A DYNAMIC APPROACH TO THE DECISION TO INVEST IN R&D: THE ROLE OF SUNK COSTS

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Abstract

In this paper we test for the presence of sunk costs in firms' R&D activities by analysing the persistence of these activities using firm level panel data. We develop and estimate a dynamic discrete choice model where each firm' current R&D expenditure is a function, among other factors, of its previous experience in performing R&D activities. The data used is a panel data of Spanish manufacturing firms draw from the *Encuesta sobre Estrategias Empresariales*, for the period 1990-2000. We find that prior R&D experience significantly affects the current decision to invest in R&D, and that, although important, the effect of prior R&D experience depreciates fairly quickly over time.

Keywords: R&D decision, persistence, sunk costs, panel data, multivariate dynamic binary choice model.

JEL Classification: C23, L60, O33

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1.- Introduction

Understanding the determinants of firms R&D investments has received much attention among researchers and policy makers (see, among other, the work of Levin, Cohen and Mowery, 1985, Cohen, Levin and Mowery, 1987, Cohen and Levin, 1989, or the survey by Cohen, 1995). More recently, the analysis has focused on the complexity of the process of innovation by firms and the heterogeneous nature of R&D activities.[1] In particular, a number of papers have examined the determinants of the different alternatives firms face once they have decided to invest in R&D. The choice between own generation of technology or its external acquisition has been analysed, among others, by François (1985), Braga y Wilmore (1991), Mohnen y Lépine (1991), Siddhartan (1992), Lee (1996), Katrak (1997), Veugelers (1997), Cassiman and Veugelers (1999), and Beneito (2002, 2003).

In spite of the large number of papers analysing the determinants of firms' decision to invest in R&D, to our knowledge, the role of sunk costs in shaping this decision has not yet been explicitly analysed. The idea that the resources used in innovation activities are subject to indivisibilities is not new (Arrow, 1962). The development of R&D activities may involve creating an R&D department and hiring or training specialised workforce, which are start-up costs that in turn may be consider as sunk costs. Further, and more importantly, according to the evolutionary theories of technological innovation (Nelson and Winter, 1982), one crucial factor in the technological choice made by firms is the *accumulative nature* of innovation (cumulativeness) that makes current innovation possibilities dependent on past innovations and on the learning achievements of the firm (Malerba and Orsenigo, 1993). This is related to the fact that a minimum period of maturity is needed for the R&D expenditures of the firm to translate into an innovating output with a positive impact on profits, which usually implies that the firm chooses its R&D trajectory within a medium or long run perspective. These distinctive features of the innovating activities suggest the existence of sunk costs associated with the performance of R&D activities.

[1] Within the literature of the evolutionary theories of technological innovation, the multiplicity of the R&D activities performed by firms has been postulated by the concepts of technological trajectories (Pavitt, 1984) or technological regimes (Nelson and Winter, 1982, Malerba and Orsenigo, 1993).

There is a body of literature in which firms technological advancement is conceptualised as a learning process (Garvin, 1993, Malerba, 1992, Dodgson, 1991, 1993, Hitt et. al., 2000, Lall, 1992, Cohen and Levinthal, 1989). Innovation capability is determined by learning, by the knowledge and skills needed for firms to effectively absorb, operate and improve existing technologies, and create new ones (Lall, 1992). The crucial factors behind innovation capability are the knowledge and skills brought into the firm by the entrepreneur and the workforce, being experience and staff training crucial elements. Also interactions with suppliers, customers, public research agencies and industry associations may provide external missing inputs into the learning process. The cumulative nature of knowledge in the learning process should induce persistence in the performance of R&D activities by firms.

In the game theory literature of innovation, a number of papers have considered the association between the innovation activity and sunk costs. Scherer (1967) and Reinganum (1981) assume sunk costs and time dependent payoffs to innovation competition. Dasgupta (1986) work on patent races models the strategic interaction among firms as a first-price all-pay auction where all firms incur into sunk costs. More recently, Kaplan, Luski and Wettstein (2003) present a game theoretical model where all firms compete to be the first to innovate and earn the whole reward (patent) incurring in a cost that is sunk and thus independent of which firm wins the race.

Within the IO literature, the consideration of the sunk costs nature of R&D investments is due to Sutton (1991) and has its origin in his models of vertical product differentiation (Shaked and Sutton, 1982, 1987). Using a two-stage game framework, Sutton considers R&D investment as sunk costs incurred by the firm in a first stage to raise the quality of its product and so the consumers' willingness to pay (and therefore profits) in the second stage of the game.

Although it is generally accepted that R&D activities are associated with sunk costs, there is a lack of empirical evidence on this relationship and this is the main contribution of this paper.[2]

The aim of this paper is to test for the presence of sunk costs in firms' R&D activities by analysing the persistence of these activities using firm level panel data. In order to do so, we develop and estimate a dynamic discrete

[2] Astrebo and Simons (2003) present and test a model of survival in which the decision to commercialize an invention depend upon sunk costs, uncertainty and expected profits. In their model of the effects of innovation attributes on survival, they acknowledge the sunk costs associated with R&D expenditures.

choice model where each firm' current R&D decision is a function, among other factors, of its previous experience in performing R&D activities. The model also allows for showing the importance, for the firm's decision to invest in R&D, of other factors such as firm economic and technological opportunities, appropriability conditions, firm characteristics and spillovers. Our approach is thus similar to that in Roberts and Tybout (1997) who analyze sunk cost hysteresis in the export market using a sample of Colombian manufacturing firms.

It is important to note that persistence in performing R&D activities might be caused by sunk costs but also by underlying (observed and unobserved) firm heterogeneity (i.e., persistent differences across firms in the gross profit from R&D investments) or serial correlation in exogenous shocks. Persistence in behaviour due to permanent differences in profitability across firms could create the appearance of sunk costs in the model. Therefore, to properly identify the role of sunk costs we use an econometric framework that allows to control for all competing sources of persistence in the R&D investments.

The data used is a panel data of Spanish manufacturing firms draw from the *Encuesta sobre Estrategias Empresariales* (ESEE hereafter), for the period 1990-2000. This is the first attempt to analyse the role of sunk costs in firm's decision to invest in R&D using a dynamic approach and accounting for a wide range of firm characteristics.[3]

To anticipate our results, we find that prior R&D experience significantly affects the current decision to invest in R&D, and that, although important, the effect of prior R&D experience depreciates fairly quickly over time.

The rest of the paper is organised as follows. In section 2 we discuss the characteristics of our sample and analyse R&D patterns for Spanish manufacturing. Section 3 introduces an empirical model of entry and exit in R&D activities with explicit consideration of the role of sunk costs. In section 4, we discuss our estimation strategy. In section 5, we describe the explanatory variables. The estimation results are summarized in section 6. Finally, section 7 concludes.

[3] To the best of our knowledge, the only empirical work using Spanish data that acknowledges the existence of sunk costs associated with innovating activities is that of González and Jaumandreu (1998). They assume that, due to the indivisibilities of some resources, there is a minimum R&D expenditure that, together with market demand conditions and technological opportunities, determines threshold levels of R&D expenditures under which firms do not find it profitable to invest. Their results show that sizable thresholds exist and that these thresholds are related to demand and technological factors.

2. The data

To analyse the determinants of firms' R&D decisions we use data drawn from the ESEE, an annual survey of Spanish manufacturing firms carried out by the Ministry of Industry since 1990. The ESSE is representative of the Spanish manufacturing firms classified by industrial sector and size categories and includes exhaustive information at the firm level.

The sampling procedure of the ESEE is the following. In the base year, 1990, firms were chosen using a selective sampling scheme with different participation probabilities depending on the firm size category. All firms with more than 200 employees (large firms) were requested to participate and the participation rate reached approximately 70% of the number of firms in the population. Firms that employed from 10 to 200 (small firms) were randomly sampled by industry and size strata (according to 20 different productive activities and 4 size intervals), holding around a 5% of the population. Firms with less than 10 employees are excluded from the survey. Hence, the coverage of the dataset is different depending on the size group of firms. The different sampling properties of these two size groups as well as the possible relationship between size and the R&D decision advice to carry out a separate analysis of the representativeness of the sample and transitions in and out of R&D activities by size group. Furthermore, the influence of size in the R&D decision will be taken into account in our econometric analysis.

In our work we use a panel of continuously operating firms from 1990 to 2000. The choice of a continuous panel is motivated by two reasons. First, to analyse firm R&D trajectories for as many years as possible we sample out those firms that fail to supply R&D information in any given year of the sampling period. Second, given our need to estimate a dynamic specification with lagged endogenous variables, we would like to build up a panel as long as possible (as in Roberts and Tybout, 1997 or Bernard and Jensen, 2003 analyses of firms' export decision). Furthermore, we drop any firm that failed during the sampling period.[4]

After applying these criteria, we end up with a balanced panel of 757 firms that is not necessarily representative of the complete ESEE sample. This is the sample we use in our analysis. Table 1 shows that in our sample small

[4] Including these firms would involve to model the probability of failing and would complicate substantially the analysis. However, this assumption is not innocuous as shown in Esteve, Sanchis and Sanchis (2003), where using a sample drawn from the ESEE, they find that R&D firms are less likely to fail.

firms are slightly over-represented if compared to the complete sample: in 1990, both the proportion of firms and the share of the small firms group in employment, sales and R&D expenditure are larger in our sample than in the complete ESEE sample. On average, in our selected sample, small firms represent 13.34%% of total employment, 11.46% of total sales and 4.68% of total R&D expenditure.

[Insert Table 1 about here]

For the small firms size group, Table 2 shows that although R&D intensity is lower in our sample than in the complete sample, other relevant characteristics such as the pr oportion of R&D / non R&D firms, firm size or the share of R&D firms on total sales and employment are similar in both samples.

As for the large firms size group, the proportion of R&D / non R&D firms is similar in both groups. However, R&D intensity is higher in our continuing sample than in the complete sample and the participation of R&D firms in total employment and sales is lower in our sample than in the complete one. Furthermore, R&D firms in our continuing sample are substantially smaller than in the complete one.

These differences between the complete sample and our continuing sample mean that we could be not estimating the true probability of performing R&D. However, we believe that the resemblances between our sample and the complete one still make valid our analysis.

[Insert Table 2 about here]

We show in Table 3 the R&D characteristics of our sample for the period 1990-2000 by size group. The proportion of R&D firms increased for both groups along the period, though such proportion always remained much higher for large firms. Thus, the R&D firms' proportion in small firms slightly rose from 17.22% to 21.75% and in large firms from 69.12% to 78.06%. At the same time, R&D intensity (defined as R&D expenditure over sales) grew much faster in large firms than in small ones: whereas for small firms R&D intensity just increased 4.76% (from 0.63% to 0.66%), for large firms it increased 62.05% (from 1.66% to 2.69%). This can be explained because large firms' annual growth rate of R&D expenditure almost doubled the annual growth rate of sales (9.44% and 5.08%, respectively), while in the small ones the annual growth rate of R&D expenditure was arround one point higher than the sales rate (6.34% and 5.59%, respectively). Hence, whilst in 1990 the R&D intensity of large firms is 2.6 times that of small ones (1.66% and 0.63%, respectively), in 2000 it is four times larger (2.69% versus 0.66% for small firms).

[Insert Table 3 about here]

2.1. Flows in and out of R&D activities

To evaluate the importance of the flows in and out of R&D activities, we analyze the transition rates in our sample (Table 4).[5] In this table, each row describes the transition from the R&D status in the first column to the status in the second column. Each one of the entries in these rows is the proportion of firms in each of the year-t status that choose each of the two possible status in year $t + 1$. As in former tables the top panel applies to small firms and the bottom panel to large firms. Additionally, Figure 1 shows the number of R&D and non-R&D firms as well as the entry rate (proportion of non-R&D firms in t that perform R&D in t+1) and the exit rate (proportion of R&D firms in t that do not perform R&D in t+1) for each year of the sampling period.

Both Figure 1 and the second and third rows of each panel of Table 4 (transitions from non R&D to R&D and from R&D to non R&D), that show the entry and exit rates from R&D activities, uncover that carrying out R&D one year does not mean necessarily permanence in this activity. For small firms, the average exit rate exceeds the average entry rate (21.1% and 5.9%, respectively), suggesting a high rate of turnover. For large firms the average entry rate more than doubles average exit rate (15% and 7%, respectively). Thus after a decrease in the number of large firms performing R&D in the years 1991-1992, the number of large firms that perform R&D steadily increases until 1999. This points out a trend of incorporation to R&D activities and of permanence in this R&D status: it is very likely that once a large firm starts performing R&D it keeps doing it. As a result of these entry and exit rates there was a net gain of 32 R&D firms (29 of them were classified as small firms in 1990 and 3 as large ones)[6]. Notwithstanding, the proportion of small firms performing R&D is still very small if compared with that of the large

[5] To calculate the transition rates firms have been assigned to size groups according to their employment size in 1990. Using each year employment size and with a lot of changes in group assignments, transition rates could be higher than 100%.
[6] For large firms, from a sample period minimum of 136 R&D firms in 1992, the number of R&D firms increases up to 153 in 2000.

firms (whereas in 2000, 70.54% of the large firms performed R&D, this percentage for the small firms was 22.59%).

[Insert Table 4 and Figure 1 about here]

Simultaneously to this R&D activities substantial entry and exit, there is an important degree of persistence in the status of an individual firm: 52.53% of large firms and 61.11% of small firms never change status. Columns 1 and 2 of Table 5 show the proportion of R&D firms and non-R&D firms in 1990 that had the same status in one of the subsequent 10 years.[7] The percentage of firms in the small firms group that performed R&D in 1990 and was also performing R&D in 1995 is slightly over 61% and five years later this percentage is even larger 66.7%. In the large firms group persistence is even more intense as 78% of the firms performing R&D in 1990 also carried out R&D in 1995 and five years later this percentage is even larger, 81.3%. Whereas for the large firms group persistence in the non-R&D status, though important, is not as intense as in the R&D status, for the small firms group persistence in the non-R&D status is even stronger than in the R&D status. From the large firms that did not perform R&D in 1990 64% did not do it five years later and 53.7% did not perform R&D in 2000. Among the small firms, persistence in the non-R&D status is even higher, as the aforementioned percentages raise to almost 91% and 86.6%, respectively. This lower rate of persistence for large firms in the non-R&D status confirms the trend of incorporation to the R&D activities detected above.

[Insert Table 5 about here]

Columns 3 and 4 report the predicted rates of persistence in each of the two status. These are calculated using the annual transition rates given by the data and reported in Table 4. Regardless the size group and all over the sampling period, predicted persistence is lower than sample actual persistence. Hence, we can extract two conclusions: first, that the probability of performing R&D is higher for firms that have performed R&D before, i.e there is a high rate of re-entry by former R&D firms; second and analogously,

[7] We follow Bernard and Jensen (2003) to build up this table. In columns 1 and 2 of Table 5 we do not distinguish between firms that perform R&D (do not perform R&D) continuously and firms that change status. For example, in the 1996 percentage we include both firms that performed R&D all the years from 1990 to 1996 and firms that performed R&D in 1990 and 1996, but not in one or more of the years between 1990 and 1996.

firms performing R&D with a non-R&D past have a higher probability of quitting their R&D activities. The aim of this paper is to disentangle whether this status persistence results from firm attributes or the existence of sunk costs associated to R&D activities.

After having detected heterogeneity of entry and exit rates across size groups, we analyze if there exists heterogeneity across industries. Figure 2, shows average annual entry and exit rates for the 20 manufacturing sectors of the NACE-93 classification and the overall sample of firms. While most of the industries exhibit turnover patterns that are similar to the overall sample, some industries such as office machines show lower entry and exit rates that the average and others such as printing and printing stuff show exceptionally high exit rates. Furthermore, only the metallic products and motors and cars industries show entry rates that are lower than exit rates. These results suggest that sunk costs of entry and exit as well as firm characteristics must be important determinants of the decision to perform R&D activities. We propose next an econometric model to analyse the role of firm characteristics and sunk costs in shaping the firms´ R&D decision.

[Insert Figure 2 about here]

3. Modelling the R&D decision.

We follow Roberts and Tybout (1997) in modelling the decision to invest in R&D by a rational, profit-maximizing firm. The firm considers expected profits today and in the future from the decision to perform R&D, net of entry and exit sunk costs. In each period t the variation in gross profits adjusted for sunk costs is given by the following expression

$$\hat{p}_{it} = y_{it}\left[p_{it}\left(p_t, s_{it}\right) - F_{it}^{0}(1 - y_{i,t-1}) - \sum_{j=2}^{J_i}\left(F_{it}^{j} - F_{it}^{0}\right)\tilde{y}_{i,t-j}\right] - G_{it}y_{i,t-1}(1 - y_{it}) \qquad (1)$$

were the indicator variable y_{it} takes the value of 1 if the firm performs R&D in period t and 0 otherwise. p_{it} is the current increment to gross profits associated with the decision of performing R&D; firm-specific characteristics, market characteristics and spillovers (industry, regional and local) are included in the vector s_{it}; while other factors such as credit market conditions, R&D policy and macro conditions are included in p_t. J_i is the age of the firm and $\tilde{y}_{i,t-j} = \left(y_{i,t-j}\prod_{k=1}^{j-1}\left(1-y_{i,t-k}\right)\right)$ summarizes firm *i* recent R&D experience and takes the value of 1 if the last period that firm *i* performed R&D was period $t-j$ and 0 otherwise. To account for sunk costs we make the following assumptions. First, a firm that has never done R&D would face an entry cost of F_{it}^{0} and would earn the first year doing R&D, $p_{it}\left(p_{it}, s_{it}\right)-F_{it}^{0}$. Second, a firm that did R&D in the previous period, i.e. if $y_{i,t-1}=1$, does not have to pay the entry cost in t and would earn $p_{it}\left(p_{t}, s_{it}\right)$, but if this firm decides to exit it would incur in an exit cost represented by $-G_{it}$. Finally, we also consider firms that abandon R&D activities in previous periods (t - j with $j \geq 2$) and decide to re-start R&D again. In this case, we will assume that the firm faces a re-entry cost of F_{it}^{j}, which would leave the firm earnings, $p_{it}\left(p_{i}, s_{it}\right)-F_{it}^{j}$. The j subscript indicates that re-entry costs depend on the length a firm has been away from R&D activities. This time-dependence could reflect the depreciation of knowledge and experience accumulated during the R&D period or the increasing cost of updating the firm to the "changing" R&D activities. The *i* and *t* subscripts allow for sunk costs to vary both across firms (with differences in size, experience, ownership and other characteristics) and time (changes in financial or credit market conditions, R&D policies that affect choices of firms, etc.).

We assume that in period *t* managers plan the firm R&D participation sequence that maximises the expected current and discounted future profits net of sunk costs.[8] This maximised payoff is,

$$V_{it} = \max_{\{y_{is}\}_{s=t}^{\infty}} E_t\left(\sum_{s=t}^{\infty} d^{\,s-t}\hat{p}_{is}\right) \tag{2}$$

where E_t is an expectations operator conditioned on the set of firm information at time t and d is a time discount rate. Firm *i* chooses the current y_{it} value that satisfies the Bellman´s equation:

$$V_{it} = \max_{y_{it}} \hat{p}_{it} + dE_t\left[V_{i,t+1} \middle| \{y_{it-j}\}_{j=0}^{J_i}\right] \tag{3}$$

[8] We assume that the firm chooses the profit-maximizing level of R&D expenditures if it undertakes R&D.

Incorporating entry and exit sunk costs in a multi-period decision problem provides a means for present and past R&D decisions by the firm to influence future decisions.

A firm that decides performing R&D in t gets as expected present value of payoffs

$$p_{it} + dE_t\left(V_{i,t+1}\middle| y_{it} = 1, \left|y_{it-j}\right|_{j=1}^{J_i}\right) - F_{it}^0(1 - y_{i,t-1}) - \sum_{j=2}^{J_i}\left(F_{it}^j - F_{it}^0\right) y_{i,t-j} \qquad (4)$$

and one that decides not doing it

$$dE_t\left(V_{i,t+1}\middle| y_{it} = 0, \left|y_{it-j}\right|_{j=1}^{J_i}\right) - G_{it} y_{i,t-1} \qquad (5)$$

The *ith* firm will decide to do R&D during period *t* whenever (4) minus (5) is positive, that is when

$$p_{it} + d\left[E_t\left(V_{i,t+1}\middle| y_{it} = 1\right) - E_t\left(V_{i,t+1}\middle| y_{it} = 0\right)\right] - F_{it}^0 + \left(F_{it}^0 + G_{it}\right) y_{i,t-1} - \sum_{j=2}^{J_i}\left(F_{it}^j - F_{it}^0\right) y_{i,t-j} \geq 0$$

(6)

The empirical specification to model a firm decision to do R&D is derived from the participation condition given by equation (6). Defining the latent variable p_{it}^* as current gross operating profits plus the discounted expected future return from being an R&D firm in year *t*,

$$p_{it}^* = p_{it} + d\left[E_t\left(V_{i,t+1}\middle| y_{it} = 1\right) - E_t\left(V_{i,t+1}\middle| y_{it} = 0\right)\right] \qquad (7)$$

R&D participation is then given by the following dynamic discrete choice process:

$$y_{it} = \begin{cases} 1 \quad if \quad p_{it}^* - F_{it}^0 + \left(F_{it}^0 + G_{it}\right) y_{i,t-1} - \sum_{j=2}^{J_i}\left(F_{it}^j - F_{it}^0\right) y_{i,t-j} \geq 0 \\ 0 \qquad otherwise \end{cases} \qquad (8)$$

Following Roberts and Tybout (1997), we approximate $p_{it}^* - F_{it}^0$ as a reduced-form expression in exogenous firm characteristics and spillovers (X_{it}), macro conditions (m_t), and noise (e_{it}). Firm characteristics, spillovers and macro conditions are assumed to be observable to the firm in period *t*,

$$p^*_{it} - F^0_{it} = m_i + bX_{it} + e_{it} \qquad (9)$$

Finally, we also consider some identifying assumptions (also used in Roberts and Tybout, 1997) in relation to sunk entry, re-entry and exit costs. First, we assume that sunk costs do not vary across time. Second, we suppose that sunk entry costs for firms that have not performed R&D for at least J years are the same, $F^0_i = F^0$, and that all firms that have not performed R&D for $j < J$ years incur in the same re-entry sunk costs, $F^j_i = F^j$.[9] Finally, we consider that all firms currently doing R&D have the same exit cost $G_i = G$.[10] Using the above assumptions, re-defining $F^0 - F^j = g^j$ for j = 2,...,J and $F^0 + G = g^0$, and substituting equation (9) into (8), we have the estimation equation used in our empirical exercise,

$$y_{it} = \begin{cases} 1 \quad if \quad m_t + bX_{it} + g^0 y_{i,t-1} + \sum_{j=2}^{J} g^j \tilde{y}_{i,t-j} + e_{it} \geq 0 \\ 0 \quad \text{otherwise} \end{cases} \qquad (10)$$

From the last expression one can note that the participation decision does not depend on the firm R&D background if sunk costs are zero. This allows testing for the importance of sunk costs in the decision to do R&D by testing whether g^0 and the values of g^j, for j = 2,..., J, are jointly equal to zero. If they are significantly different from zero then it is possible to analyse the rate of depreciation of R&D experience and accumulated knowledge in R&D activities by looking at these coefficients individually.

4. Econometric issues.

Given that we are interested in isolating the effects of true state dependence (sunk costs hysteresis) in R&D activities (to the extent that R&D experience raises the risk of doing R&D in the future), we control in our modelling and estimation for: (i) endogenous initial conditions, (ii) differences in observed and unobserved characteristics between firms ("heterogeneity") and (iii) serial

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[9] The assumption that all firms that have not done R&D for $j > J$ years face the same entry costs is not very restrictive when a generous value for J is considered.

[10] These assumptions could be relaxed by including in the specification interaction terms between lagged participation variables and plant characteristics or macro variables.

correlation in the error terms. Observed persistence may be due to persistence of observable firm characteristics, serial correlation of errors, true state dependence or permanent unobserved heterogeneity. In the last three cases we observe that for given observable characteristics firms choose an option more frequently when they have chosen it in the past. However, there is only true state dependence if previous choices affect the current one. Unobserved heterogeneity or serial correlation can cause persistence in the current R&D status independently of the behavioural effects of past R&D experience (see Heckman, 1981a). In dynamic models if we do not control for permanent unobserved heterogeneity and serial correlation of errors the state dependence coefficients are seriously biased: one can get significant coefficients even when there is no state dependence and persistence is only due to permanent heterogeneity and/or serial correlation in the errors.

Thus, it is clear that to isolate the importance of sunk costs, it is critical that we control for all other sources of persistence in the R&D status. Much of this task is accomplished by including the vector of observable firm characteristics X_{it} in equation (10). However, it is highly probable that even after controlling for all the observed characteristics, there will still remain unobserved ones such as managerial ability, technology and other unobserved firm effects which affect the decision to do R&D by the firm. Since these characteristics are potentially permanent, or at least highly serially correlated and unobserved by the econometrician, they will induce persistence in R&D behaviour, either in or out of that activity, and thus will cause us to overestimate the entry costs and experience effects. In practice this means that the error term in equation (10) (e_{it}) can be thought of as comprising two components, a permanent firm-specific element (a_i) and a transitory component (u_{it}), which captures other exogenous shocks. Hence, we allow in our specification, for two sources of serial correlation in e_{it}. One coming from dependence of $\text{cov}(e_{it}, e_{it-1})$ on the permanent component of the error, and another coming from serial correlation in transitory shocks to R&D profits.[11] Furthermore, we assume $\text{cov}(X_{it}, e_{it}) = 0 \;\; \forall\, i, t$, and we normalize

[11] Roberts and Tybout (1997), in their study of sunk costs in the export decision by Colombian plants, employ a version of the random effects probit estimator suggested by Heckman (1981b). They assume that the errors are comprised of a permanent firm-specific element and a purely transitory component. The permanent component is assumed to be uncorrelated across firms, and the transitory component correlated across time. These assumptions allow them to estimate equation 10 as a dynamic random effects probit, after assuming that the errors are normally distributed. Bernard and Jensen (2003), however, assume that the transitory components are uncorrelated across time.

$Var(e_{it}) = 1$. If we use an estimator that ignores serial correlation, the model will incorrectly attribute this persistence in R&D status to sunk costs.[12]

There remains an additional problem. We observe a firm R&D status in years 1 through *T*, and our lag structure reaches back *J* periods, so equation (10) can be used to model the R&D decision in years $J+1$ through *T*. But values corresponding to the first *J* years ($y_{i1},\ldots,y_{iJ}$) cannot be treated as exogenous determinants of y_{it} because each depend on a_i and previous realizations of u_{it}, both of which are correlated with e_{it}. Heckman (1981c) suggests dealing with this "initial-conditions" problem by using an approximate representation for y_{it} when $t \le J$ and allowing the disturbances for the first *J* periods to be correlated with the disturbances in every other period. Specifically, suppose that expected profits, inherent to R&D, during the *J* pre-sample years can be represented with the equation

$$p_{it}^{*} - F_{it}^{0} = l X_{it}^{p} + e_{it}^{p} \quad (11)$$

where X_{it}^{p} is a distributed lag in pre-sample realizations on exogenous variables.[13] Then presample R&D-participation is described by[14]

$$y_{it} = \begin{cases} 1 & \text{if } 0 \le l X_{it}^{p} + e_{it}^{p} \\ 0 & \text{otherwise} \end{cases} \quad (12)$$

instead of equation (10).

We assume that the pre-sample disturbance term (e_{it}^{p}) has the same structure and properties than e_{it}. Furthermore, we allow serial correlation in disturbances to cause correlation between y_{it} ($t > J$) and the lagged participation variables $y_{i1},\ldots,y_{iJ}$. We assume that the joint distribution of the error terms $e_{i1}^{p},\ldots,e_{iJ}^{p},e_{iJ+1},\ldots,e_{iT}$, is multivariate standard normal, and it is characterised by $\{(T \times T) - T\}/2$ free distinct (and estimable) correlations.[15] In

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[12] Unmodelled persistence in the error structure would be picked up by the lagged endogenous variables and it could be incorrectly interpreted as high entry costs. This is known in the empirical literature on labour-market participation as "spurious state-dependence" (see e.g., Heckman, 1981a, b).

[13] Heckman (1981b) suggested that initial conditions could be modelled using information prior to start R&D activities. In the empirical work we include all the firm characteristics (X_{it}) as explanatory variables in X_{it}^{p}. We also include two-year lagged values of the firm's variables.

[14] Bernard and Jensen (2003) only include one lag of the endogenous variable and so they only need to model y_{i1} as initial condition.

[15] We allow for a free correlation structure over time.

our empirical work $J = 3$ and $T = 10$. Given our assumptions, we may write the full correlation matrix as:

$$\begin{vmatrix} 1 & r_{12} & r_{13} & r_{14} & r_{15} & r_{16} & r_{17} & r_{18} & r_{19} & r_{110} \\ r_{21} & 1 & r_{23} & r_{24} & r_{25} & r_{26} & r_{27} & r_{28} & r_{29} & r_{210} \\ r_{31} & r_{32} & 1 & r_{34} & r_{35} & r_{36} & r_{37} & r_{38} & r_{39} & r_{310} \\ r_{41} & r_{42} & r_{43} & 1 & r_{45} & r_{46} & r_{47} & r_{48} & r_{49} & r_{410} \\ r_{51} & r_{52} & r_{53} & r_{54} & 1 & r_{56} & r_{57} & r_{58} & r_{59} & r_{510} \\ r_{61} & r_{62} & r_{63} & r_{64} & r_{65} & 1 & r_{67} & r_{68} & r_{69} & r_{610} \\ r_{71} & r_{72} & r_{73} & r_{74} & r_{75} & r_{76} & 1 & r_{78} & r_{79} & r_{710} \\ r_{81} & r_{82} & r_{83} & r_{84} & r_{85} & r_{86} & r_{87} & 1 & r_{89} & r_{810} \\ r_{91} & r_{92} & r_{93} & r_{94} & r_{95} & r_{96} & r_{97} & r_{98} & 1 & r_{910} \\ r_{101} & r_{102} & r_{103} & r_{104} & r_{105} & r_{106} & r_{107} & r_{108} & r_{109} & 1 \end{vmatrix}$$

where there are values of 1 on the leading diagonal and correlations $r_{ts} = r_{st}$ as off-diagonal elements. The set of correlation coefficients $r_{41}, r_{51}, r_{61}, r_{71}, r_{81}, r_{91}, r_{101}, r_{42}, r_{52}, r_{62}, r_{72}, r_{82}, r_{92}, r_{102}, r_{43}, r_{53}, r_{63}, r_{73}, r_{83}, r_{93}, r_{103}$, summarises the association between unobservable factors determining initial conditions R&D status and sample years R&D status. A positive (negative) sign of all of them indicates that firms which were more likely to be initially (on initial conditions years) performing R&D were more (less) likely to remain (during sample years) R&D firms compared to the non-R&D ones. When they are jointly equal to zero, then there is no initial conditions problem: R&D status at $1,...,J$ may be treated as exogenous and the model reduces its dimension to a $T-J$ multivariate probit model. And if $r_{ts}, \forall t \neq s$, are all jointly equal to zero, then R&D equations may be estimated using simple univariate probit models. We estimate the general model with free correlations and test whether initial conditions are exogenous and whether equation errors are serially uncorrelated.

Our model is a dynamic random effects multivariate probit model, which is estimated using maximum-likelihood (ML) techniques involving T-dimensional integrals. We solved this computational problem using simulated maximum likelihood (SML) methods. Multivariate standard normal probability distribution functions are replaced by their simulated counterparts. Accordingly, we use the Geweke-Hajivassiliou-Keane (GHK) simulator.[16]

[16] The technique reduces dimensionality problems by simulating transition probabilities rather than probabilities for the entire sequence of y_{it} realizations. These simulations are done using the highly accurate GHK algorithm. The GHK simulator exploits the fact that a multivariate normal distribution function can be expressed as the product of sequentially conditioned univariate normal distribution functions, which can be easily and accurately evaluated. See

Additionally, to control for the fact that we have repeated observations on the same firm, we use a pseudo maximum likelihood estimator drawing on ideas from the survey statistics literature. The complex survey statistics literature has developed methods for adjusting the estimates of the parameter covariance matrix to account for sample clustering, using formulae that allow for arbitrary correlations between observations within the same sample cluster. See *inter alia* Huber (1967) and Binder (1983) and White (1982), for an independent derivation in the econometrics literature. We defined each cluster to consist of all the panel observations of a given firm. The sample log-likelihood is a "pseudo-likelihood" in this case (Gourieroux and Monfort, 1996), from which can be derived a "robust" variance estimator of the parameter estimates using Taylor-series linearisation. Our estimator is a Pseudo Simulated Maximum Likelihood (PSML) estimator as the pseudo-likelihood was evaluated using the GHK simulator.

5. The explanatory variables.

To parameterise the reduced-form model given by equation (10) describing the firm's R&D investment decision, we assume that variation in R&D profitability and set-up costs (apart from unobserved characteristics) arises from the following sources: time-specific effects, firm and market characteristics and spillovers.

The inclusion of time-specific effects tries to capture macro-level changes in R&D conditions and institutional factors such as R&D policy variations, the business cycle, credit-market conditions, etc.

Among the firm characteristics we distinguish four different groups[17]: economic opportunities, technological opportunities, R&D appropriability conditions and other firm characteristics.

The incentives to invest in R&D depend firstly on the economic opportunities faced by firms, that is, the scope of future demand, the size and growth of the market, and also the willingness to pay for new or improved products (Schmoockler, 1962). To proxy economic opportunities we consider the growth of firm's sales, the size of the market (local or regional, national,

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Hajivassiliou and Ruud (1994) and Gourieroux and Monfort (1996) for discussions of simulation methods and their applications to maximun likelihood estimation of multivariate limited dependent variable models. A Stata program that implements this estimator is available from Cappellari and Jenkins (2003).

[17] See the Appendix for a definition of variables.

and national or international), export intensity (Kleinschmidt and Cooper, 1990, and Kotable, 1990), the degree of product standardisation, and diversification. Exporting firms may need to innovate in order to face the competitive pressures in the international markets. Firms producing a standardised product may experience fewer incentives to innovate, since demand will not respond considerably to quality improvements (González, Jaumandreu and Pazó, 1999). The degree of product diversification is also associated with greater incentives to innovate since the firm may use its R&D results among its different products. The second group of variables influencing R&D investment decision relates to technological opportunities (Scherer, 1965, Lunn and Martin, 1986, Cohen and Levinthal, 1989). To proxy for technological opportunities we use two-digit industry dummies, labour qualification (skill) and age. According to Cohen, Levin and Mowery (1987), technological opportunities decrease with the life cycle of the firm's product.

Appropriability conditions are also a factor influencing the firm's decision to undertake R&D activities. The incentives to innovate depend on the extent to which the results from innovative activities can be appropriated by the firm or easily diffused within or across industries. The higher the appropriability of the returns to innovation, the higher the incentive to invest in R&D (Bertstein and Nadiri, 1988, 1989; Mansfield, 1985; Levin *et al.*, 1987; Levin, 1988). However, in the literature one can find two opposite effects of low levels of appropriation on innovation. On the one hand, low apropriability has a disincentive effect on R&D activities because firms are unable to appropriate the benefits of their investments (Arrow, 1962, Spence, 1984). On the other hand, when appropriability is low spillovers among firms are high and in order to take advantage of these spillovers firms may need to develop sufficient "absorptive capacity", which implies own innovation activities (Cohen and Levinthal, 1990, Kamien and Zang, 2000). To proxy for appropriability conditions we follow Beneito (2003) and calculate the ratio between total number of patents granted and the total number of firms that assert to have achieved innovations in the firms' industrial sector.

A number of firm characteristics are also assumed to influence firm's R&D decisions. The association between R&D investment and firm' size has attracted a lot of attention in the literature (Schumpeter, 1942, Acs and

Audretsch, 1987[18], Kamien and Schwartz, 1982, Cohen and Levin, 1989 for a review, and Evangelista et al., 1997). The results are mixed but in general they suggest that large firms tend to be more innovative, although this positive association is not necessarily linear. We also consider the financial and economic conditions under which the firm operates, and include as explanatory variables the degree of financial autonomy (measured as an equity to debts ratio, following Beneito, 2003), the price cost margin (following González, Jaumandreu and Pazó, 1999), labour productivity and a dummy capturing whether the firm accounts for a significant market share. We consider advertising intensity, as a proxy for the degree of horizontal product differentiation. We also include the foreign capital participation and the foreign content of the firm's physical capital, as well as a dummy capturing the legal structure of the firm.

The decision to invest in R&D will be also influenced by market characteristics, such as the degree of market concentration and competition. We calculate the concentration ratio of the four largest firms in the relevant market[19] and account for the firm's number of direct competitors. There is no clear-cut relationship between R&D activities and market power. Firms facing market competitive pressure may have incentives to innovate and obtain future market power. However, ex ante market power generates financial means to innovate and reduces risk levels. According to Scherer (1965), there is 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.

Finally, the literature on R&D has stressed the importance of spillovers on the decision to invest. Interaction with suppliers, customers, public assistance agencies, industry associations, universities and the like, can provide missing external inputs into the firm' learning process. Interaction may allow gathering information about technologies and markets, and help to obtain other inputs to complement the internal learning process, such as staff training, parts and complements and consulting services (Rothwell and Dodgson, 1991, Dogson, 1993, Lundvall, 1988, 1992). There is also a number of papers suggesting that geographical proximity generates positive

[18] Acs and Audretsch (1987) find size to be related to industry characteristics: large firms are more innovative in sectors with high concentration and barriers to entry and small firms are more innovative in sectors with low concentration and newly emerging or growing technologies.
[19] We follow Fariñas and Huergo (1994), Huergo (1998) and Beneito (2003), who calculate market concentration ratios as described in the Appendix.

externalities, market linkages and possibilities for collaboration that in turn foster technological improvements and innovations (see Romijn and Albaladejo, 2002, and the references therein). Caniels (2000) stresses the importance of local knowledge spillovers, including quick diffusion of new technologies and knowledge through close interaction with other firms. However, there is also evidence questioning the benefits of proximity (Suarez-Villa and Walrod, 1997, Stemberg, 1999), probably due to factors such as falling transport and communication costs and rising speed and quality of long distance interactions (Currant and Blackburn, 1994).

According to Griliches (1992), spillovers may be understood as ideas borrowed by research teams of firm/industry *i* from the results obtained by firm/industry *j*. We estimate the impact of spillovers from the R&D activities undertaken by other firms in the same industry or region. We consider three separate forms of spillovers: industry-specific, region-specific and local to the industry and region. Industry-specific spillovers are captured by R&D activities undertaken within the same industry but outside the region where the firm operates. Region-specific spillovers are captured by R&D activities in the same region but different industries, and local spillovers are captured by the R&D activities performed in the same industry and region in which firms operate.

In order to assess the importance of previous R&D experience on the firms current R&D investment, we include in our estimation three lags of past R&D investment. As noticed earlier, if sunk costs are not zero the current decision of the firm to invest in R&D will depend upon the firm's R&D history.

6. Estimation results.

As anticipated in section 2, the final data set used to estimate equation (10), consists of 8327 observations: eleven annual observations for 757 firms that cover the 1990-2000 period. The observations for 1991-1993 are treated as the J = 3 pre-sample years and are used to control for the initial conditions problem. The observations for 1990 are used as regressors for the 1991 initial conditions set. The observations for 1994-2000 are used to estimate the relevant parameters in equation 10.

[Insert Table 7 about here]

In the above table we report the estimation results. This estimation includes the past participation history in R&D activities up to a three lags structure, allows for serially correlated errors, individual effects and controls for endogeneity of initial conditions.

The result from a test of joint significance of all the r-correlation coefficients imply rejection of the null hypothesis that they are jointly equal to zero, with a $c^2_{45} = 269.01$ and p-value approximately equal to zero. Hence, this confirms that the proper estimation method should be a multivariate probit model, as using univariate probit models we would be ignoring two possible sources of persistence: unobserved individual heterogeneity and serial correlated error terms. Furthermore, we also perform a test for the endogeneity of initial conditions by testing the joint significance of r-correlation coefficients between initial conditions errors (J≤3) and sample years errors (J>3). Exogeneity of initial conditions is strongly rejected, with a $c^2_{21} = 141.766$ and a p-value approximately equal to zero. Thus, initial conditions should not be treated as exogenous. The null hypotheses of these tests can be find at the bottom of Table 7.

6.1. Sunk costs parameters.

We start analysing the coefficients of $y_{i,t-1}$, $\tilde{y}_{i,t-2}$ and $\tilde{y}_{i,t-3}$ that capture the importance of sunk costs. A Wald test of joint significance of these three coefficients suggests to reject the hypothesis that these are jointly equal to 0, with a c^2_3 statistic of 93.68 and a p-value approximately 0. Hence, we can conclude, that even after controlling for a general form of serial correlation, past R&D history matters. This result supports the hypothesis of the hysteresis theory that establishes the existence of sunk costs in the decision to undertake R&D activities.

As regards individual coefficients, the coefficient of $y_{i,t-1}$ is large and positive revealing that the fact that a firm was doing R&D activities last year has a strong positive impact on the probability of doing such activities this year. Additionally, this coefficient can be considered as an estimate of the "hysteresis band" (Dixit, 1989).[20] The coefficients of $\tilde{y}_{i,t-2}$ and $\tilde{y}_{i,t-3}$ measure, respectively, the reductions enjoyed by those firms that last performed R&D activities two and three years ago in the full sunk costs of entry faced by a new R&D firm. These coefficients are non significant. These results indicate a rapid

[20] The sum of sunk costs of entry for a firm that has never done R&D and sunk costs of exit for a current R&D firm.

depreciation of the experience in R&D activities: there is no significant difference between the re-entry cost of a firm that last performed R&D activities two or three years ago and a firm that never did it before. Furthermore, the lack of significance of $\tilde{y}_{i,t-2}$ and $\tilde{y}_{i,t-3}$ is supporting that our choice of a three-year lag structure seems enough to capture the relevant R&D history of a firm.[21]

6.2. Time dummies, firm characteristics and spillovers.

Next we analyse the impact of time dummies, firm characteristics and spillovers on the expected profits net of sunk entry costs ($p_{it}^{*} - F^{0}$) of a firm with no previous experience on undertaking R&D activities. Although, no time dummy is significant at a 5% level, we get that the year 1995, 1996, 1998 and 2000 dummy variables are significant at a 10% level. In addition, the hypothesis that time dummies are jointly equal to zero is not rejected (the χ_6^2 test is 8.67 and the corresponding *p*-value 0.192). This partial lack of responsiveness in expected future profits of performing R&D over time might indicate that these activities are not very sensitive to changes in macro-variables during the sample period, suggesting that both sunk costs and firm characteristics are the main factors determining firms R&D trajectories.

We further analyse the influence of observable firm characteristics on net profitability related to undertaking R&D activities. In relation to variables proxiyng for economic opportunities, we get a significant and negative effect of the firm' sales growth on the decision to undertake R&D activities. This result suggests that firms experiencing high sales' growth do not have incentives to innovate since their market are still expanding. We also find that export intensity has a significant and positive effect on the decision to invest on R&D, suggesting that firms need to innovate more in order to face more competitive international markets. Alternatively, following González et al. (1999), this result could indicate that the higher the proportion of sales in the exports markets, the higher the responsiveness of the demand to quality improvements and so, the higher the incentives to undertake R&D activities. The positive association between export intensity and R&D is also found by Cassiman and Veugelers (1999), González et al. (1999) and Beneito (2003).[22]

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[21] Analysing the decision to export with a similar approach, Roberts and Tybout (1997) include three lags of export participation although only the first of them is significant and Bernard and Jensen (2003) study includes two lags of export participation and both of them result significant.

[22] Using the same approach followed in this paper but applied to the analysis of the hysteresis in the exports market, Máñez, Rochina and Sanchis (2003) found that the intensity of R&D

In relation to the technological opportunities, we introduce a set of two-digit industry dummies. In general, we get positive and significant effects for this set of dummies and, interestingly, whenever the effects are significant, these are higher for high technological industries (see table 8).

The appropriability measure shows also a positive and significant coefficient, as González et al (1999). This suggests that the higher the appropriability conditions faced by firms, the higher their incentives to undertake R&D investments. The coefficient on the variable that proxies for labour force quality is significant indicating that those firms with a higher degree of workforce qualification have a higher innovation capacity and so greater incentives to perform R&D activities. This result is also obtained by González et al (1999) and is consistent with the "absorptive capacity" theory of Cohen and Levin (1989). Relating to firms' size, increases in firm size (measured by the number of workers) raises the probability of undertaking R&D activities. The larger firms are more likely to perform R&D activities, but not the oldest firms, as the coefficient of the *age* variable, often considered as a proxy for efficiency, is not significant. The positive association between firms' size and R&D investments is consistent with existing literature. González et al (1999) and Cassiman and Veugelers (1999) both find that larger firms have a higher propensity to undertake R&D activities. Beneito (2003), however, could not establish this clearcut association.

Relating to financial and economic conditions under which firms operate, our results show that the coefficient of labour productiviy is positive and significant, but the coefficient of our measure of the firms' price cost margin is significant and negative. This result could suggest that the better the economic conditions faced by firms, the lower the pressure to undertake R&D activities. Turning to advertising intensity, which we use as a proxy for the degree of horizontal product differentiation, we find that its coefficient is positive and significant. Firms with higher advertising expenditures are more prone to invest in R&D activities. Our results have confirmed that firms participated by foreign capital are mainly productive platforms as they are less likely to carry out R&D activities. However, the higher the foreign content of firms' physical capital, the higher the probability to invest in R&D.

Regarding to the variables trying to capture market characteristics, we do not find a significant effect of the concentration ratio nor the number of competitors on the probability to undertake R&D activities.

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expenditures have a positive effect on the firms' export probability. See also Merino (1998) and Moreno and Rodríguez (1998) for a positive association between R&D activities and exports.

Looking at spillovers, only regional spillovers seem to have a positive and significant impact on the probability of doing R&D. This may suggest that the presence of other industry R&D investors in the same region lowers the cost of entry in the innovation market, possibly by increasing the availability of specialized inputs such as R&D networks or workers with previous experience in R&D. Neither industry nor local spillovers are significant.

6.2. Goodness of fit.

As in Roberts and Tybout (1997), to evaluate the goodness of fit of our model we compare actual and predicted R&D trajectories. For the seven-year period 1994-2000 there are 128 (2^7) possible R&D trajectories for an individual firm.[23] Across the 748 firms of our sample, some of these trajectories either are never observed or are quite unusual. Hence, to simplify the comparison of actual and predicted trajectories, we group the 128 possible trajectories into 6 categories based on two criteria: the firm R&D status in 1994 and whether the firm changes R&D status once or more between 1995 and 2000. Table 9 shows that actual and predicted frequencies for these six categories are quite similar. Furthermore, the results of a chi-square contingency table test, comparing actual and predicted frequencies (c^2=1.879 with *p*-value of 0.866), indicate that there are not significant differences between both of them. These results suggest that our functional form, lags structure and error structure are quite appropriate and that our model predicts quite accurately observed R&D patterns.

[Insert Table 9 about here]

7. Concluding remarks.

Our analysis has confirmed the existence of sunk costs in firms' R&D activities. In a dynamic framework and using panel data, we have rejected the null hypothesis that sunk costs related to starting and leaving R&D activities are not important when firms have to decide whether to start or not R&D activities. Thus, we have found evidence supporting the sunk costs as the main explanation of the observed firm persistence in and out of R&D activities.

[23] Actual and predicted frequencies for the complete 128 possible trajectories are shown in Table A2 in the appendix.

Our estimation results have indicated that those firms that leave R&D activities suffer a rapid depreciation of their experience. Re-entry costs that faces a firm that last performed R&D two years ago are not significantly different from those faced by a firm that have never undertook R&D activities before. This phenomenon could be suggesting that R&D activities take place in a rapidly changing environment and that the ability to work in this environment depreciates fairly quickly once a firm quits R&D activities.

Firm heterogeneity has shown to be also an important source of persistence in R&D activities as both observed and unobserved firm characteristics are important to explain firms' R&D trajectories. Regarding to the firms' economic opportunities, the probability of undertaking R&D increases with export intensity. Among firms' technological opportunities, we have found that the higher degree of appropriability of R&D results, the higher the probability of performing R&D. Firms in high technological industries also are more prone to invest in R&D. Larger, more productive and more skilled labour force firms show a higher propensity to undertake R&D activities. Firms that horizontally differentiate their products by means of advertising also have a higher probability of exporting.

Our results have confirmed that firms participated by foreign capital are mainly productive platforms as they are less likely to carry out R&D activities. However, the higher the foreign content of firms' physical capital, the higher the probability to invest in R&D.

Only regional spillovers have a positive impact on the probability of performing R&D.

The combined importance of sunk costs and firm characteristics in the probability of investing in R&D suggest possible R&D promotion policies. On the one hand, policies directed at providing information and access R&D activities or creating R&D networks could reduce the sunk costs of entry. On the other hand, policies aimed to help firms to increase productivity, to stimulate product differentiation behaviours or to participate in the export market would have a positive impact on the probability of performing R&D.

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Table 1: Sample representativeness : large vs. small firms, 1990.

	1990 complete sample		*Continuing Sample 1990*	
	Small firms	Large firms	Small firms	Large firms
Number of firms	1476	708	540	217
% of the firms	67.58%	32.42%	71.33%	28.67%
% of total employment	9.34%	90.66%	13.34%	86.66%
% of total sales	6.92%	93.08%	11.46%	88.54%
% of total R&D	3.91%	96.09%	4.68%	95.32%

Table 2: Sample representativeness : R&D firms vs. non R&D firms, 1990.

	1990 complete sample		***Continuing Sample 1990***	
	Non R&D Firms	R&D firms	Non R&D Firms	R&D firms
1. Small firms				
Number of firms	1215	261	447	93
% of firms of the sample	82.32%	17.68%	82.78%	17.68%
Average size (employees)	32.64	66.43	32.56	61.86
R&D expenditure/Sales	0%	2.48%	0%	2.07%
% total employment	69.59%	30.41%	71.67%	28.33%
% total sales	66.88%	33.12%	69.69%	30.31%
2. Large firms				
Number of firms	225	483	67	150
% of sample	31.78%	68.22%	30.88%	69.12%
Average size (employees)	506.30	900.50	572.97	626.16
R&D Expenditure/Sales	0.%	1.79%	0%	2.57%
% total employment	20.76%	79.24%	29.01%	70.99%
% total sales	18.94%	81.06%	35.95%	64.55%

Table 3: R&D characteristics.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
1. Small firms											
Number of R&D firms	93	114	113	125	116	114	127	110	122	125	122
Number of Non-R&D firms	447	430	451	455	457	458	448	454	441	441	439
% of R&D firms	17.22%	20.96%	20.04%	21.55%	20.24%	19.93%	22.09%	19.50%	21.67%	22.08%	21.75%
Total Sales	265.256	278.537	305.052	357.729	371.515	387.515	441.610	440.470	464.283	497.948	463.779
Total R&D Expenditure	1.676	1.616	2.041	2.367	2.265	2.733	3.245	2.371	2.231	3.187	3.160
R&D Exp./Sales (%)	0.63%	0.58%	0.66%	0.65%	0.60%	0.69%	0.71%	0.52%	0.46%	0.61%	0.66%
1. Large firms											
Number of R&D firms	150	143	128	122	131	126	129	141	153	153	153
Number of Non-R&D firms	67	70	65	53	53	59	53	52	41	38	43
% of R&D firms	69.12%	67.14%	66.32%	68.93%	71.20%	68.11%	70.88%	73.06%	78.87%	80.10%	78.06%
Total Sales	2051.117	2105.595	2074.821	1924.480	2272.114	2508.862	2492.462	2736.083	2932.460	3126.133	3410.264
Total R&D Expenditure	34.132	28.970	35.259	60.324	68.082	53.813	59.686	49.792	63.466	75.389	87.753
R&D Exp./Sales (%)	1.66%	1.40%	1.73%	3.19%	3.05%	2.16%	2.43%	1.83%	2.24%	2.55%	2.69%

Total R&D expenditure and total sales are in thousand of millions. The denominator or the ratio R&D Exp./Sales includes sales of both R&D and Non R&D firms.

Table 4: Firms transition rates in the R&D market 1990-2000.

Year *t* status	Year *t*+1 status	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99	1999-2000	Average 1990-2000
1. Small firms												
Non R&D	Non R&D	0.9128	0.9554	0.9402	0.9443	0.9542	0.941	0.9533	0.9264	0.9335	0.943	0.9404
	R&D	0.0872	0.0446	0.0598	0.0557	0.0458	0.059	0.0467	0.0736	0.0665	0.057	0.0596
R&D	Non R&D	0.1935	0.2456	0.2095	0.2752	0.233	0.1313	0.2411	0.1714	0.2353	0.1765	0.2112
	R&D	0.8065	0.7544	0.7905	0.7248	0.767	0.8687	0.7589	0.8286	0.7647	0.8235	0.7888
2. Large firms												
Non R&D	Non R&D	0.806	0.9189	0.8765	0.7848	0.9178	0.8026	0.863	0.7887	0.8689	0.8793	0.8507
	R&D	0.194	0.0811	0.1235	0.2152	0.0822	0.1974	0.137	0.2113	0.1311	0.1207	0.1494
R&D	Non R&D	0.1333	0.0909	0.0588	0.0797	0.0625	0.0851	0.0556	0.0342	0.0321	0.0818	0.0714
	R&D	0.8667	0.9091	0.9412	0.9203	0.9375	0.9149	0.9444	0.9658	0.9679	0.9182	0.9286

Each one of the entries in the table is the proportion of firms in each of the year *t* status that chooses each of the two possible status in year *t*+1.

Table 5: Persistence of R&D activities (and Non-R&D)

Proportion of 1990 firms with the same export status.

	(1) R&D firms Actual	(2) Non-R&D firms Actual	(3) R&D firms Expected	(4) Non-R&D firms Expected
2. Small firms				
1991	80.65%	91.28%	80.65%	91.28%
1992	73.11%	91.72%	60.84%	87.21%
1993	69.89%	90.16%	48.10%	81.99%
1994	63.44%	90.16%	34.86%	77.43%
1995	61.29%	90.60%	26.74%	73.88%
1996	63.44%	88.14%	23.23%	69.52%
1997	60.21%	89.04%	17.63%	66.27%
1998	63.44%	86.58%	14.61%	61.40%
1999	63.44%	86.58%	11.17%	57.31%
2000	66.67%	86.58%	9.20%	54.05%
3. Large firms				
1991	86.67%	80.60%	86.67%	80.60%
1992	80.67%	77.62%	78.79%	74.06%
1993	80.67%	74.63%	74.16%	64.92%
1994	81.33%	67.16%	68.25%	50.95%
1995	78.00%	64.18%	63.98%	46.76%
1996	80.00%	64.18%	58.54%	37.53%
1997	82.00%	65.67%	55.28%	32.39%
1998	84.00%	55.22%	53.39%	25.54%
1999	84.00%	50.74%	51.68%	22.19%
2000	81.33%	53.73%	47.45%	19.52%

Note: The figures in columns (1) and (2) represent the percentage of R&D (non R&D) firms that were also R&D (non-R&D) in the listed year, i.e. 62.65 of the small firms that carry out R&D in 1990 also did it in 1996. The figures in columns (3) and (4) show the expected percentages if entering and exiting firms were chosen randomly with annual transition rates given by the data. Let us an example how we calculate columns (3) and (4) figures. In 1990 the number of R&D firms in the small firms group was 83 (see Table 4) and from Table 5 we know that the exit rate for the small firms group for the 1990-1991 period is 20.48%. Therefore, the expected number of R&D firms in 1991 is obtained as 83*(1-0.2048)=66, and 66 is approximately 79.51% of 83.

Table 6: Variables definition.

$y_{i,t-1}$	Dummy that takes value one if the firm performed R&D in year t -1.
$y_{i,t-2}$	Dummy that takes value one if the firm did not perform R&D last year but performed R&D two years ago.
$y_{i,t-3}$	Dummy that takes value one if the last time that the firm performed R&D was three years ago.
Year dummies	Dummy variables that take value 1 for the corresponding year.
Sales growth	Growth rate of domestic sales in real terms (in %).
Regional market	Dummy variable that equals 1 if the geographic limits of the firm's main market is local, provincial or regional, and 0 otherwise.
National Market	Dummy variable that equals 1 if the geographic limits of the firm's main market is national, and 0 otherwise
International-National market	Dummy variable that equals 1 if the geographic limits of the firm's main market is foreign or both national and foreign, and 0 otherwise.
Export intensity	Exports to sales ratio (in %).
Standardized product	Dummy variable that equals 1 if the firm asserts to offer a standardized product (as opposed to specifically designed for the customers), and 0 otherwise
Appropriability	Ratio of the total number of patents over the total number of firms that assert to have achieved innovations in the firm's industrial sector (50 sectors of the NACE-93 classification)
Labour quality	Ratio of the number of highly qualified workers to total employment (once the R&D labour force is deducted) (in %).
Size1	Dummy variable that equals 1 if the number of workers of the firm is below or equal to 20, and 0 otherwise.
Size2	Dummy variable that equals 1 if the average number of workers of the firm is above 20 and below or equal to 50, and 0 otherwise.
Size3	Dummy variable that equals 1 if the average number of workers of the firm is above 50 and below or equal to 100, and 0 otherwise.
Size4	Dummy variable that equals 1 if the average number of workers of the firm is above 100 and below or equal to 200, and 0 otherwise.
Size5	Dummy variable that equals 1 if the average number of workers of the firm is above 200 and below or equal to 500, and 0 otherwise.
Size6	Dummy variable that equals 1 if the average number of workers of the firm is above 500, and 0 otherwise.
Price-cost margin (PCM)	Approximated by the value of gross output minus variable costs of production, divided by the value of gross output. The gross value output is computed as sales + stock variation + other revenues. The variable cost of production is computed as intermediate consumption (raw material and services) + labour costs. R&D services have been excluded from costs, and an estimation of the costs represented by R&D personnel has been deduced from the total labour costs.
Productivity	Log of labour productivity.
Significant market share	Dummy variable taking the value of 1 if the firm asserts to account for a significant market share in its main market, and 0 otherwise.
Equity-debt ratio	This variable is computed from the balance sheet of the firm, provided by the questionnaire of the ESEE. It is defined as the sum of total own funds of the firm over total debts
Public sales	Dummy variable that takes value one if more than 25% of firm sales go to the public sector.
Advertising	Advertising expenditure normalized by sales (in %).
Foreign	Dummy variable that takes value one if more than 25% of the firm shares are foreign owned.
FEQ	Firm's average percentage of foreign physical equipment
Corporate	Dummy variable that takes value one if the firm is a limited liability corporation.

Table 6: Variables definition (*continuation*).

CR4	This is the four-firm concentration ratio, i.e. the market share accounted for by the four largest firms in the principal market in which firms compete. This variable shows a high degree of no response in the ESEE. For this reason an estimation of this variable has been carried out for those firms that do not respond. Following Huergo (1994) and Fariñas and Huergo (1994), the four-firm concentration ratio is computed from the responses of firms in the same 'market', this market being identified taking into account the industrial sector (50 industries defined from the three-digit NACE classification), the geographic limits in which they mainly commercialise their products (local, regional, national or abroad) and the number of competitors themselves claim to have in their main market.
Number of competitors 0-10	Dummy variable that equals 1 if the firm asserts to have less than (or equal to) 10 competitors with significant market share in their main market, and 0 otherwise.
Number of competitors 10-25	Dummy variable that equals 1 if the firm asserts to have more than 10 and less than (or equal to) 25 competitors with significant market share in their main market, and 0 otherwise
Number of competitors > 25	Dummy variable that equals 1 if the firm asserts to have more than 25 competitors with significant market share in their main market, and 0 otherwise.
Region-specific spillovers	Fraction of firms that perform R&D in the region but outside the corresponding NACE-93 industry (20 industries).
Industry-specific spillovers	Fraction of firms that perform R&D in the NACE-93 industry (20 industries) but outside a given region.
Local-spillovers	Fraction of firms that perform R&D in the region and the NACE-93 industry.
Age	Log of the number of years since the firm was born.
Diversification	This variable tries to approximate the degree of differentiation of the firm's line of business. The ESEE provides information about the main products offered by the firm that account for at least the 50% of its total amount of sales. Using such information, this variable has been defined as the number of products that account for at least this percentage.
Industry dummies	20 industrial sectors of the NACE-93 classification[24]

[24] See table A2 for the classification of industries.

Table 7: Probit models for the decision to undertake R&D activities.

	Coefficient	Standard Error
$y_{i,t-1}$	1.891***	(0.202)
$\tilde{y}_{i,t-2}$	0.214	(0.140)
$\tilde{y}_{i,t-3}$	0.204	(0.143)
Year 1995	-0.120	(0.100)
Year 1996	0.014	(0.101)
Year 1997	-0.121	(0.095)
Year 1998	0.100	(0.100)
Year 1999	0.017	(0.996)
Year 2000	-0.083	(0.101)
Sales growth	-7.0e-05**	(3.6e-05)
National market	0.051	(0.074)
International and National market	0.077	(0.089)
Export intensity	0.067**	(0.030)
Standardized product	-0.050	(0.064)
Appropriability	0.035**	(0.019)
Labour quality	0.013**	(0.006)
Size2	0.219***	(0.078)
Size3	0.301***	(0.122)
Size4	0.603***	(0135)
Size5	0.910***	(0.136)
Size6	1.175***	(0.179)
PCM	-0.002***	(0.001)
Productivity	0.131***	(0.049)
Significant market share	0.090	(0.061)
Equity-debt ratio	-1.67e-05	(6.8e-05)
Advertising	0.015**	(0.008)
Foreign	-0.241***	(0.087)
FEQ	0.002***	(0.001)
Corporate	-0.001	(0.076)
Concentration ratio 4 (CR4)	0.001	(0.001)
Number competitors <10	-0.008	(0.069)
Number competitors 10-25	0.004	(0.094)
Regional Spillovers	0.008**	(0.004)
Industry Spillovers	-0.006	(0.005)
Local Spillovers	0.001	(0.001)
Age	0.045	(0.057)
Public Sales	-0.095	(0.202)
Number of products (diversification)	-0.032	(0.056)
Food and tobacco	0.063	(0.182)
Beverages	0.404	(0.310)
Textiles	0.286	(0.179)
Leather and shoes	0.494**	(0.238)
Wood	0.124	(0.286)
Paper	0.181	(0.239)
Printing	-0.219	(0.223)
Chemical products	1.033***	(0.330)
Rubber and plastic	0.686***	(0.233)
Non metallic miner	0.483***	(0.187)
Metallurgy	0.866***	(0.340)
Metallic products	0.391**	(0.183)
Machinery and mech. eq.	0.915***	(0.279)
Office machines	0.167	(0.381)
Electronic	0.834***	(0.289)
Motors and cars	0.752***	(0.267)
Other transport material	0.324	(0.237)
Furniture	0.234	(0.262)
Other manufacturing goods	0.310	(0.240)
Intercept	-3.908***	(0.496)
Tests for column (1) estimations:		
1. Test of joint significance of the between periods correlation coefficients[a]	$c^2_{45} = 269.01$	p − value = 0.000
2. Test of joint significance of the correlation between the J = 3 initial conditions periods and J > periods[b]	$c^2_{21} = 141.766$	p − value = 0.000

***, **, * indicate significance at the 1%, 5% and 10% respectively

[a] The null hypothesis of this test is:

$$H_0 : r_{21} = r_{31} = r_{41} = r_{51} = r_{61} = r_{71} = r_{81} = r_{91} = r_{101} = r_{32} = r_{42} = r_{52} = r_{62} = r_{72} == r_{82} = r_{92} = r_{102} =$$
$$= r_{43} = r_{53} = r_{63} = r_{73} = r_{83} = r_{93} = r_{103} = r_{54} = r_{64} = r_{74} = r_{84} = r_{94} = r_{104} = r_{65} = r_{75} = r_{85} = r_{95} =$$
$$= r_{105} = r_{76} = r_{86} = r_{96} = r_{106} = r_{87} = r_{97} = r_{107} = r_{98} = r_{108} = r_{109} = 0$$

[b] The null hypothesis of this test is:

$$H_0 : r_{41} = r_{51} = r_{61} = r_{71} = r_{81} = r_{91} = r_{101} = r_{42} = r_{52} = r_{62} = r_{72} = r_{82} = r_{92} = r_{102} =$$
$$= r_{43} = r_{53} = r_{63} = r_{73} = r_{83} = r_{93} = r_{103}$$

Table 8: Industrial technological intensity.

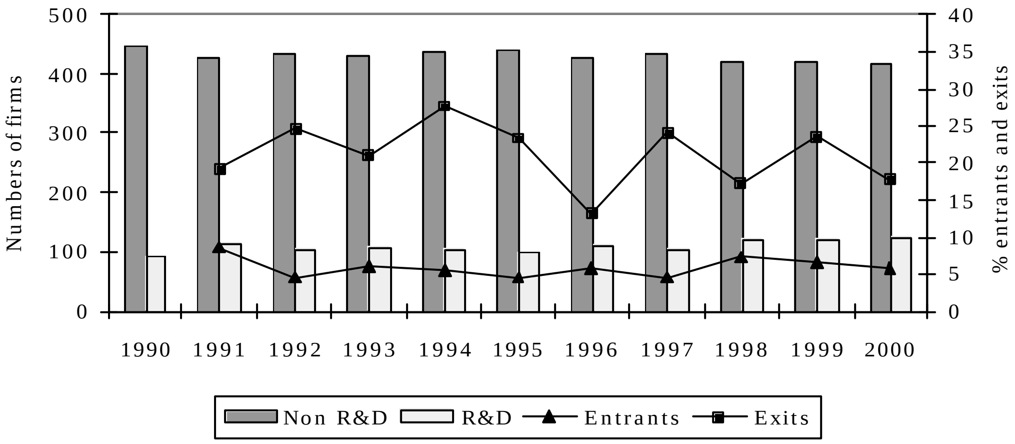
Low technological intensity	Coefficient	S.E.
Beverages	0.404	(0.310)
Textiles	0.286	(0.179)
Leather and shoes	0.494**	(0.238)
Wood	0.124	(0.286)
Paper	0.181	(0.239)
Printing	-0.219	(0.223)
Non metallic miner	0.483***	(0.187)
Metallic products	0.391**	(0.183)
Furniture	0.234	(0.262)
Other manufacturing goods	0.310	(0.240)
Medium technological intensity		
Food and tobacco	0.063	(0.182)
Rubber and plastic	0.686***	(0.233)
Metallurgy	0.866***	(0.340)
Machinery and mech. eq.	0.915***	(0.279)
Motors and cars	0.752***	(0.267)
High technological intensity		
Chemical products	1.033***	(0.330)
Office machines	0.167	(0.381)
Electronic	0.834***	(0.289)
Other transport material	0.324	(0.237)

Table 9: Observed vs. predicted frequencies of y_{it} trajectories.

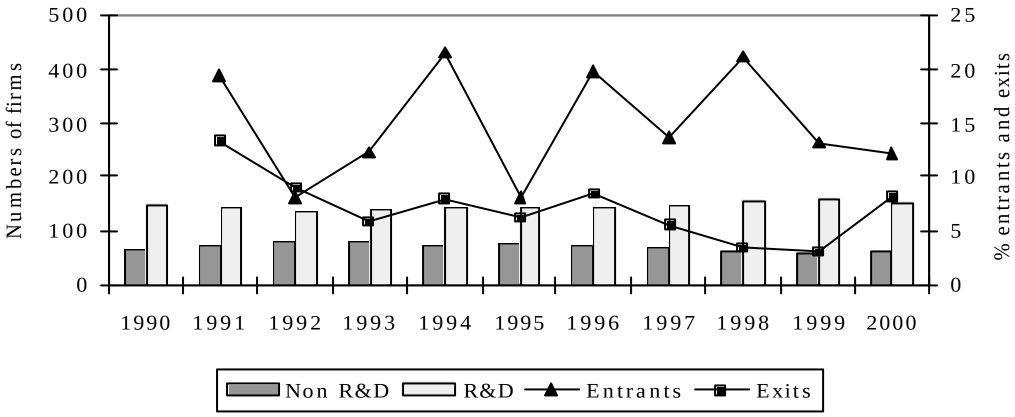
Trajectory type	Observed frequencies	Predicted frequencies
Always non R&D firm	0.493	0.508
Begin as non R&D firm , switch once	0.082	0.076
Begin as non R&D firm, switch at least twice	0.099	0.091
Always an R&D firm	0.214	0.214
Begin as R&D firm, switch once	0.048	0.040
Begin as R&D firm, switch at least twice	0.064	0.071

Figure 1: Transitions in and out of R&D activities

a. Small Firms

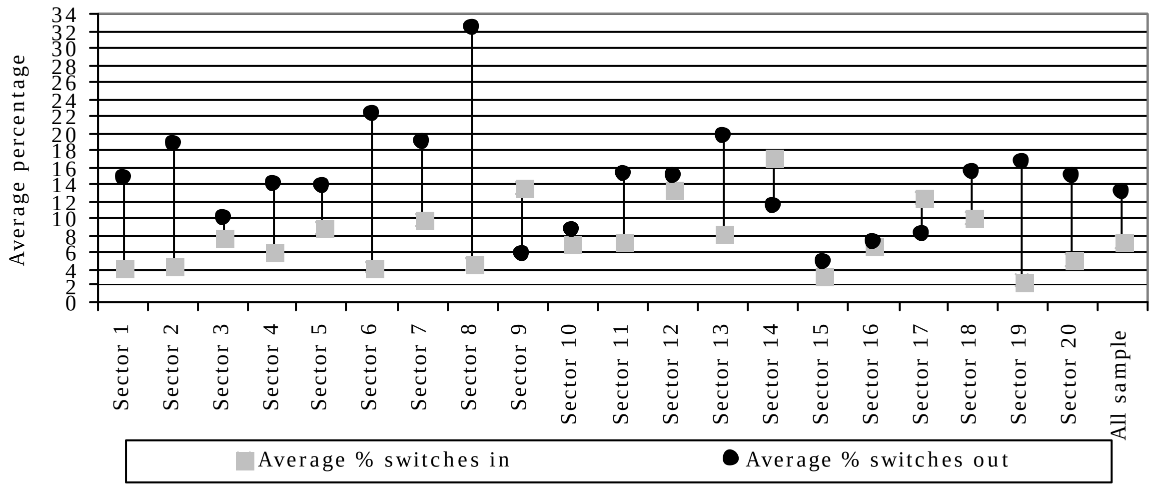


b. Large Firms



Note: The number of R&D firms and non-R&D firms are represented by the bar graph (left hand axis). The percentage of plants exiting and entering the R&D market are shown by the lines.

Figure 2: Industry switching in and out of R&D activities



Note: The average annual entry rates (into the R&D market) and exit rates (out of the R&D market) are represented by the squares and the circles respectively.

Appendix.

Table A.1: Industrial sector classification.

Code	Sectors
1	Meat industry
2	Food and tobacco
3	Beverages
4	Textiles
5	Leather and shoes
6	Wood
7	Paper Industry
8	Printing and printing stuff
9	Chemical products
10	Rubber and plastic products
11	Non metallic miner products
12	Metallurgy
13	Metallic products
14	Machinery and mechanic equipment
15	Office machines
16	Electronic and electric machinery and material
17	Motors and cars
18	Other transport material
19	Furniture
20	Other manufacturing goods

Table A2: Actual and predicted frequencies.

R&D activities status									R&D activities status								
94	95	96	97	98	99	00	Actual Frequency	Expected Frequency	94	95	96	97	98	99	00	Actual Frequency	Expected Frequency
1	1	1	1	1	1	1	0.2140	0.2139	0	1	1	1	1	1	1	0.0092	0.0094
1	1	1	1	1	1	0	0.0092	0.0040	0	1	1	1	1	1	0	0.0040	0.0040
1	1	1	1	1	0	1	0.0066	0.0013	0	1	1	1	1	0	1	0.0013	0.0027
1	1	1	1	1	0	0	0.0026	0.0053	0	1	1	1	1	0	0	0.0026	0.0053
1	1	1	1	0	1	1	0.0040	0.0013	0	1	1	1	0	1	1	0.0000	0.0013
1	1	1	1	0	1	0	0.0000	0.0000	0	1	1	1	0	1	0	0.0000	0.0013
1	1	1	1	0	0	1	0.0026	0.0040	0	1	1	1	0	0	1	0.0000	0.0000
1	1	1	1	0	0	0	0.0053	0.0053	0	1	1	1	0	0	0	0.0013	0.0000
1	1	1	0	1	1	1	0.0026	0.0053	0	1	1	0	1	1	1	0.0000	0.0027
1	1	1	0	1	1	0	0.0013	0.0000	0	1	1	0	1	1	0	0.0000	0.0013
1	1	1	0	1	0	1	0.0000	0.0000	0	1	1	0	1	0	1	0.0000	0.0000
1	1	1	0	1	0	0	0.0013	0.0000	0	1	1	0	1	0	0	0.0000	0.0000
1	1	1	0	0	1	1	0.0053	0.0040	0	1	1	0	0	1	1	0.0013	0.0000
1	1	1	0	0	1	0	0.0000	0.0000	0	1	1	0	0	1	0	0.0013	0.0000
1	1	1	0	0	0	1	0.0000	0.0027	0	1	1	0	0	0	1	0.0013	0.0000
1	1	1	0	0	0	0	0.0053	0.0027	0	1	1	0	0	0	0	0.0013	0.0027
1	1	0	1	1	1	1	0.0040	0.0027	0	1	0	1	1	1	1	0.0013	0.0000
1	1	0	1	1	1	0	0.0013	0.0000	0	1	0	1	1	1	0	0.0000	0.0000
1	1	0	1	1	0	1	0.0000	0.0000	0	1	0	1	1	0	1	0.0000	0.0000
1	1	0	1	1	0	0	0.0013	0.0000	0	1	0	1	1	0	0	0.0000	0.0013
1	1	0	1	0	1	1	0.0000	0.0000	0	1	0	1	0	1	1	0.0000	0.0000
1	1	0	1	0	1	0	0.0000	0.0000	0	1	0	1	0	1	0	0.0000	0.0000
1	1	0	1	0	0	1	0.0000	0.0000	0	1	0	1	0	0	1	0.0000	0.0000
1	1	0	1	0	0	0	0.0000	0.0027	0	1	0	1	0	0	0	0.0000	0.0000
1	1	0	0	1	1	1	0.0026	0.0013	0	1	0	0	1	1	1	0.0026	0.0013
1	1	0	0	1	1	0	0.0013	0.0000	0	1	0	0	1	1	0	0.0000	0.0000
1	1	0	0	1	0	1	0.0000	0.0000	0	1	0	0	1	0	1	0.0000	0.0000
1	1	0	0	1	0	0	0.0000	0.0013	0	1	0	0	1	0	0	0.0026	0.0000
1	1	0	0	0	1	1	0.0026	0.0000	0	1	0	0	0	1	1	0.0000	0.0013
1	1	0	0	0	1	0	0.0000	0.0040	0	1	0	0	0	1	0	0.0000	0.0013
1	1	0	0	0	0	1	0.0000	0.0040	0	1	0	0	0	0	1	0.0013	0.0000
1	1	0	0	0	0	0	0.0092	0.0067	0	1	0	0	0	0	0	0.0026	0.0053
1	0	1	1	1	1	1	0.0026	0.0107	0	0	1	1	1	1	1	0.0172	0.0053
1	0	1	1	1	1	0	0.0013	0.0000	0	0	1	1	1	1	0	0.0000	0.0040
1	0	1	1	1	0	1	0.0000	0.0000	0	0	1	1	1	0	1	0.0000	0.0000
1	0	1	1	1	0	0	0.0000	0.0013	0	0	1	1	1	0	0	0.0000	0.0000
1	0	1	1	0	1	1	0.0000	0.0000	0	0	1	1	0	1	1	0.0013	0.0000
1	0	1	1	0	1	0	0.0000	0.0000	0	0	1	1	0	1	0	0.0013	0.0000
1	0	1	1	0	0	1	0.0013	0.0000	0	0	1	1	0	0	1	0.0013	0.0040
1	0	1	1	0	0	0	0.0013	0.0000	0	0	1	1	0	0	0	0.0013	0.0027
1	0	1	0	1	1	1	0.0000	0.0000	0	0	1	0	1	1	1	0.0053	0.0027
1	0	1	0	1	1	0	0.0000	0.0000	0	0	1	0	1	1	0	0.0000	0.0000
1	0	1	0	1	0	1	0.0000	0.0000	0	0	1	0	1	0	1	0.0000	0.0000
1	0	1	0	1	0	0	0.0000	0.0000	0	0	1	0	1	0	0	0.0026	0.0000
1	0	1	0	0	1	1	0.0000	0.0013	0	0	1	0	0	1	1	0.0013	0.0013
1	0	1	0	0	1	0	0.0000	0.0000	0	0	1	0	0	1	0	0.0013	0.0013
1	0	1	0	0	0	1	0.0000	0.0000	0	0	1	0	0	0	1	0.0000	0.0000
1	0	1	0	0	0	0	0.0026	0.0013	0	0	1	0	0	0	0	0.0119	0.0053
1	0	0	1	1	1	1	0.0026	0.0040	0	0	0	1	1	1	1	0.0079	0.0120
1	0	0	1	1	1	0	0.0000	0.0000	0	0	0	1	1	1	0	0.0053	0.0000
1	0	0	1	1	0	1	0.0000	0.0000	0	0	0	1	1	0	1	0.0013	0.0027
1	0	0	1	1	0	0	0.0000	0.0000	0	0	0	1	1	0	0	0.0053	0.0027
1	0	0	1	0	1	1	0.0000	0.0027	0	0	0	1	0	1	1	0.0013	0.0027
1	0	0	1	0	1	0	0.0000	0.0013	0	0	0	1	0	1	0	0.0000	0.0000
1	0	0	1	0	0	1	0.0000	0.0013	0	0	0	1	0	0	1	0.0000	0.0000
1	0	0	1	0	0	0	0.0013	0.0027	0	0	0	1	0	0	0	0.0066	0.0080
1	0	0	0	1	1	1	0.0013	0.0027	0	0	0	0	1	1	1	0.0172	0.0120
1	0	0	0	1	1	0	0.0000	0.0000	0	0	0	0	1	1	0	0.0053	0.0053
1	0	0	0	1	0	1	0.0013	0.0000	0	0	0	0	1	0	1	0.0013	0.0013
1	0	0	0	1	0	0	0.0040	0.0013	0	0	0	0	1	0	0	0.0092	0.0053
1	0	0	0	0	1	1	0.0026	0.0013	0	0	0	0	0	1	1	0.0119	0.0201
1	0	0	0	0	1	0	0.0013	0.0013	0	0	0	0	0	1	0	0.0106	0.0094
1	0	0	0	0	0	1	0.0026	0.0027	0	0	0	0	0	0	1	0.0185	0.0174
1	0	0	0	0	0	0	0.0172	0.0160	0	0	0	0	0	0	0	0.4927	0.5080