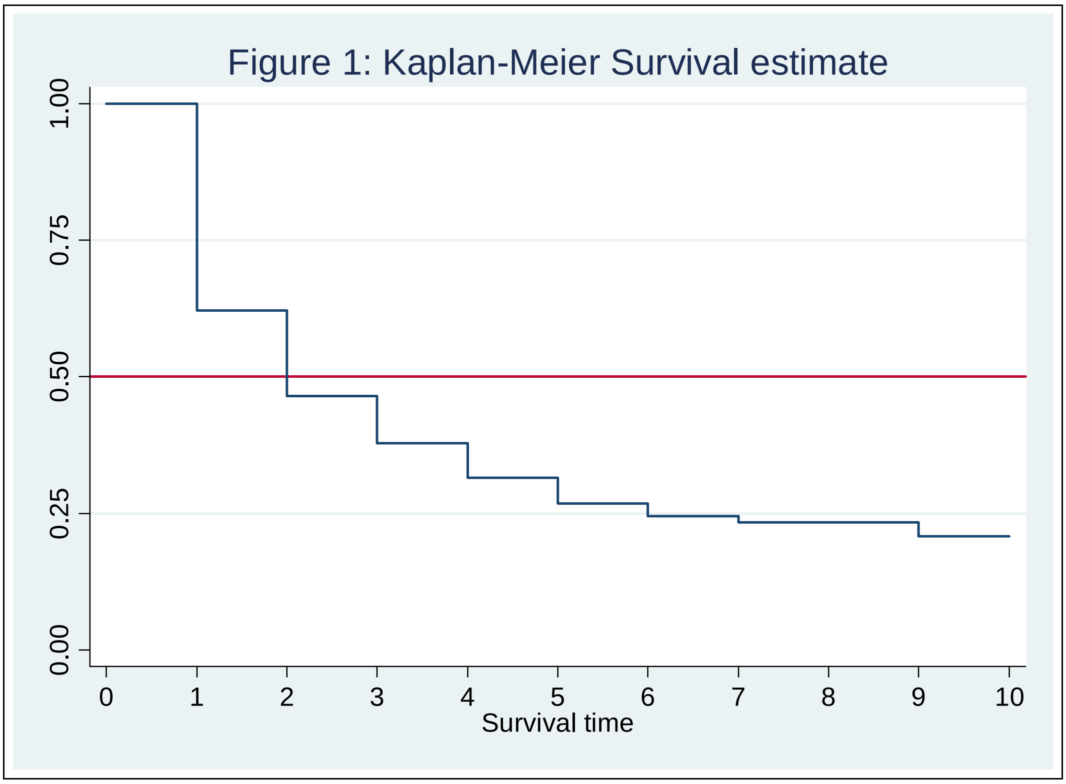
[3] See http://www.funep.es/esee/en/einfo_que_es.asp for details.

year. Should we have included these spells in the analysis we would incur a problem of left-censoring that would lead us to underestimate the duration of the R&D spells. To avoid this problem of left-censoring, we only include in the analysis those R&D spells for which we have information on the starting year of the spell. Therefore, as we do not consider spells already going on in 1990, the first R&D spells in our sample begin in 1991.

Secondly, the ESEE provides broad information on characteristics at the firm level on a yearly basis, which may help to unravel the factors driving the length of R&D spells. Thirdly, this survey also allows identifying firms that perform R&D activities in a continuous way, abandon these activities or stop answering the survey during the *observation window* (1990-2000). We exclude from the analysis those R&D spells corresponding to firms that exit the survey during the observation window. Given that the end of these spells could be due to firm failure, their consideration could bias the results of our analysis.

Our final sample is composed of 1296 observations corresponding to 481 R&D spells. These 481 R&D spells correspond to 383 firms. Out of these firms, 295 firms (77%) experience only one R&D spell, 78 firms (20%) undergo two R&D spells and 10 firms (3%) show three R&D spells. Mean durations of R&D spells decrease with the number of spells by firm, given that the period of analysis is ten years. Thus, whereas mean spell duration for firms with one R&D spell is four years, for firms with two or three R&D spells it is two years. In our sample, 48% of the R&D spells ended during the sample period. The mean and median duration of these spells are 4.57 and 3 years, respectively. Moreover, the non-parametric estimate of the survival function, using the Kaplan-Meier estimator, shows that 50% of the R&D spells last more than 3 years, and that at least 27% of them persist more than 10 years (see Figure 1 below).



Descriptive statistics of our sample are reported in Table 1. As one of our main interest lies on the effects of R&D capital on the length of R&D spells, we classify R&D spells according to the level of R&D capital of the firm (*Low*, *Med-low*, *Med-high*, *High*).[4] Table 1 reports the average value of the continuous variables and the percentage of ones for the dummy variables used in our analysis as determinants of the duration of R&D spells, both for the overall sample and for each of the four categories in which we classify R&D spells according to the level of R&D capital. Tests on the comparison across different categories of spells using one-way analysis of variance are also provided (see the last two columns of Table 1). Firms with *High R&D* capital spells are significantly larger and hire more R&D workers than firms with lower levels of R&D capital. Further, the proportion of firms that obtain innovations (either process or product innovations, or patents) and perform internal R&D significantly increases with the level of R&D capital. As for the exporting status, the probability of exporting increases with the level of R&D capital. Further, the proportion of firms that have a significant market share in its main market also increases with the level of R&D capital.

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[4] See Table A1 in the Appendix for the definition of the four categories of R&D capital.

**Table 1: Descriptive statistics by R&D capital levels.**

| | Average Values | | | | | One-way analysis of variance (by R&D capital) | |
|---|---|---|---|---|---|---|---|
| ***Continuous variables*** | **Total Sample** | **Low R&D capital** | **Med-Low R&D capital** | **Med-High R&D capital** | **High R&D capital** | **Statistic** | ***p*-value** |
| Appropriability | 0.63 | 0.59 | 0.64 | 0.65 | 0.62 | 0.61 | 0.608 |
| Size | 226.58 | 70.52 | 119.54 | 190.27 | 538.52 | 41.38 | 0.000 |
| R&D employment | 2.93 | 0.81 | 1.43 | 2.94 | 6.68 | 50.10 | 0.000 |
| | **Percentages** | | | | | **One-way analysis of variance (by R&D capital)** | |
| ***Dummy variables*** | **Total Sample** | **Low R&D capital** | **Med-Low R&D capital** | **Med-High R&D capital** | **High R&D capital** | **Statistic** | ***p*-value** |
| Internal R&D | 0.768 | 0.671 | 0.768 | 0.818 | 0.823 | 9.55 | 0.000 |
| Innovation results | 0.674 | 0.597 | 0.647 | 0.713 | 0.743 | 6.58 | 0.000 |
| Low tech. Intensity industry | 0.509 | 0.582 | 0.511 | 0.538 | 0.399 | 8.07 | 0.000 |
| Medium tech. Intensity industry | 0.325 | 0.303 | 0.289 | 0.329 | 0.379 | 2.33 | 0.073 |
| High tech. Intensity industry | 0.166 | 0.115 | 0.200 | 0.132 | 0.221 | 6.34 | 0.000 |
| Market share | 0.602 | 0.413 | 0.618 | 0.664 | 0.726 | 26.90 | 0.000 |
| Exporter | 0.736 | 0.526 | 0.695 | 0.830 | 0.905 | 52.60 | 0.000 |

Notes:

1. Total sample, R&D capital categories: average for continuous variables and percentages for dummy variables.
2. In the last column we test the null hypothesis of equality of the mean values for the four R&D capital categories.

Regardless their level of R&D capital, most firms operate in *Low-tech intensity* industries. However, it should be noted that the percentage of *Med-high* and *High* R&D capital firms operating in *High-tech* industries is higher than that corresponding to the other two R&D capital categories. This suggests that the firm level of R&D capital and the technological intensity of the industry in which the firm operates might be positively correlated.

## 4. EMPIRICAL APPROACH.

Our empirical analysis is carried out using survival methods, which are appropriate to analyse the determinants of the duration of R&D spells (which we will refer to as spell survival, following the terminology of these methods). First, these methods take into account the evolution of the exit risk (in our case, the probability that the R&D spell ends) and its determinants over time since they control both for the occurrence and the timing of exit. Secondly, survival methods are appropriate in the presence of right censoring, that is, when we only know that the R&D spell has survived at least up to a given period $j$ (some R&D spells have not finished by the end of the *observation window*, i.e. they are still in operation). Thirdly, these methods can easily accommodate time-varying covariates, which is a desirable feature given that the probability of survival of R&D spells may vary over time as the firm environment changes.

In order to examine the determinants of the duration of R&D spells we use two different methodologies. First, we examine the influence of explanatory variables individually by carrying out non-parametric log-rank tests of the null hypothesis of equality of survival functions across the $r$-groups in which R&D spells are classified according to the $r$-values of each covariate. These tests are extensions of non-parametric rank tests used to compare two or more distributions for censored data. Under the null hypothesis there is no difference in the survival rates for each of the $r$-groups at any failure times (spell endings), and this statistic distributes as a $\chi^2$ with $r$-1 degrees of freedom. 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 (spell endings) for each of the $r$-groups. Given that one of our focuses is to disentangle the effects of R&D capital, we perform the above tests for different categories of spells according to their level of R&D capital.

Secondly, we undertake a multivariate analysis in order to evaluate the effect of each explanatory variable on the hazard rate (risk of R&D spell ending) controlling for the effect of other covariates. In particular, we implement discrete time proportional hazard models in which the duration of R&D spells is treated as a discrete variable, not because it is intrinsically discrete but because data are available on a yearly basis (interval-censored data). Although the underlying transition process between performing and not performing R&D activities may happen in a continuous way, we only observe these transitions on a yearly basis. The estimation methods allow for a fully non parametric specification of the baseline hazard and to control for R&D spells unobserved heterogeneity (both parametrically and non-parametrically), which helps to fully identify the effects of survival time on R&D duration (duration dependence).[5]

Time intervals in our dataset are of one year. Thus, the interval boundaries are the positive integers *j=1, 2, 3, 4,…,* and the interval *j* is $(j-1, j]$. An R&D spell *i* can either be complete ($c_i = 1$) or right censored ($c_i = 0$). A censored R&D spell *i* with length *j* intervals contributes to the likelihood function with the discrete time survivor function (the probability of survival up to the end of interval *j*):

$$S_i(j) = \Pr(T_i > j) = \prod_{k=1}^{j}(1 - h_{ik}), \tag{1}$$

where $T_i = \min\{T_i^*, C_i^*\}$, and $T_i^*$ is some latent failure time and $C_i^*$ some latent censoring time for spell *i* ; and, $h_{ik} = \Pr(k-1 < T_i \leq k \mid T_i > k-1)$ is the discrete hazard (the probability that spell *i* ends in interval *k* conditional on the probability of surviving up to the beginning of this interval). A complete spell *i* in the *j*-interval contributes to the likelihood with the discrete time density function (the probability of ending the spell within the *j* interval):

$$f_i(j) = \Pr(j-1 < T_i \leq j) = S(j-1) - S(j) = \frac{h_{ij}}{1-h_{ij}}\prod_{k=1}^{j}(1 - h_{ik}). \tag{2}$$

Using expressions (1) and (2), the log likelihood function for the sample of spells is:

$$\log L = \sum_{i=1}^{n} c_i \log\left(\frac{h_{ij}}{1-h_{ij}}\right) + \sum_{i=1}^{n}\sum_{k=1}^{j}\log(1 - h_{ik}). \tag{3}$$

Allison (1987) and Jenkins (1995, 2004) show that (3) can be rewritten as the log likelihood function of a binary dependent variable, $y_{ik}$, with value one if spell *i* ends in year *k*, and zero otherwise:

$$\log L = \sum_{i=1}^{n}\sum_{k=1}^{j}\left[y_{ik}\log h_{ik} + (1 - y_{ik})\log(1 - h_{ik})\right]. \tag{4}$$

This allows to estimate discrete time hazard models by binary dependent variable methods and to incorporate time-varying covariates.

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

Following Prentice and Gloeckler (1978), we assume that $h_{ik}$ is distributed as a complementary log-log (*cloglog*) distribution to obtain the discrete time representation of an underlying continuous time proportional hazard:

$$
\begin{aligned}
c\log\log\left[1-h_j\left(x_{ij}\right)\right] \equiv \log\left(-\log\left[1-h_j\left(x_{ij}\right)\right]\right) = \beta_0 + x_{ij}\beta + \gamma_j \\
\Rightarrow h_j\left(x_{ij}\right) = 1-\exp\left[-\exp\left(\beta_0 + x_{ij}\beta + \gamma_j\right)\right],
\end{aligned}
\qquad (5)
$$

where $\gamma_j$ is the interval baseline hazard (a non-parametric specification that allows to test for a flexible type of duration dependence), and $x_{ij}$ are covariates which may be time-varying (although constant within intervals).

Incorporating unobserved heterogeneity, the *cloglog* model in (5) becomes

$$h_j\left(x_{ij}\right) = 1-\exp\left[-\exp\left(\beta_0 + x_{ij}\beta + \gamma_j + u_i\right)\right], \qquad (6)$$

where $u_i \equiv \ln\left(\nu_i\right)$, and $\nu_i$ originally enters the underlying continuous hazard function multiplicatively, $h\left(t,x_{it}\right) = h_0\left(t\right)\exp^{\beta_0 + x_{it}\beta}\cdot \nu_i$. Usually $\nu$ is assumed to be Gamma distributed with unit mean, and variance $\sigma^2$ to be estimated from the data (Meyer, 1990).

Alternatively, unobserved heterogeneity can be treated non-parametrically by assuming that there are several different types of individuals (or “mass-points” in the distribution of individual heterogeneity) so that each individual has associated probabilities to the different “mass-points” (Heckman and Singer, 1984). This implies different intercepts for the hazard function, each one for a different type. For instance, if a model with two types is assumed (type=1, 2), then the hazard becomes

$$h_{j,type}\left(x_{ij}\right) = 1-\exp\left[-\exp\left(m_{type} + \beta_0 + x_{ij}\beta + \gamma_j\right)\right]. \qquad (7)$$

The intercept for type-1 individuals is $\beta_0$ and for type-2 individuals it is equal to $m_{type2} + \beta_0$ (the “mass-point” for type-1 is normalized to zero).[6]

## 5. RESULTS.

In this section we present the main results. We first discuss the influence of the level of R&D capital on the duration of the R&D spell using a univariate test (i.e. log-rank test)

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[6] An up-to-date Stata program drawn up by S. Jenkins that implements the *cloglog* with gamma-distributed unobserved heterogeneity is available, using Stata, by typing *ssc install pgmhaz8*. An initial version of the program was presented in Jenkins (2001). Similarly, a Stata program elaborated by S. Jenkins that implements the *cloglog* model with non parametric unobserved heterogeneity is available by typing *ssc install hshaz* inside Stata.

introduced in the previous section. This descriptive evidence is completed with graphical evidence obtained through the non-parametric estimation (using the Kaplan-Meier estimator) of the survival functions corresponding to the different categories of spells classified by their level of R&D capital. Secondly, we present the log-rank tests of equality of survival functions across groups of firms classified by explanatory variables for each category of R&D capital. Finally, we discuss the results obtained in a multivariate duration analysis that accounts for the potential influence of various explanatory variables. Although we carried out the estimation three multivariate duration specifications (a specification that does not account for unobserved heterogeneity, a specification that accounts for unobserved heterogeneity assuming a gamma distribution and a specification that accounts for the unobserved component through mass points), our preferred specification is the model accounting for unobserved heterogeneity using mass points, since this model does not impose any parametric distribution to the unobserved heterogeneity

We start the presentation of our results, analysing through a log-rank test the influence of the level of R&D capital. The value obtained for this log-rank test (62.93 with *p*-value 0.000) suggests that the probability of the R&D spell survival (duration of the R&D spell) increases with the level of R&D capital. To this evidence we add a graphical study. Thus, Figure 2 shows the non-parametric estimation (using the Kaplan-Meier estimator) of the survival functions corresponding to the different categories of spells classified by their level of R&D capital. By inspection, the Kaplan-Meier survival functions are ordered according to R&D capital levels: the highest survival probabilities correspond to the *High R&D* capital spells, the lowest to the *Low R&D* capital group, and the corresponding to *Med-Low* and *Med-High* R&D capital spells show intermediate survival prospects. Therefore, the conclusion we can draw is that the length of R&D spells increases with the level of R&D capital. Although this result has been obtained without taking into account the effect of other variables that could affect the duration of R&D spells (that we will take into account if the multivariate duration analysis that we present below), it may be interpreted as a first piece of evidence in favour of a learning effect in the performance of R&D activities.

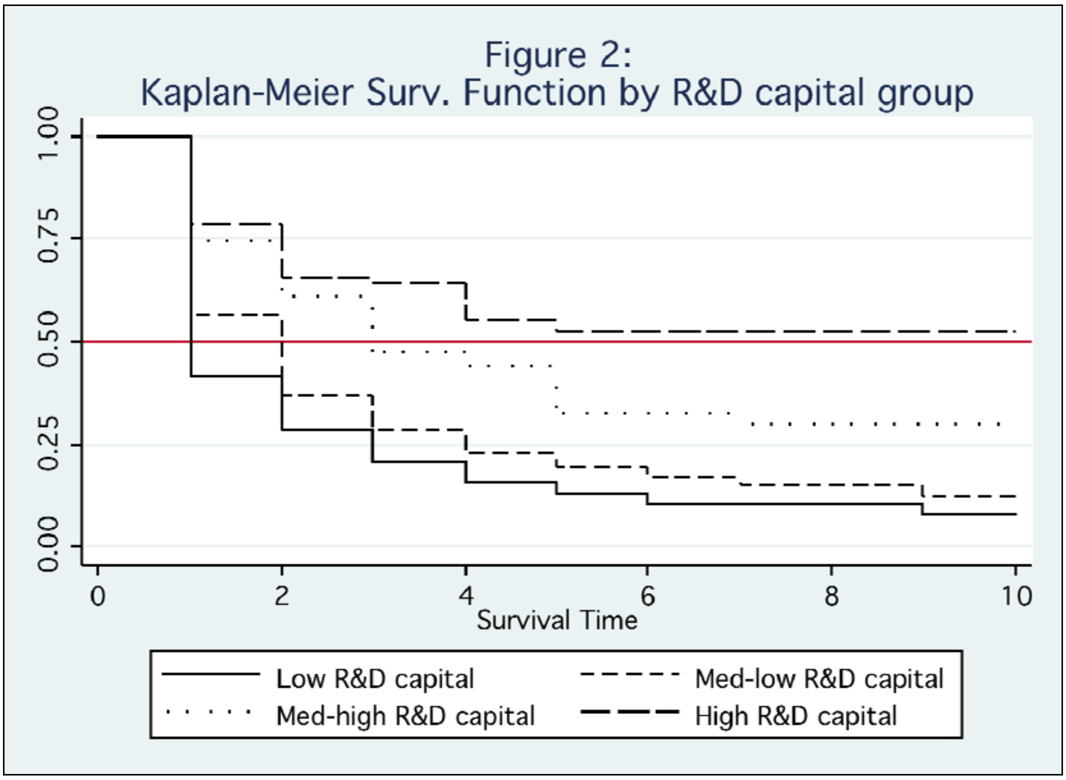

Figure 2:
Kaplan-Meier Surv. Function by R&D capital group

The second piece of evidence we present are the results of the log-rank test of equality of survival functions across groups of firms classified by explanatory variables (these tests are performed for each category of R&D capital).[7] This evidence is presented in Table 2. We obtain that among the *low R&D capital* spells the highest probability of survival corresponds to firms performing internal R&D. In the case of spells with *Med-Low R&D capital*, the best survival prospects correspond to firms that enjoy high appropriability conditions and declare to account for a significant market share in its main market. As for spells with *Med-High R&D capital*, those corresponding to firms with a large number of R&D employees and with a labour force between 200 and 500 employees enjoy the best survival prospects. Finally, those spells with *high R&D capital* corresponding to large firms (more than 500 workers), with a large number of R&D employees, performing internal R&D and serving both local and foreign markets enjoy the longest duration. In summary, the results of these tests suggest that the influence of most variables on the length of R&D spells is highly dependent on the level of R&D capital. Therefore, these results provide additional evidence on the role played by the firm R&D capital in explaining the duration of R&D spells.

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[7] In order to perform the non-parametric tests we split the continuous variables according to the criteria established in Table A1 in the Appendix. In order to rank each group by their survival probabilities we use the incidence rate defined as the ratio between the number of events (spell failures) and the total time at risk.

**Table 2: Non-parametric tests of equality of survival functions by explanatory variables, controlling for R&D capital group.**

| | Low R&D capital | | | Med-Low R&D capital | | | Med-High R&D capital | | | High R&D capital | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Log-rank | *p*-value | Higher surv. prob. | Log-rank | *p*-value | Higher surv. prob. | Log-rank | *p*-value | Higher surv. prob. | Log-rank | *p*-value | Higher surv. prob. |
| ***Continuous variables*** | | | | | | | | | | | | |
| Appropriability | 3.06 | 0.216 | -- | 4.93 | 0.085 | High appr. | 2.17 | 0.338 | -- | 0.73 | 0.693 | -- |
| Size | 1.76 | 0.881 | -- | 4.97 | 0.419 | -- | 9.25 | 0.099 | 200-500 | 12.76 | 0.026 | +500 |
| R&D employment | 0.87 | 0.648 | -- | 0.99 | 0.611 | -- | 4.70 | 0.095 | Third | 5.61 | 0.060 | Third |
| ***Dummy variables*** | | | | | | | | | | | | |
| Internal R&D | 3.11 | 0.077 | Int. R&D=1 | 0.28 | 0.593 | | 0.72 | 0.397 | | 6.73 | 0.009 | Int. R&D=1 |
| Innovation results | 0.88 | 0.348 | -- | 0.83 | 0.363 | -- | 1.28 | 0.257 | -- | 1.61 | 0.204 | -- |
| Industry. tech. int. | 0.11 | 0.945 | -- | 2.46 | 0.293 | -- | 1.14 | 0.566 | -- | 3.19 | 0.203 | -- |
| Market share | 0.03 | 0.858 | -- | 2.82 | 0.093 | M. Share=1 | 0.26 | 0.610 | -- | 0.73 | 0.393 | -- |
| Exporter | 0.12 | 0.732 | -- | 0.79 | 0.373 | -- | 2.24 | 0.134 | -- | 8.83 | 0.03 | Exporter=1 |

Finally, we have carried out a multivariate duration analysis that accounts for the potential effect of various explanatory variables. We now proceed to discuss the results obtained in the multivariate duration analysis. Table 3 reports the results of estimating several specifications of the discrete time proportional hazard model (complementary log-log model, *cloglog*) in order to investigate the determinants of R&D persistence and, in particular, the effect of the variables capturing learning. In all the estimations we treat the shape of the baseline hazard function non-parametrically. As in any proportional hazard specification, a unit change in a covariate leads to a proportional shift on the hazard rate. The assumption of proportionality has been tested using the tests proposed by Grambsch and Therneau (1994). The null hypothesis that the hazard rates are proportional cannot be rejected.

In Column 1.1 of Table 3 we present the estimates of the coefficients for the baseline function (that proxies the effect of the passage of survival time on the hazard of failure, that is, on the probability that the spell ends), without controlling for any R&D spell characteristic that may also affect survival.[8] The estimates suggest a pattern of negative duration dependence, that is, the risk of ending of an R&D spell decreases with survival time.

The Column 1.2 in Table 3 displays the unconditional effect of the level of R&D capital on the probability of ending an R&D spell i.e., the effect of R&D capital on R&D persistence without controlling for other firm/spell characteristics, which may also affect survival. In order to capture possible non-linear effects of R&D capital on duration, we introduce this variable as a set of four dummy variables, being the omitted category in our regression the one corresponding to *Low-R&D* capital. The other three dummies correspond to *Med-Low*, *Med-High* and *High* R&D capital (second, third and upper quartile of the R&D capital distribution, respectively). Our estimates show that the level of R&D capital has a strong and significant effect on the probability of the R&D spell survival. Further, the highest the R&D capital, the lower the risk of ending the R&D spell (all the estimates corresponding to the different levels of R&D capital are significant and significantly different among them). This finding gives support to our *hypothesis 1* about firms with high R&D capital being more likely to endure longer R&D spells.[9]

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[8] It should be noted that given that we do not have transitions in survival years 8 and 10 (these are duration lengths with no spell completions), and given that a fully non-parametric specification of the baseline hazard function is used, the coefficients for the dummy variables corresponding to survival years 8 and 10 (*d8* and *d10*) cannot be separately estimated. Therefore, in estimation there is a unique dummy for survival years *d7-d8*, or for survival years *d9-d10*.

[9] In addition, the introduction of the variables accounting for R&D capital leads to a reduction of the coefficients of the baseline function, suggesting a smoother pattern of negative duration dependence.

**Table 3. Maximum likelihood estimates for the discrete time proportional hazards models.**

| | **Column 1. *Cloglog* model without unobserved heterogeneity** | | | | | | **Column 2. Gamma unobserved heterogeneity** | | **Column 3. Two-mass points estimates** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Column 1.1. Baseline** | | **Column 1.2. Baseline and R&D capital** | | **Column 1.3. Full specification** | | | | | |
| | Coeff. | *p*-value | Coefficient | *p*-value | Coefficient | *p*-value | Coefficient | *p*-value | Coefficient | *p*-value |
| ***Learning effects*** | | | | | | | | | | |
| d1 | -0.744 | 0.000 | -0.243 | 0.020 | 0.307 | 0.323 | 1.154 | 0.050 | 1.349 | 0.003 |
| d2 | -1.233 | 0.000 | -0.756 | 0.000 | -0.110 | 0.751 | 1.109 | 0.150 | 1.243 | 0.027 |
| d3 | -1.591 | 0.000 | -1.103 | 0.000 | -0.436 | 0.244 | 0.985 | 0.258 | 1.120 | 0.075 |
| d4 | -1.693 | 0.000 | -1.209 | 0.000 | -0.435 | 0.275 | 1.221 | 0.222 | 1.353 | 0.056 |
| d5 | -1.821 | 0.000 | -1.354 | 0.000 | -0.580 | 0.170 | 1.213 | 0.265 | 1.362 | 0.074 |
| d6 | -2.406 | 0.000 | -1.918 | 0.000 | -1.230 | 0.025 | 0.676 | 0.575 | 0.826 | 0.349 |
| d7-d8 | -3.569 | 0.000 | -3.104 | 0.000 | -2.264 | 0.004 | -0.363 | 0.784 | -0.226 | 0.827 |
| d9-d10 | -2.708 | 0.000 | -2.215 | 0.002 | -1.541 | 0.048 | 0.461 | 0.741 | 0.559 | 0.606 |
| Med-low R&D cap. | | | -0.254 | 0.064 | -0.089 | 0.554 | -0.277 | 0.204 | -0.288 | 0.180 |
| Med-high R&D cap. | | | -0.827 | 0.000 | -0.520 | 0.006 | -0.814 | 0.005 | -0.783 | 0.003 |
| High R&D cap. | | | -1.210 | 0.000 | -0.722 | 0.002 | -0.991 | 0.001 | -0.918 | 0.001 |
| ***Success-breeds-success*** | | | | | | | | | | |
| Innovation results | | | | | -0.205 | 0.092 | -0.256 | 0.102 | -0.245 | 0.113 |
| Appropriability2 | | | | | 0.067 | 0.649 | 0.045 | 0.805 | 0.063 | 0.730 |
| Appropriability3 | | | | | -0.257 | 0.111 | -0.388 | 0.057 | -0.364 | 0.059 |
| ***Sunk R&D costs*** | | | | | | | | | | |
| Med-tech. Ind. | | | | | -0.130 | 0.340 | -0.289 | 0.179 | -0.342 | 0.103 |
| High-tech. Ind. | | | | | -0.316 | 0.104 | -0.576 | 0.060 | -0.608 | 0.030 |
| Size2 | | | | | -0.137 | 0.411 | -0.231 | 0.320 | -0.256 | 0.276 |
| Size3 | | | | | -0.101 | 0.649 | -0.192 | 0.528 | -0.258 | 0.395 |
| Size4 | | | | | -0.213 | 0.331 | -0.435 | 0.173 | -0.488 | 0.101 |
| Size5 | | | | | -0.473 | 0.048 | -0.747 | 0.024 | -0.795 | 0.009 |
| Size6 | | | | | -0.555 | 0.102 | -0.971 | 0.044 | -1.025 | 0.017 |
| Internal R&D | | | | | -0.277 | 0.049 | -0.294 | 0.114 | -0.318 | 0.074 |
| R&D employment2 | | | | | -0.044 | 0.779 | -0.122 | 0.566 | -0.124 | 0.536 |
| R&D employment3 | | | | | -0.429 | 0.331 | -0.739 | 0.181 | -0.680 | 0.178 |
| ***Other controls*** | | | | | | | | | | |
| Market share | | | | | -0.076 | 0.540 | -0.136 | 0.435 | -0.142 | 0.387 |
| Exporter | | | | | -0.123 | 0.367 | -0.194 | 0.312 | -0.100 | 0.593 |
| Year dummies | | | | | YES | | YES | | YES | |
| Log-likelihood | -680.828 | | -647.907 | | -628.080 | | -625.644 | | -624.849 | |
| N. of observations | 1296 | | 1296 | | 1291 | | 1291 | | 1291 | |
| N. of spells | 481 | | 481 | | 481 | | 481 | | 481 | |

In Column 1.3, Column 2 and Column 3 of Table 3, we report the estimates when controlling for other sources of R&D spell heterogeneity different from R&D capital. We include variables accounting for the "success-breeds-success" hypothesis, sunk costs and other controls which account for other characteristics that may be relevant for the risk of the R&D spell ending, as discussed in section 2. The only difference of the estimates in Column 1.3 with respect to Columns 2 and 3 is the inclusion in the latter two of an unobserved heterogeneity term. Whereas in Column 2 we assume a gamma distribution for the unobserved heterogeneity component, in Column 3 we treat the unobserved heterogeneity component non-parametrically. For both models accounting for individual heterogeneity, we reject the null hypothesis that individual unobserved heterogeneity is not relevant. For the model assuming a parametric specification for the unobserved heterogeneity using a Gamma distribution we reject the null hypothesis that the unobserved heterogeneity variance component ($\sigma^2$) is equal to zero (the *p*-value for the likelihood ratio test is 0.014), indicating that unobserved heterogeneity is statistically significant.[10] For the specification treating unobserved heterogeneity non-parametrically through "two mass-points", we reject the null that the coefficient of the mass-point for type 2 firm spells is statistically not different to the one of the mass-point for type 1 firm spells (the coefficient of the mass-point for type 2 is -2.062 with a *p*-value of 0.000),[11] indicating that there is unobserved individual heterogeneity.

The above results suggest that we should rely on the specifications accounting for unobserved heterogeneity. However, our preferred specification is the model accounting for unobserved heterogeneity using mass points, since this model does not impose any parametric distribution to the unobserved heterogeneity. Thus, in what follows we interpret the results of this specification (Column 3 in Table 3).

### *Learning effects*

Our results provide evidence supporting the two hypotheses we use to test for the existence of a learning effect in the performance of R&D activities (*hypothesis 1 and 2*). First, we find that firms with a high R&D capital enjoy longer R&D spells. Further, our results suggest that the impact of R&D capital on spell duration is not linear and we observe the existence of a minimum degree (threshold) of R&D capital in order to a learning effect start working for a firm. In particular, we find that firms belonging either to *Medium-High* or *High R&D* capital groups enjoy significantly longer R&D spells than firms

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[10] See Gutiérrez *et al.* (2001) and Jenkins (2004) for details about this test.

[11] In estimation, the coefficient for the mass point for type 1 firm spells is normalized to zero, and we estimate the coefficient for the second mass point.

with a *Low* or *Medium-Low R&D* capital. Therefore, R&D capital accumulation only brings learning beyond a minimum level of R&D accumulation. This result gives support to *hypothesis 1,* that is, that the duration of the R&D spell raises with R&D capital.

Secondly, the estimates of the coefficients for the duration interval dummies (*d1,…, d9-d10*) inform us about the pattern of duration dependence. Once we have controlled for firm, industry, market and business cycle characteristics, we interpret the observed pattern of duration dependence in the light of the effects of the passage of time on the probability of survival. The estimates corresponding to survival years 1 to 5 are significant and positive (and not significantly different among them). The estimates corresponding to survival years 6, 7-8 and 9-10 are not significantly different from zero (although they are significantly different from the constant hazard rate for the period 1 to 5 survival years). This means that the risk of ending of an R&D spell is positive but constant during the initial 5 years of the spell and, suddenly, from the year 5 onwards the risk of ending goes to zero. Therefore, our results indicate that there exists a pattern of n*egative duration dependence* acting through a threshold corresponding to a period of 5 years of continuous performance of R&D activities. This result suggests that learning to survive in the performance of R&D activities takes on average 5 years, and once this length has been exceeded the passage of time does not affect firm R&D persistence, either in a positive or in a negative way.

These results support our *hypothesis 1 and 2* and may be considered as providing evidence of learning-by-doing and learning-to-learn effects in R&D activities (Rosenberg, 1976; Nelson and Winter, 1982). They may also be interpreted as consistent with industry dynamic models where the main source of dynamics arises from firm *active learning* (Ericson and Pakes, 1995; Pakes and Ericson, 1998).

*Success-breeds-success*

According to the “success-breeds-success” approach (Mansfield, 1968, Stoneman, 1983), previous innovation success should enhance survival prospects of firms R&D spells. From our results we observe that firms that obtain innovation results (either in the form of patents and utility models, or in the form of product and process innovations) seem to endure longer R&D spells (giving support to our *hypothesis* 3), although the variable INNOVATION RESULTS is only significant at 11.3% level.

Regarding the innovative APPROPRIABILITY conditions faced by firms, our results suggest that firms operating in an environment with high appropriability conditions enjoy longer R&D spells as compared to industries with medium and low appropriability conditions (the reference category). This result is in line with Levin *et al.* (1987) and Levin (1988), who predict that the higher the degree of appropriability of the firm innovation output, the higher will be the incentives to invest in R&D. Thus, this result supports our *hypothesis 4.*

*Sunk R&D costs*

Our results indicate that R&D spells of firms operating in high-tech industries enjoy better survival prospects with respect to firms operating in either low or medium-tech industries. This result gives support to *hypothesis 5* (stating that sunk R&D costs are expected to be larger in high-tech industries) and is in line with Sutton (1991), Åstebro (2002, 2004) and Mañez *et al.* (2009).

In relation to firm size and after controlling for all other variables, our results show that the R&D spells of larger firms have lower chances of ending. We obtain that the coefficients corresponding to firms with more than 100 employees are negative and significant (SIZE4, SIZE5 and SIZE6).[12] Moreover, in absolute value, the negative coefficient for SIZE4 is significantly smaller than the coefficients of SIZE5 and SIZE6, and the coefficients of SIZE5 and SIZE6 are not significantly different between them. Thus, the better survival prospects are for R&D spells of firms with more than 200 employees (SIZE5 and SIZE6 groups). This result is consistent with our *hypothesis 6* and is in line with existing studies of innovation persistence, which have also found that large firms show higher persistence in innovative behaviour (Geroski *et al*., 1997; Cefis and Orsenigo, 2001; Cefis, 2003; and Mañez *et al.*, 2009).

As regards the R&D activities undertaken by firms we find, interestingly, that the internal/external nature of R&D activities has an important impact on the length prospects of the R&D spell. Our results suggest that firms undertaking R&D activities internally enjoy better R&D survival prospects than firms contracting externally these activities (the coefficient of the variable INTERNAL R&D is negative and significant at 7.4 % level of significance). This evidence supports our *hypothesis 7*. However, once controlling for the internal nature of the firm R&D activities, we do not find that the number of R&D employees has an impact on R&D spell duration (the coefficients of the R&D EMPLOYMENT variables are not significant), and therefore, we cannot provide support to our *hypothesis 8*.

*Other controls influencing R&D spell length*

A number of other factors may also influence the R&D spell length. In relation to market competition factors, we find that either firm MARKET SHARE or firm EXPORT participation do not seem to affect the firm expected R&D spell length, as neither of these variables is significant.

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[12] However, the coefficient for SIZE4 (firms between 100-200 employees) is significant at a 10.1% level.

Finally, regarding the year dummies introduced to capture the effects of the business cycle on R&D spells duration, we do not find any significant effect for any of them.[13]

## 6. CONCLUDING REMARKS.

This paper has investigated the determinants of the persistence of firms in performing R&D activities. Unless previous studies, that have focused on firm innovation persistence by analysing the number of innovation results obtained by firms (either patents and/or major innovations), we have examined persistence from an input point of view, and in particular, persistence in the firm decision to invest in R&D activities. Our main focus has been testing for the role of learning, and in particular, whether learning from R&D performance affects firms' persistence in R&D activities.

In order to do so, we have used survival methods, including non-parametric tests and the estimation of discrete time proportional hazard models. The advantages of our estimation methods, as compared to previous analysis of innovation persistence, is that they have allowed for a fully non-parametric estimation of the baseline hazard function, permitting a full identification of the effect of survival time on the length of the R&D spell. In addition, the estimation of both parametric and non-parametric unobserved heterogeneity survival models has allowed a robust test for the presence of unobserved individual heterogeneity. We have used for estimation a representative sample of the population of Spanish manufacturing for the period 1990 to 2000. The dataset has been drawn from the *ESEE*, a survey carried out annually since 1990 that provides broad information at the firm level.

Our findings may be considered as providing evidence of learning-by-doing and learning-to learn effects in R&D activities (Rosenberg, 1976, Nelson and Winter, 1982). In particular, we have obtained that R&D capital is an important driver of persistence in R&D activities, and that firms R&D spells exhibit "negative duration dependence", indicating that the probability that the R&D spell comes to an end decreases as the performance of R&D goes on, that is, with the duration of the spell. These results may also be considered as giving support to industry dynamic models where the main source of dynamics arises from firm *active learning* (e.g. Ericson and Pakes, 1995). We have also obtained that unobserved heterogeneity is important, indicating that persistence is also linked to individual unobserved heterogeneity. This result is consistent with the industry dynamic models of *passive learning* (Jovanovic, 1982), in which dynamics is driven by inherent and fairly constant characteristics of the firm (natural endowments, managerial abilities, etc.).

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[13] The coefficients for the time dummies are not reported in Table 3 due to space limitations, but they are available from the authors upon request.

We have also found support for the approach of *success-breeds-success* and the role of sunk R&D costs in explaining persistence in the performance of R&D activities by firms.

Our findings make an important contribution to the understanding of the determinants of firm persistence in R&D activities, and in particular, of the role of learning in firms R&D persistence. If the achievement of innovation results (both product and process innovations and patents) depends crucially on the persistence in the realization of R&D activities, our results may have important implications both for public policy and firm managers. As for public policies, if persistence in R&D activities is desirable, given that it renders higher returns, policy makers should devote resources to those firms with a higher probability to perform R&D in a continuous way. As for managers, our results suggest that firms should invest in R&D in a continuous way to take advantage of learning effects associated with the performance of these activities. Thus, although undertaking internal R&D (*versus* externally contracting R&D) and creating their own R&D department may increase the sunk costs associated to the performance of R&D activities, these costs are also factors that increase the propensity to perform R&D in a continuous way, fostering the achievement of innovation results that are the final aim of R&D activities.

# REFERENCES.

Aghion, P., Bloom, N, Blundell, R., Griffith, R., Howitt, P., 2004. Competition and innovation: an inverted U-relationship 2004. Discussion Paper 04-06, University College London.

Allison, PD., 1987. Event history analysis: Regression for longitudinal data. California: Sage: Newbury Parca.

Arrow, K., 1962. Economic welfare and the allocation of resources for inventions. In Nelson R (Ed.), The rate and direction of inventive activity. Princenton University Press.

Åstebro, T., 2002, Noncapital Investment Costs and the Adoption of CAD and CNC in U.S. Metalworking Industries. Rand Journal of Economics 33, 672-688.

Åstebro, T., 2004. Sunk Costs and the Depth and Probability of Technology Adoption'. The Journal of Industrial Economics 52, 381-399.

Beneito, P., Rochina M.E., Sanchis, A., 2007. R&D experience and innovation success. Instituto Valenciano de Investigaciones Económicas (IVIE) Working Paper Series EC, 10.

Cefis, E., 2003. Is there persistence in innovative activities? International Journal of Industrial Organization 21; 489-515.

Cefis, E., Orsenigo, L., 2001. The persistence of innovative activities. A cross-countries and cross-sectors comparative analysis. Research Policy 30, 1139-1158.

Cohen, W. M., Klepper, S., 1996. A Reprise of Size and R&D. Economic Journal 106, 925-951.

Cohen, W. M., Levinthal, D.A., 1989. Innovation and learning: the two faces of R&D. The Economic Journal 99; 569-596.

Crépon, B., Duguet, E., 1997. Estimating the innovation function from patent numbers: GMM on count panel data. Journal of Applied Econometrics12, 243-263.

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

Flaig, G., Stadler, M., 1994, Success breeds success. The dynamics of the innovation process. Empirical Economics 19, pp. 55-68.

Flaig, G., Stadler, M., 1998. On the dymanics of product and process innovations. A bivariate random effects probit model. Jahrbücher für Nationalokönomie und Statistik 217, 401-417.

Geroski, P.A., Van Reenen, J., Walters, C.F., 1997. How persistenly do firms innovate? Research Policy 26, 33-48.

Grambsch, P.M., Therneau, T.M., 1994. Proportional Hazards Tests and Diagnostics based on Weighted Residuals. Biometrika 81, 515-526.

Griliches, Z., 1979. Issues in assessing the contribution of R&D to productivity growth. Bell Journal of Economics 10, 92-116.

Gutiérrez, R.G., Carter, S., Drukker, D., 2001. On boundary-value likelihood-ratio tests. Stata Technical Bulletin 60.

Heckman, J.J., Singer, B., 1984. A method for minimizing the impact of distributional assumptions in econometric models for duration data. Econometrica 52(2), 271-320.

Jenkins, S.P., 1995. Easy estimation methods for discrete-time duration models. Oxford Bulletin of Economics and Statistics 57, 129-138.

Jenkins, S.P., 2001. Discrete time proportional hazards regression. Stata Technical Bulletin 39.

Jenkins, S.P., 2004. Survival Analysis. Unpublished manuscript, Institute for Social and Economic Research, University of Essex, Colchester, UK. Downloable form http://www.iser.essex.ac.uk/teaching/degree/ stephenj/ ec968/pdfs/ec968lnotesv5.pdf.

Jovanovic, B., 1982. Selection and the Evolution of Industry. Econometrica 50, 649-670.

Kiefer, N.M., 1988. Economic duration data and hazard functions. Journal of Economic Literature 6, 646-670.

Kleinschmidt, E.J., Cooper, R.B., 1990. The performance impact of an international orientation on product innovation. European Journal of Markeing 22, 56-71.

Kotable, M., 1990. The relationship between offshore sourcing and innovativeness of US multinational firms: an empirical investigation. Journal of International Business Studies 21, 623-638.

Le Bas, C., Cabagnols, A., Gay, C., 2003. An evolutionary view on persistence in innovation. In P. Saviotti, ed. Applied Evolutionary Economics, Northhampton, MA: Edward Elgar.

Levin R., 1988. Appropriability, R&D spending and technological performance. American Economic Review 78, 424-448.

Levin, R., Klevorick, A., Nelson, R., Waters, S., 1987. Appropriating the returns from industrial research and development. Brookings Papers on Economic Activity 3, 783-831.

Malerba, F., Orsenigo, L., 1999. Technological entry, exit and survival: an empirical analysis of patent data. Research Policy 28, 643-660.

Mañez, J.A., Rochina-Barrachina, M.E., Sanchis, A., Sanchis, J.A., 2009. The role of sunk cost in the decision to invest in R&D. The Journal of Industrial Economics, forthcoming.

Mansfield, E., 1968, *Industrial Research and Technological Innovation: An Econometric Analysis*, New York.

Meyer, R., 1990. Unemployment insurance and unemployment spells'. Econometrica 58, 757-782.

Nelson, R., Winter, S., 1982. An Evolutionary Theory of Economic Change. Cambridge: Harvard University press.

Pakes, A, Ericson, R., 1998. Empirical implications of alternative models of firm dynamics. Journal of Economic Theory 79, 1-45.

Peters, B., 2009. Persistence in innovation: stylised facts and panel data evidence. Journal of Technological Transfer, 34, 2, 226-243.

Prentice, R., Gloeckler, L., 1978. Regression analysis of grouped survival data with application to breast cancer data. Biometrics 34 (1), 57-67.

Raymond, W., Mohnen, P., Palm, F. Schim van der Loeff, S., 2006. Persistence of innovation in Dutch manufacturing: is it spurious? UNU-Merit Working Paper 2006-011. Maastrichts.

Roper, S., Hewitt-Dundas, N., 2008. Innovation persistence: survey and case-study evidence. Research Policy 37, 149-162.

Rosenberg, N., 1976. Perspectives on Technology. Cambridge: Cambridge University Press.

Scherer, F.M., 1967. Market structure and the employment of scientists and engineers. American Economic Review 57 (3), 524-531.

Schumpeter, J., 1942. Capitalism, Socialism and Democracy. New York: Harper Brothers.

Stoneman, P., 1983. The Economic Analysis of Technological Change. New York.

Sutton, J., 1991. Sunk Costs and Market Structure. Cambridge, Massachusetts: The MITT Press.

# Appendix

**Table A1. Variable definitions.**

| | |
|---|---|
| *Learning effect* | |
| R&D capital | Stock of R&D capital, measured by the perpetual inventory method: $K_{it} = (1-\delta) K_{it-1} + R_{it-1},$ where $\delta$ is the rate of depreciation, $K$ is the R&D-capital stock and $R$ are real R&D expenditures (current R&D has been deflated using industrial prices for the whole manufacturing industry). To calculate the R&D capital according to the equation above we consider the initial value of $R$ as firm R&D expenditure at the beginning of the spell and a depreciation rate of 15% percent. |
| Low R&D capital | Variable taking value 1 if the R&D capital of spell *i* in duration year *j* is in the lowest quartile of the distribution of the R&D capital of all spells in duration year *j*, and 0 elsewhere. |
| Medium-low R&D capital | Variable taking value 1 if the R&D capital of spell *i* in duration year *j* is in the second quartile of the distribution of the R&D capital of all spells in duration year *j*, and 0 elsewhere. |
| Medium-high R&D capital | Variable taking value 1 if the R&D capital of spell *i* in duration year *j* is in the third quartile of the distribution of the R&D capital of all spells in duration year *j*, and 0 elsewhere. |
| High R&D capital | Variable taking value 1 if the R&D capital of spell *i* in duration year *j* is in the highest quartile of the distribution of the R&D capital of all spells in duration year *j*, and 0 elsewhere. |
| *Success-breeds-success* | |
| Innovation results | Dummy variable taking value 1 if the firm obtains at least an innovation result (a patent, a utility model, a product innovation or a process innovation), and 0 otherwise. |
| Appropriability | Variable taking value 1 if the firm total number of patents and utility models over the total number of firms that assert to have achieved innovations in the firm industrial sector (20 sectors of the two-digit NACE-93 classification) belongs to the first tercile of the distribution, value 2 if belongs to the second tercile of the distribution, and value 3 if belongs to the last tercile of the distribution. |
| Appropriability1 | Dummy variable taking value 1 if the firm total number of patents and utility models over the total number of firms that assert to have achieved innovations in the firm industrial sector belongs to the first tercile of the distribution, and 0 otherwise. |
| Appropriability2 | Dummy variable taking value 1 if the firm total number of patents and utility models over the total number of firms that assert to have achieved innovations in the firm industrial sector belongs to the second tercile of the distribution. |
| Appropiability3 | Dummy variable taking value 1 if the firm total number of patents and utility models over the total number of firms that assert to have achieved innovations in the firm industrial sector belongs to the third tercile of the distribution. |
| *Sunk R&D costs* | |
| Industrial technological intensity | Variable taking value 1 if the firm belongs to a low-technological intensity industry, value 2 if the firm belongs to a medium-technological intensity industry, and value 3 if the firm belongs to a high-technological intensity industry. See Table A2 for industry classification. |
| Low technological industry | Dummy variable taking value 1 if the firm belongs to a low-technological intensity industry, and 0 otherwise. |
| Medium technological | Dummy variable taking value 1 if the firm belongs to a medium-technological intensity industry, and 0 otherwise. |

| | |
|---|---|
| industry | |
| High technological industry | Dummy variable taking value 1 if the firm belongs to a high-technological intensity industry and, and 0 otherwise. |
| Size | Variable taking value 1 if the number of employees of the firm is lower than 21, value 2 if the number of employees is greater than 20 and lower than 51, value of 3 if the number of employees is greater than 50 and lower than 101, value of 4 if the number of employees is greater than 100 and lower than 201, value of 5 if the number of employees is greater than 200 and lower than 501, and value of 6 if the number of employees is greater than 500. To calculate the number of employees we do not account for R&D employment. |
| Size1 | Dummy variable taking value 1 if the number of employees of the firm is lower than 21 and 0 otherwise. We do not account for R&D employment. |
| Size2 | Dummy variable taking value 1 if the number of employees of the firm is greater than 20 and lower than 51 and 0 otherwise. We do not account for R&D employment. |
| Size3 | Dummy variable taking value 1 if the number of employees of the firm is greater than 50, and lower than 101 and 0 otherwise. We do not account for R&D employment. |
| Size4 | Dummy variable taking value 1 if the number of employees of the firm is greater than 100 and lower than 201 and 0 otherwise. We do not account for R&D employment. |
| Size5 | Dummy variable taking value 1 if the number of employees of the firm is greater than 200 and lower than 501 and 0 otherwise. We do not account for R&D employment. |
| Size6 | Dummy variable taking value 1 if the number of employees of the firm is greater than 500 and 0 otherwise. We do not account for R&D employment. |
| Internal R&D | Dummy variable taking value 1 if the firm performs R&D activities internally. |
| External R&D | Dummy variable taking value 1 if the firm performs R&D activities externally. |
| R&D employment | Variable taking value 1 if the number of R&D employees of the firm is 0, value 2 if the number of R&D employees is greater than 0 and lower than 11, and value 3 if the number of R&D employees is greater than 10. |
| R&D employment1 | Dummy variable taking value 1 if the number of R&D employees of the firm is 0, and 0 otherwise. |
| R&D employment2 | Dummy variable taking value 1 if the number of R&D employees of the firm is greater than 0 and lower than 11, and 0 otherwise. |
| R&D employment3 | Dummy variable taking value 1 if the number of R&D employees of the firm is greater than 10 and 0 otherwise. |
| *Other controls* | |
| Market share | Dummy variable taking value 1 if the firm claims to account for a significant market share in its main market, and 0 otherwise. |
| Exporter | Dummy variable taking value 1 if the firm declares to export a positive amount and 0 otherwise. |
| Year dummies | Dummy variables taking value 1 for the corresponding year and 0 otherwise. |

**Table A2. Industrial technological intensity (NACE-93 two digits industrial classification).**

| **Industry** | **Industrial technological intensity** |
|---|---|
| Meat industry | Low |
| Food and tobacco | Medium |
| Beverages | Low |
| Textiles and clothing | Low |
| Leather and shoes | Low |
| Wood | Low |
| Paper industry | Low |
| Printing and printing products | Low |

| | |
|---|---|
| Chemical products | High |
| Rubber and plastic | Medium |
| Non metallic mineral products | Low |
| Ferrous and non-ferrous metals | Medium |
| Metallic products | Low |
| Industrial and agricultural machinery | Medium |
| Office machines | High |
| Electric and electronic machinery and material | High |
| Vehicles, cars and motors | Medium |
| Other transport equipment | High |
| Furniture | Low |
| Other manufacturing goods | Low |

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