# A SURVIVAL ANALYSIS OF MANUFACTURING FIRMS IN EXPORT MARKETS*

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**Abstract**

This paper examines persistence of firms in export markets using a sample of Spanish manufacturing firms for the period 1990-2000. The data are drawn from the Spanish *Encuesta sobre Estrategias Empresariales*. The paper is mainly focus on finding evidence of two major hypotheses. On the one hand, the longer a firm exports the longer it will remain doing so. On the other hand, firms exporting to "closer" markets would generally last longer than firms exporting to more unknown or uncertain markets. For this purpose, we estimate three discrete time (interval data) proportional hazard models that account for right censoring, fully non-parametric baseline hazard and both parametric and fully non-parametric unobserved individual heterogeneity. Our results strongly support both hypotheses. Furthermore, we also find some other firm, product and market characteristics which are revealed to be important determinants for survival of Spanish firms in export markets, such as size, productivity, export and R&D intensities, and final consumption goods.

**Key words:** persistence in trade, duration dependence, integrated markets, competitiveness, survival analysis

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## 1. Introduction.

Most of the existing literature analysing persistence patterns in firms´ exporting behaviour focuses on assessing the importance of sunk costs hysteresis in the decision to export. The theoretical literature on sunk costs and exporting was developed by Dixit (1989a,b), Baldwin (1988), Baldwin (1989), Baldwin and Krugman (1989) and Krugman (1989). Acknowledging for the existence of sunk costs implies that current exports depend on past export trajectories and, more interestingly, that transitory changes in trade policy or macroeconomic conditions may lead to permanent changes in market structure, that is, sunk entry or exit costs produce hysteresis in export flows. Furthermore, when there is uncertainty about market conditions, the existence of sunk costs affects the entry and exit patterns as trade flows are less responsive to changes in market conditions, such as exchange rates or incentives (subsidies) for exports. Thus, in these models, the cause of persistence in firms' exporting behaviour is the existence of sunk cost.

The first attempt to address the sunk-cost hysteresis hypothesis in the empirical literature on exporting is Roberts and Tybout (1997), who directly analyse exporting entry and exit patterns using plant-level panel data for Colombian manufacturing. More recent empirical evidence on sunk costs hysteresis are Bernard and Wagner (1998), Bernard and Jensen (2004), Campa (2004) and Máñez *et al.* (2004), for German plants, U.S. plants and Spanish firms, respectively.

This paper provides a new way to analyse persistence in firms´ exporting behaviour and represents a departure from the previous existent empirical literature. We are not interested in the determinants of the firm decision to export, or in analysing how sunk costs affect the dynamics of firms' export behaviour. Instead, we are interested in investigating what keeps a firm exporting over time once a firm becomes an exporter. In particular, our main focus lies in explaining the dynamics of firms' exporting behaviour *per se*, instead of describing the type of dynamics imposed by models relaying on the existence of sunk costs.

To the best of our knowledge, there is only one study comparable to the analysis we attempt to undertake in this paper. This is the work by Bosco-Sabuhoro and Gervais (2004), who use survival methods to analyse the factors determining the success or failure of Canadian establishments in foreign markets[1]. However, our work differs from their study in many respects. First, we use a sample of Spanish manufacturing firms for the period 1990-2000, drawn from the Spanish *Encuesta sobre Estrategias Empresariales* (ESEE, hereafter). Differently to our survey data, their study uses information from an Exporter Registry, what has both some advantages and disadvantages. In the advantages side, they have a larger number of available observations and more disaggregated information about export markets. In the disadvantages side, they lack some relevant firm characteristics, such as size, labour productivity or R&D intensity, which have been found in the empirical literature as important drivers of firms' export decision,[2] and they do not account for the richness of information provided by time varying covariates. Secondly, Bosco-Sabuhoro and Gervais (2004) do not control for the existence of unobserved individual heterogeneity (such as unobserved firms organizational capabilities, network contacts, the purchasing of specific assets, etc.), which in survival analysis may lead to strongly inconsistent estimates of the included covariates. In this respect, our estimation methods allow for both parametric and non-parametric unobserved individual heterogeneity. Thirdly, our survival methods also allow for fully non-parametric estimation of the baseline hazard, what jointly with the control for unobserved individual heterogeneity contributes to fully identify the effects of survival time on duration in exports (duration dependence). Fourthly, our approach treats time as a discrete variable, not because it is intrinsically discrete but because the data is provided on a yearly base (we know whether a firm has exported in a given year of the survey). Fifthly, different from Bosco-Sabuhoro and Gervais (2004), who use plant data, we have firm data, which are the observation units appropriate for modelling both the export decision and the permanence in the export markets. As stated by Bosco-Sabuhoro and Gervais (2004), "Belonging to a multi-plant enterprise increases the hazard of failure on export markets. This runs against the existing empirical literature (Bernard and Jensen, 1997, 2001; Roberts and Tybout, 1997). Export standards might require large sunk costs that would encourage firms not to export from all their plants." Finally, the models we use are also adequate in the presence of right-censored observations and easily handle time-varying covariates. In order to avoid left

[1] Other somehow related papers are Besedeš and Prusa (2003) and Besedeš and Prusa (2004), although these papers use survival analysis to study the duration of US imports.
[2] See, e.g. Roberts and Tybout (1997), Bernard and Wagner (1998), Bernard and Jensen (2004), Campa (2004), and Máñez *et al.* (2004)

censoring problems, we only consider those exporting periods that start in our observation window (from 1990 to 2000).[3]

Our paper is mainly focused on testing two major hypotheses related to export persistence. First, we test whether the longer the period a firm exports, the longer it will remain doing so (negative duration dependence and patterns of negative duration dependence, hypotheses *H1* and *H2* in section 3). Secondly, we test whether firms exporting to "closer" markets would generally last longer in these exporting markets than firms exporting to more unknown or uncertain markets (hypothesis *H9* in section 3). Furthermore, we also test for other hypotheses related to firm, product and export market characteristics.

Our results strongly support both major hypotheses. Furthermore, we also find some other firm, product and export market characteristics which are revealed to be important determinants for exports survival of Spanish firms, such as size, productivity, export and R&D intensities, and final consumption goods. These findings contribute to better understand the determinants of the firm's survival in export markets and have implications for export promotion policies. On the one hand, policies oriented to improve information and access to foreign markets by providing exporting infrastructures could reduce the sunk costs of entry. On the other hand, policies directed at increasing productivity or stimulating R&D investments would have a positive impact on the spell length in export markets.

The rest of the paper is organised as follows. In section 2 we present the data and analyse exporting spells (episodes) for Spanish manufacturing firms. Section 3 is devoted to examine our hypotheses about the determinants of survival in the export markets. Our statistical methodology is revised in section 4. The estimation results are summarised in section 5. Finally, section 6 concludes.

## 2. Analysing data and exporting spells.

The dataset has been built up using information from the *Encuesta sobre Estrategias Empresariales (ESEE)*, which is an annual survey of Spanish manufacturing firms sponsored by the Ministry of Industry carried out since 1990. The ESEE is a representative sample of the population of Spanish manufacturing firms classified by industry and size that provides broad

[3] Our sampling scheme is commonly named *inflow with follow up* (see Jenkins, 2004).

information at the firm level.[4] The unit of observation in this study is the exporting spell, we understand by exporting spell the uninterrupted number of years a firm exports. A spell is considered as starting in year *j* if the firm did not export in year *j-1* but it exports in year *j*. Analogously, a spell is computed to end in year T when this is the first year in which the firm does not export after a series of one or more consecutive years in which the firm exports.

Some features of this dataset make it suitable to examine the determinants of firms' lifetimes in exporting using survival methods. First, it is comprised by a representative sample of the population of Spanish manufacturing firms classified by industries and size categories in 1990, keeping the same criteria for latter incorporations. All these firms are followed up to 2000. Some of the firms in the sample export the first year they are in the sample, so that we do not know if this is the starting year of their exporting spell or if this spell started some years before. Should we include these spells in the analysis we will incur in a problem of left-censoring that will lead to underestimate the duration of the exporting spells. To avoid this problem of left-censoring, in the analysis we only include the spell of a given firm if we know the exact year in which the spell initiates, e.g. we include a spell that starts in year *j* if we know that the firm to which corresponds this exporting spell did not export in (*j-1*). Therefore, as we do not consider spells already going on in 1990 the first exporting spells in our sample start in 1991.

Secondly, the ESEE provides broad information on characteristics at the firm level on a yearly basis, which may help unravel the factors driving survival prospects of exporting spells.

Thirdly, this survey also allows identifying firms that continue exporting, quit this activity or stop answering the survey over the *observation window* (1990-2000). We exclude from the analysis those spells corresponding to firms that fail along the observation window. As for many of these spells the end of the exporting spell coincides with firm failure, their consideration could bias the results of our analysis.

[4] The sampling procedure of the ESEE is as follows. Firms with less than 10 employees are not included in the survey. Firms with 10 to 200 employees were randomly sampled by industry and size strata (according to 21 different productive activities and 4 size intervals), holding around a 4% of the population in 1990. All firms with more than 200 employees were requested to participate, obtaining a participation rate around 60% in 1990. Important efforts have been made to minimise attrition and to annually incorporate new firms with the same sampling criteria as in the base year so that the sample of firms remains representative of the Spanish manufacturing industry over time (see http://www.funep.es for further details).

After applying the above mentioned criteria we end up with a sample of 1414 observations corresponding to 407 exporting spells, 40.3% of which ended during the sample period. These 407 spells correspond to 317 different firms. Of them, 238 have one, 68 two and 11 three exporting episodes. The mean and median duration of these spells are 6.30 and 5 years, respectively. Moreover, the non-parametric estimate (using the Kaplan-Meier estimator) of the survival function (Figure 1) shows that around 37.5% of the firms survive in export markets less than 4 years, and 50% of the firms are still operating in export markets after 8 years.

[Insert Figure 1 about here]

## 3. Hypotheses about the determinants of continuity in export markets.

There are many factors that may help to determine how long an exporting spell will last. These include duration dependence; firm's, products and export market characteristics; and business cycle factors.[5] Table 1 provides detailed information on the variables involved in the hypotheses bellow.

[Insert Table 1 about here]

### Duration dependence

*H1: Negative duration dependence.*

Negative duration dependence arises when the probability that the spell will end falls the longer it goes on. According to this hypothesis we are interested in measuring the sign and amount of the relationship between the length of time a firm spends in a spell, and the probability that the spell will end at some time *T*. This measures the relationship between cumulative within-spell accumulation of knowledge (reflecting a learning curve in the export market and a learning-by-doing process) and the likelihood that the spell will continue. Furthermore, it can also be a consequence of the risk of depreciation of knowledge accumulated in the export markets once a firm exits those markets, what will make harder for the firm to re-enter the market than to continue. It seems sensible to think that firms face costs associated with entering foreign markets that may be sunk in nature. They reflect the cost of the firm-specific and market-specific assets that are required to sell in that

[5] Year dummy variables are introduced to account for macroeconomic effects.

markets. For instance, non-exporting firms have to research foreign demand and competition, establish marketing and distribution channels, a brand name through advertising, adjust their product characteristics and packaging to meet foreign tastes and/or fulfil quality and security legislation of other countries. Studies about the role of sunk costs on the firms´ R&D decision (Roberts and Tybout, 1997; Bernard and Wagner, 1998; Bernard and Jensen, 2004; and Máñez *et al.*, 2004) provide evidence of a fairly fast depreciation of knowledge in the export markets,[6] which will probably influence the decision of firms to continue on export markets *versus* exiting them and re-entering again.

In order to assess the joint effect of learning-by-doing and sunk costs in the export markets, we control in estimation for the existence of duration dependence, which allows testing for negative duration dependence. Both if sunk costs and learning-by-doing matter, current participation in the export markets will depend upon past participation and then we would expect negative duration dependence.

*H2: Negative duration dependence does not affect linearly the hazard rate.* Firms are more likely to exit export markets in the first years exporting than later on (theoretical implication of the Ericson and Pakes, 1995, 1998, models of industry dynamics, and empirically supported by Besedeš and Prusa, 2003, for import trade relationships). Besedeš and Prusa (2003) show that not only the survival and hazard functions indicate that there is negative duration dependence, meaning that the conditional probability of failure decreases as duration increases, but also that after a large decrease in the probability of survival over the first few years, the survival function levels off and decreases very little. This result indicates the presence of a type of threshold effect. In other words, it seems that once a trade relationship is established and has survived the first few years it is likely that it will survive a long time. This finding is similar to that documented by Pakes and Ericson (1998) for retail trade establishments.[7]

[6] These works theoretically allow for the possibility that not all of the sunk assets erode when the firm exits, implying that re-entry costs are bellow entry costs.

[7] Pakes and Ericson interpret their results as supporting Jovanovic´s (1982) theory of learning.

Firm characteristics

We consider several hypotheses concerning the role of observable firm characteristics. We start with those related to firm success.

*H3: Once firms start exporting, the better performing ones last longer in international markets.*

To proxy for firm success we include size and productivity. One of Geroski´s (1995) stylised facts for general models of firm survival is that firms´ survival chances are positively related to their size. Larger firms are expected to survive longer (Dunne *et al.*, 1989; and Mata and Portugal, 1994 and 2000; among others). Looking specifically to survival in export markets, size may proxy for several effects. Not only larger firms have been usually successful in the past, but also size may be associated with lower average or marginal costs (larger firms are more likely to have output levels close to minimum efficient scale, so that small firms face a cost disadvantage), providing a separate mechanism for size to increase the likelihood of exporting and survival in the export markets. Another link between size and export may reflect scale economy-based exporting (Krugman, 1984), where the exploitation of economies of scale is a usual argument to support a positive association between firm size and exports. Furthermore, size may be picking up other factors such as better access to specific inputs (larger firms may find it easier to raise capital and may be in a better position to recruit qualified workers), better access to information, may face better tax conditions, etc., which can affect firm performance. To proxy for size, we introduce a dummy variable (*size group*) which takes value one for firms of more than 200 workers.

There are also reasons to expect firm productivity to increase the likelihood of exporting and survival in international markets. If the fixed costs of selling are higher in the export market than in the domestic market or if output prices are lower, only firms with high productivity will find it profitable to enter and continue in the export market. This is usually referred to as the self-selection hypothesis in the models of industry dynamics.[8] Furthermore, more productive firms are in a better position to face a strong competitive pressure in international markets given that productivity is highly related to differential competitiveness of firms. A firm productivity crucially determines

[8] See for example, Ericson and Pakes (1995), Pakes and Ericson (1998) or Baldwin and Rafiquzzaman (1995). Delgado *et al.* (2002) find evidence supporting the self-selection hypothesis using data drawn from the ESEE.

its relative efficiency and therefore its probability of surviving, as pointed out by the learning literature. For a generic market, Jovanovic (1982), Ericson and Pakes (1995), Olley and Pakes (1996) and Melitz (2002) predict that the probability of survival is smaller for low-productive firms. In our analysis we use labour productivity per worker. We consider three dummy variables splitting firms according to whether the firm is in the first, second or upper third of the productivity distribution (*productivity1*, *productivity2* and *productivity3*).

*H4: The larger the trade volume of a firm, the more likely it is to continue exporting.*

According to this hypothesis we will look for a positive relationship between export intensity of a firm, at the beginning and during the exporting spell, and the length of the spell. Dynamic economies of scale may derive from here if the higher the export intensity of a firm the higher the subsequent accumulation of knowledge and learning-by-doing about export markets, export channels, foreign demand and tastes, etc. However, there is also another argument, independent from the dynamic economies of scale one, to justify a positive relationship between export intensity and spell length in exports, that is, the fact that this variable may be also reflecting the degree of firm dependence from export markets. According to this second argument a firm with a high export intensity ratio will put all its strength to survive in export markets, because otherwise it faces the risk of going out of a market that cannot be easily or fast enough substituted by the domestic market. For highly export-oriented firms we expect longer durations in the export markets. We measure export intensity as the firm's export to sales ratio. We introduce a dummy variable that takes the value of 1 if the firm's *export intensity* is greater than 5% (this breaking point approximately coincides with the median for this variable in our sample).

*H5: Foreign owned firms last longer in export markets.*

A sizable body of research has focused on the role of ownership in cross-border trade. One can think that non-domestically owned firms might enjoy better access to foreign markets due to complementarities with other business within the same group. It has been frequently argued that firms participated by foreign capital are, in general, more efficient and so their presence in foreign markets should be higher and longer. Furthermore, when foreign direct investment is based on competitive advantages of the firm with respect to the exporting market, it is expected a positive relation between foreign ownership and exporting activity. In this case, the domestic market might be seen as a productive platform and the foreign capital participation might be considered a signal of unobserved quality of the participated firm. We control for the ownership structure of the firm with a dummy variable (*foreign*) that takes the value one if the firm's capital is participated by foreign capital.

*H6: The higher the R&D intensity the longer the duration in export markets.*
High values of this variable may be capturing technological leadership or technological leadership distance. Long distances to the technological leader will derive in competitive market pressures creating short-term trade relationships. In the literature of dynamic trade models Vernon's (1966) pointed out that the technological leaders develop and export a product until others learn how to manufacture it and enter the market. Furthermore, R&D intensive firms may be also signalling a non-standardised technology that requires intensive R&D investment. According to the Resource-Based view of the firm (Mata and Portugal, 2002) the ability of firms to develop specific capabilities largely determines their survival prospects. Another argument points out that exporting firms may need to innovate to face a higher competitive pressure in international markets (Kleinschmidt and Cooper, 1990; and Kotable, 1990) and to adapt to changing competitive environments. In doing so they will probably enjoy better survival prospects. In general, it is expected that R&D activities improve firms´ competitive advantage.

Finally, we could also include this variable into the group of product characteristics. As R&D intensity also measures at some extent the firm innovation-related activities could be proxying for vertical product differentiation, as vertical differentiation is related to product quality differentiation. Thus, we would expect that the higher the vertical differentiation of the firm, the higher the probability of exporting and duration of the exporting spell. We include in our analysis four dummy variables classifying firms in non-innovative and low, medium and highly innovative firms according to the R&D intensity ratio (*R&D intensity1*, *R&D intensity2*, *R&D intensity3* and *R&D intensity4*).

Product characteristics

*H7: Industries selling differentiated products enjoy longer exporting spells.*

The idea that trade in homogeneous and differentiated goods is different was already in Krugman (1980) and Helpman and Krugman (1985). This idea is empirically analysed by Besedeš and Prusa (2004), who find that the hazard rate is at least 18 percent higher for homogeneous goods than for differentiated products in US import trade relationships. According to Rauch (1999), we could classify products into one of three types: differentiated, reference priced, and homogeneous. An important issue in this classification is that it captures the concept of product substitutability. On the one hand, products that are sold in organized exchanges (like corn, oil, wheat, etc.) are exactly those products typically cited as being homogeneous. Consumers may neither know nor care about the source of the product that they are purchasing. On the other hand, products like many types of steel and chemicals, which prices are listed in industry guides and trade journals, will likely have some unique attributes (e.g., quality may vary by source country) but are essentially substitutable. In this case, consumers will know the source country, but this may only have a small impact on their purchasing decision. In the final category there are differentiated products. These are products that not only have many characteristics that vary across suppliers but may even be specifically tailored to the end-user's needs. Automobiles are perhaps the most often cited example of such a good; in fact, most consumer goods are classified as differentiated. To give some light to the question about why differentiated products last longer in export markets Rauch (1999) shows that network/search measures are more important for trade in differentiated products than for homogeneous products and also probably sunk costs are higher given that differentiated products should be desired by consumers. Differentiated products are likely to involve relationship-specific investments and as a result one might expect far longer live relationships.

To pick up the differentiated product characteristic of an industry we include the dummy variable *final consumption*, which identifies whether the firm belongs to an industrial sector classified as a final consumption good category. In this classification we include the following sectors: Meat industry, food and tobacco, beverages, textiles, leather and shoes, motors and cars, furniture and other manufacturing goods (category that excludes other manufacturing goods such as intermediate goods and/or equipment goods). This classification of goods is also interesting in this study due to the composition of Spanish manufacturing exports, where a high proportion of exports is concentrated in final consumption goods. The expected longer duration for this type of goods in export markets may also reflect comparative advantages for Spain in the export markets of these products and/or economies of scale in production.

[Insert Table 2 about here]

Export market characteristics

It seems clear that export market characteristics should matter in determining survival in export markets.

*H8: Exporting firms last shorter when there are adverse demand shifts in export markets.*

The decision to export and to continue in the export markets can also be affected by foreign demand factors such as the evolution of the foreign markets. If foreign markets start experiencing a recession, firms originally exporting to that markets may not be very much attracted anymore by those markets and they may end up exiting them. To capture this situation we have included a dummy variable called *recessive demand*, that takes the value of 1 if the firm both declares to face a recessive demand in its main market and exports more than 50% of its sales. The purpose in crossing these two variables is to ensure that the answer to the question of whether the firm faces a recessive demand in its main market *versus* a stable or increasing one refers to the foreign market where the firm actually exports.

*H9: Longer durations are associated to "closer" export markets.*

To account further for the influence of export market characteristics in export survival, we include three dummy variables capturing different destinations (*European Union, other OCDE* countries, and *rest of the world*). These variables may be picking up many influences including the effects of distance, trade policy, market size, and exchange rate fluctuations. According to this hypothesis we would expect longer exporting spells associated to the European Union export markets than to the other OCDE countries, and longer exporting spells associated to the other OCDE countries than to the rest of the world.

The reasons for this ordering may be the following. Lower updating (sunk-) costs over time[9] in “closer” markets such as the European Union because of common institutions, cultural similarities, closer consumer tastes, shorter physical distance, no internal borders, no tariffs and/or uncertainty and risk associated to changes in tariff systems, and smaller fluctuations of exchange rates between countries, with the subsequent reduction on international transaction risks. Notice that trade gravity models also support some of these factors.

## 4. Econometric methodology.

Our sampling process has been one of inflow sampling with right censoring in which we remove those spells for which we do not know their exact starting year. Hence, we do not have left censoring in our sample. However, there are spells that do not complete their duration along the sample period. Additionally to the incidence of right-censoring, some of the covariates used to explain firm duration in export markets vary over time (time-varying covariates). The consideration of time-varying covariates allows overcoming the limitation arising from considering firm characteristics previous to the beginning of the period analysed or at the time of entry as the unique determinants of the firm survival probability across time (see Mata *et al.*, 1995). We consider time as a discrete variable, not because it is intrinsically discrete but because the data is provided on a yearly base (grouped or banded survival times into number of years exporting). Then, our spell lengths are positive integers and we should use econometric models capturing the particular nature of our dataset. Although for some firms we have multiple spells in the exporting state, we assume they are independent, which allows estimation by pooling the spells. However, in the results section we check the robustness of our results to this assumption. In particular, we also did the analysis limiting the sample to only first spells. This is done in order to check whether duration is independent of the spell number.

[9] Each period the firm is active, the sunk investment requires maintenance represented by a fixed maintenance cost. If the maintenance is not spent the sunk asset disappears, i.e., the firm exits.

*Discrete time proportional hazard models*

This section relies heavily on Jenkins (2004), who significantly improves the understanding, both from a theoretical and an applied point of view, of survival analysis.

Our intervals of time are of unit length (a year). Then, the interval boundaries are the positive integers *j=1, 2, 3, 4,...,* and the interval *j* is $(j-1, j]$.

One firm exporting spell can either be complete ($c_i = 1$) or right censored ($c_i = 0$). A firm *i* censored spell contributes to the likelihood function with the discrete time survivor function (the probability of survival until the end of interval *j*):

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

where $T_i = \min\{T_i^*, C_i^*\}$, being $T_i^*$ some latent failure time and $C_i^*$ some latent censoring time for firm $i$, and $h_{ik} = \Pr(k-1 < T_i \leq k | T_i > k-1)$ is the discrete hazard (the probability of ending the spell in interval $k$ conditional to the probability of survival at the beginning of this interval). A firm *i* completed spell contributes to the likelihood with the discrete time density function (the probability of ending the spell within the *jth* 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 (1) and (2), the whole likelihood function is

$$L = \prod_{i=1}^{n}\left[\Pr(j-1 < T_i \leq j)\right]^{c_i}\left[\Pr(T_i > j)\right]^{1-c_i} = \prod_{i=1}^{n}\left[\left(\frac{h_{ij}}{1-h_{ij}}\right)^{c_i}\prod_{k=1}^{j}(1-h_{ik})\right] \tag{3}$$

and the log likelihood

$$\log L = \sum_{i=1}^{n} c_i \log\left(\frac{h_{ij}}{1-h_{ij}}\right) + \sum_{i=1}^{n}\sum_{k=1}^{j}\log(1-h_{ik}) \tag{4}$$

Allison (1984) and Jenkins (1995, 2004) show that (4) can be rewritten as the log likelihood function of a binary dependent variable $y_{ik}$ with value of one if firm *i* spell ends in year *k*, and zero otherwise:

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

(5)

This implies that discrete time hazard models can be "easily" estimated by binary dependent variable models. A prerequisite is the reorganization of data in the following way. For individual 1 of the sample, abandoning exports in year four, we have:

| Identifier of individual | Spell interval identifier for the individual (j) | Created binary dependent variable (new censoring variable) |
|---|---|---|
| 1 | 1 | 0 |
| 1 | 2 | 0 |
| 1 | 3 | 0 |
| 1 | 4 | 1 |

If the individual had not exited the state at the end of the sample period then the binary dependent variable created would have been a 0 also for the fourth year and this would have been an individual censored spell. Here, an uncensored spell of an individual has as many rows as periods until the spell ends. A censored spell of an individual has as many rows as periods up to the end of the sample period. The re-organization of data in the table before will affect every individual in the sample. This allows not only an "easy" estimation method for discrete time hazard models but also it is the way of incorporating time-varying covariates in the analysis. The way the data should be re-organised coincides with the long version re-organisation of data in panel data sets.

The next step for estimation is the choice of the functional form of $h_{ik}$. As we are interested in a proportional hazard specification[10] with grouped-interval data the complementary log-log is the appropriate one. This is a discrete time representation of an underlying continuous time proportional hazard $q(t, x_{it}) = q_0(t)\exp^{b_0 + x_{it} b}$.[11] To show this let us start with the evaluation of a continuous survivor function at the end of interval *j*:

[10] This specification leads to the most well known duration models based on a specification of the hazard function. It is often used to describe the relation between the empirical exit rate and covariates in a concise way.
[11] From here onwards we already incorporate explicitly the role of explanatory variables in the survival analysis. Also notice that in our notation we are considering the possibility of time-varying covariates, assumed to be constant within a given interval.

$$S\left(j,x_{ij}\right)=\exp\left[-\int_0^j q\left(e,x\right)de\right]=\exp\left[-\exp^{b_0+x_{ij}b}\cdot\int_0^j q_0\left(e\right)de\right]=\exp\left[-\exp^{b_0+x_{ij}b}\,H_j\right],$$
(6)

where $H_j=\int_0^j q_0\left(e\right)de$ is the integrated baseline hazard evaluated at the end of interval *j*. The baseline survivor function at *j* is

$$S_0\left(j\right)=\exp\left(-H_j\right). \tag{7}$$

Using (6) the discrete time hazard can be written as

$$h\left(j,x_{ij}\right)\equiv h_j\left(x_{ij}\right)=\Pr\left(j-1<T_i\le j\,\middle|\,T>j-1,x_{ij}\right)$$

$$=\frac{\Pr\left(j-1<T_i\le j\,\middle|\,x_{ij}\right)}{\Pr\left(T_i>j-1\,\middle|\,x_{ij}\right)}=\frac{S\left(j-1,x_{ij}\right)-S\left(j,x_{ij}\right)}{S\left(j-1,x_{ij}\right)}=1-\exp\left[\left(H_{j-1}-H_j\right)\exp^{b_0+x_{ij}b}\right]$$
(8)

where rearranging terms and taking logs, we get

$$\log\left[1-h_j\left(x_{ij}\right)\right]=\left(H_{j-1}-H_j\right)\exp^{b_0+x_{ij}b}\Rightarrow\log\left(-\log\left[1-h_j\left(x_{ij}\right)\right]\right)=b_0+x_{ij}b+\log\left(H_j-H_{j-1}\right)$$
(9)

The discrete time baseline hazard for interval *j* is

$$1-h_{0j}=\exp\left(H_{j-1}-H_j\right) \tag{10}$$

then

$$\log\left(-\log\left[1-h_{0j}\right]\right)=\log\left(H_j-H_{j-1}\right)=\log\left[\int_{j-1}^{j}q_0\left(e\right)de\right]=g_j, \tag{11}$$

where $g_j$ is the interval baseline hazard which specification allows testing for the type of duration dependence. Substituting (11) back into (9):

$$\log\left(-\log\left[1-h_j\left(x_{ij}\right)\right]\right)=b_0+x_{ij}b+g_j\Rightarrow h_j\left(x_{ij}\right)=1-\exp\left[-\exp\left(b_0+x_{ij}b+g_j\right)\right], \tag{12}$$

implying that our discrete time hazard has been isolated from a $\log\left(-\log\left(\cdot\right)\right)\equiv c\log\log\left(\cdot\right)$ once we have assumed that the underlying continuous hazard is of a proportional hazard form. For this reason this discrete time proportional hazard model is known as a *cloglog* model.

When the underlying continuous proportional hazard is a Weibull model, the corresponding discrete one would specify $g_j=\left(a-1\right)\ln\left(j\right)$ in (12).[12] However, in estimation we treat the baseline hazard non-parametrically by

[12] Where the parameter (α-1) is the one controlling for duration dependence on a Weibull specification.

creating 10 interval-specific dummy variables (one for each spell year at risk), as the longer observed spell in our data set is 10 years. However, we can only estimate the first 8 dummy variables because we do not observe spell completions either in years 9 and 10. The non-parametric approach allows $g_j$ to vary from one interval to another.

Incorporating unobserved heterogeneity the *cloglog* model in (12) becomes

$$\log\left(-\log\left[1-h_j\left(x_{ij}\right)\right]\right)=b_0+x_{ij}b+g_j+u_i \Rightarrow h_j\left(x_{ij}\right)=1-\exp\left[-\exp\left(b_0+x_{ij}b+g_j+u_i\right)\right] \tag{13}$$

being $u_i \equiv \ln(n_i)$, where $v_i$ originally enters multiplicatively on the underlying continuous hazard function $q\left(t,x_{it}\right)=q_0\left(t\right)\exp^{b_0+x_{it}b}n_i$. Usually the distribution chosen for ν is a Gamma distribution with unit mean and variance $s^2$ to be estimated from the data, as well as distributed independently of *t* and *x* (Meyer, 1990). This random variable is assumed to be positive. The null hypothesis of variance equal to zero can be tested. Under the null, unobserved heterogeneity is not important and the estimated model will be the model without individual unobserved heterogeneity. The contribution to the sample likelihood for a censored observation with spell length *j* intervals is $S\left(j,x_{ij}\left|b_0,b,s^2\right.\right)$, and the contribution of someone who exits the state in the *jth* interval is $S\left(j-1,x_{ij}\left|b_0,b,s^2\right.\right)-S\left(j,x_{ij}\left|b_0,b,s^2\right.\right)$, where $S\left(j,x_{ij}\left|v_i\right.\right)=\left[S\left(j,x_{ij}\right)\right]^{v_i}$.

Alternatively, one may treat unobserved heterogeneity non-parametrically. Heckman and Singer (1984) allowed for an arbitrary distribution for the individual heterogeneity term. They did this by assuming that there is a number of different types of individuals (or "mass points" in the distribution of individual heterogeneity) and we only can assign individuals to different types according to probabilities. This is reflected in the hazard function incorporating an extra term allowing for different intercepts for different types. For instance, if one assumes a model with two types (type=1, 2), then the hazard will be

$$h_{j,type}\left(x_{ij}\right)=1-\exp\left[-\exp\left(m_{type}+b_0+x_{ij}b+g_j\right)\right], \tag{14}$$

where $m_{type}$ characterises the discrete points of support of a bivariate distribution ("mass points"), with $m_{type=1}$ normalized to zero and the probability of belonging to type 1 is $p_1 = 1 - p_2$. Mass point 2 equals $m_{type=2} + b_0$.

All the individual contributions to the likelihood function will be a mixture of contributions assuming type1 individual and type2 individual. This mixture will weight contributions of the two types according to the corresponding associated probabilities ($p_1$, $p_2$) to the "mass points".

All these discrete time proportional hazard models may be estimated in Stata. The complementary loglog without unobserved individual heterogeneity may be estimated using the *cloglog* stata command. The complementary loglog model with Gamma distributed unobserved individual heterogeneity may be estimated using Jenkins´s written program *pgmhaz8.*[13] Finally, a model with non-parametric unobserved individual heterogeneity may be estimated using Jenkins´s *hshaz* program.[14]

Not controlling for unobserved individual heterogeneity when it is important may have the following effects. First, the degree of negative duration dependence in the hazard is over-estimated. This is the result of a selection process according to which firms with unobserved heterogeneity correlated with higher exit rates finish the spell more rapidly. Then, as time goes by we have more firms with low *v* in the group of surviving firms, which implies a lower hazard and so the underestimation of the true hazard. Secondly, the $b$ parameters are under-estimated. Then, they do not have anymore an interpretation as the proportionate response of the hazard to a change in a given covariate. However, some empirical results indicate that the more flexible the baseline hazard the less important are the effects of unobserved individual heterogeneity (Dolton and van der Klaauw, 1995).

[13] An up-to-date Stata program elaborated by S. Jenkins that implements this estimator is available from http://fmwww.bc.edu/RePEc/bocode/p or, inside Stata, typing ssc install pgmhaz8. An initial version of the program was presented in Jenkins (2001).

[14] A Stata program elaborated by S. Jenkins that implements this estimator is available from http://fmwww.bc.edu/RePEc/bocode/h , or inside Stata, typing ssc install hshaz.

## 5. Results.

*(i) Non-parametric tests.*

In order to better understand the effects of the explanatory variables used in the analysis we carry out non-parametric tests for the equality of survival functions across the *r* groups of exporting spells classified in groups according to a number of explanatory variables. These tests are extensions of non-parametric rank tests to compare two or more distributions for censored data. Under the null hypothesis, there is no difference in the survival rate of each of the *r* groups at any of the exit times and the t-statistic distributes as $\chi^2$ with *r*-1 degrees of freedom. At any exit time, the contribution to the *t*-statistic is obtained as a weighted standardised sum of the difference between the actual and expected number of exits for each of the *r* groups (Cleves *et al.*, 2004).

Table 3 presents the results for the log-rank and Wilcoxon tests. The results points to the existence of remarkable differences in the survival prospects across groups of exporting episodes for each of the variables considered (except for the foreign capital participation variable *–Foreign-* and the variable capturing the evaluation of the foreign market by the firm –*Recessive demand*-).

[Insert Table 3 about here]

By inspection of column (4) in table 3, the preliminary evidence suggests that large, highly-productive firms stay longer in export markets. Firms whose sales in export markets surpass 5% of their sales also experience larger export spells. As for firms' R&D intensity, firms which R&D-to-sales ratio surpasses 2.5% are expected to have longer export episodes as their mean duration are larger. Our results further indicate that firms exporting final goods and, in higher proportion, to the European Union (and, in second place, to OECD countries) raises expected duration in exports markets.

*(ii) Estimation results.*

Table 4 shows estimation results for the discrete time proportional hazard model (complementary log-log model, cloglog). Results are sequentially presented for a cloglog model without taking into account any potential unobserved individual heterogeneity, for a cloglog model assuming a Gamma distribution for an included individual heterogeneity term and for a cloglog model treating unobserved individual heterogeneity non-parametrically. The three estimators treat also non-parametrically the shape of the baseline hazard function. When using a fully non-parametric specification of the baseline hazard function one must drop from the sample the observations corresponding to survival years without events (i.e. without spell completions) as the hazard cannot be estimated for these years (exactly as with the non-parametric baseline hazard in the continuous time Cox model). We do not have any event in survival years 9 and 10, thus after dropping the data for these survival years the size of the estimation data gets reduced to 1365 observations that correspond to 407 spells. For the same reason, and as explained in the methodological section, we cannot include in the estimation the dummy variables corresponding to survival years 9 and 10 (*d9* and *d10*). As under any proportional hazard specification, a unit change in a covariate leads to a proportional shift on the hazard rate. We have tested for specification errors obtaining that we cannot reject the null hypothesis that the model is correctly specified. Moreover, the assumption of proportionality both for all variables jointly and for each variable has been tested using the tests proposed by Grambsch and Therneau (1994). The null hypothesis that the hazard rates are proportional cannot be rejected.

It can be observed that the three estimates give quite similar results. This is not surprising because for the second and third estimators (the ones controlling for unobserved individual heterogeneity both parametrically and non-parametrically) the corresponding tests do not allow us to reject the null hypothesis that individual unobserved heterogeneity is non relevant. For model two (parametric specification by a Gamma distributional assumption) we test the null hypothesis that the unobserved heterogeneity variance component ($s^2$) is equal to zero and this can not be rejected.[15] For model three (non-parametric treatment through "two mass-points") we cannot reject that the mass-point for type 2 is statistically no different to the mass-point for type 1, what means that there is not unobserved individual heterogeneity. The fore mentioned results suggest that for our particular problem at hand the first model is the appropriate one. Hence, in what follows our comments and prediction results focus on the first model.

[15] As Jenkins (2004) noticed, the test is a "boundary" test that takes account of the fact that the null distribution is not the usual $c^2$ (d.f.=1) but is rather a 50:50 mixture of a $c^2$ (d.f.=0) variate (which is a point mass at zero) and $c^2$ (d.f.=1) (Gutierrez et al., 2001). For this reason it is called a chibar2(01) statistic in the Stata results reported by the pgmhaz8 Jenkins´ written program.

[Insert Table 4 about here]

Figure 2 depicts the predicted discrete hazard rate that shows the evolution of firm´s failure risk over time. The discrete hazard rates corresponds to a representative spell for which all covariates except the ones catching duration dependence have been set at sample mean values.[16] Additionally, it should be noted that we do not observe any spell completion for the ninth and tenth years of survival, and so we set the hazard contribution of survival years 9 and 10 equal to zero.

[Insert Figure 2 about here]

Observation of predicted discrete hazard rates in figure 2 suggest that they decrease from survival years 1 to 6, then they slightly increase up to survival year 7, and then they decrease again up to survival year 8. The same patterns in figure 2 are reproduced by the estimates on the duration interval dummies. They tell us about the shape of the baseline hazard. Smaller values are associated with smaller hazards, that is with longer durations. However, to check the significance of these increases and decreases we carry out pairwise comparisons of the duration dependence exponentiated parameter estimates. According to the results from this testing procedure we can conclude first, that differences in hazard rates from survival years 1 to 3 are statistically non-significant; secondly, that differences in hazard rates from survival years 4 to 8 are also statistically non-significant; and finally, that the statistically constant hazard rate for years 1 to 3 is statistically different (higher) than the statistically constant hazard rate for years 4 to 8. Given that in the multivariate specification and estimation procedure we have statistically rejected the existence of unobserved individual heterogeneity, we can be pretty sure that this decline in exit rates from a higher level to a lower one is showing a type of negative duration dependence.

Not only the hazard function and the estimates of the baseline hazard indicate that there is negative duration dependence (*H1*), but also that the first few years exporting (3 years) firms have a higher risk of exiting export markets that lowers significantly from year 3 to year 4 to remain constant afterwards. This result indicates the presence of a type of a threshold effect (*H2*). In other words, it looks like it takes firms 3 years to learn enough and properly about

[16] As in our analysis all the covariates are included as sets of dummy variables, to characterise the representative spell we follow a two stage procedure. First, we calculate the mean value of the continuous variable that we have used to create the corresponding set of dummy variables; then, we set equal to 1 the dummy containing this mean value (the dummies take value of 1 for a given range of values of the continuous variable).

export markets and export markets competition and, afterwards, once the learning process has reached a given threshold, they enjoy a reduction in exit risks levels and survival prospects are better, allowing them to make profits from the accumulated knowledge and to spread over time the required pre-entry sunk costs in those markets. Contrarily to Pakes and Ericson (1998) in their study about retail trade establishments, we do not interpret these results as supporting Jovanovic´s (1982) theory of passive learning but that of active learning after entry in a new market (Ericson and Pakes, 1992, 1995; Pakes and Ericson, 1998; and Baldwin and Rafiquzzaman, 1995). We support this idea in the fact that unobserved individual heterogeneity, if existent, will be capturing inherent unobserved abilities of the firms to survive or not a given length of time in export markets (passive learning). As we rejected the existence of unobserved individual heterogeneity in our data set, we cannot explain dynamics relaying on passive learning theories but on active learning ones where firms learn after entry (the active learning patterns are embodied in the baseline hazard once the estimation methods control and test for the presence of individual unobserved heterogeneity).

On the basis of the survivor function, Figure 3 shows that approximately 80% of the exporting spells endure around 3 years, and that about 70% of them last more than 10 years. These high figures give an idea of the importance of persistence in exporting behaviour.

[Insert Figure 3 about here]

All covariates in our model are introduced as sets of dummy variables with the aim of capturing possible non-linear effects of the covariates on duration.

In relation to firm characteristics and as regards the impact on firm survival in export markets of the variables used to proxy for firm performance (*H3*), after controlling for all other variables we find that large firms endure better survival prospects than small firms. The probability of exit for large firms is about 54.5% lower than that for small firms. As expected, more productive firms have lower chances of failure. The hazard rates of the firms in the upper third of the productivity distribution are lower (56%) than the hazard rate of the firms in the medium and lowest third. This may suggest the existence of a threshold in productivity.

In relation to the other firm characteristics considered in the analysis, export intensity above the median value for this variable (upper half of the export intensity distribution) extends survival prospects by about a 38% (*H4*). Foreign capital participation does not appear to significantly affect the survival of firms in export markets (thus, we do not confirm *H5*). For R&D intensity, survival is prolonged only when it represents a certain proportion of the firm's sales (*H6*). Whereas the hazard rate of firms that invest in R&D less than 2.5% of their sales (low and medium innovative firms) is not significantly different from that of firms that do not invest in these activities (non-innovative firms), the hazard rate of firms whose R&D-to-sales ratio surpasses 2.5% (highly innovative firms) is 53% lower.

As regards product characteristics, a firm belonging to a final consumption industry, that is, a firm producing a "diversified" product, enjoys a better chance of survival on international markets, being its risk of exit a 33% lower than that for firms producing and selling another types of products (*H7*).

For the variables included to pick up the effects of export market characteristics we find that the fact that the firm declares that faces a recessive demand situation in the export market is not statistically significant in our analysis (thus, we cannot confirm *H8*). However, from the results associated to the three dummy variables capturing the market areas where firms do mainly export we can conclude that firms exporting to the European Union and to the rest of the OCDE countries have a 64% and 61%, respectively, lower risk of ending an exporting spell than firms exporting to the rest of the world countries (*H9*). Furthermore, the hazard rate of spells corresponding to firms whose main market is the European Union is not significantly different to the one of spells that correspond to firms whose main market are the other OECD countries.

Regarding the year dummies introduced to capture for the business cycle, we find that the lower probability of exit corresponds to 1991 (the omitted year in estimation). Afterwards, and in ascending order according to the probability of exit, we find 1999, 1995, 1996, 1994, 1997, 1993, 1998 and 1992. However, a pairwise testing procedure shows that moving from one year dummy to the next (starting from the 1992 one) the differences in hazard risks are not statistically significant, with the exception of what happens from 1998 to 1999. Thus, the decline in hazard rates in 1999 with respect to the other non-omitted year dummies is statistically significant.

Finally, in relation to our robustness check of the independence of spells assumption for a given firm, we have repeated estimation restricting the sample to only the firms first spells. Results from both the *cloglog* model without unobserved individual heterogeneity and controlling parametrically for it with a Gamma distribution of unobservables,[17] give similar results for covariates than the analysis using information from repeated spells. Also duration dependence and cyclical behaviour patterns are maintained under this more restricted sample choice. Again we find that unobserved individual heterogeneity is unimportant in our study because we cannot reject the null of variance equal to zero for the random unobserved individual heterogeneity component. All these results are in favour to our independence of spells assumption.

## 6. Conclusion.

This paper has investigated the determinants of persistency in firms exporting behaviour. Unlike many previous studies that have focused on the causes of persistence by analysing the role of sunk costs on the decision to export, we have examined persistence or duration in export activities *per se*. Our main interest has been testing two major hypotheses. First, we have checked whether the longer the period of time a firm continuously exports, the longer it will remain doing so (negative duration dependence). Secondly, we have tested whether firms exporting to "closer" markets experience longer exporting spells than firms exporting to more unknown or uncertain markets.

In order to carry out our analysis, we have used survival methods, including non-parametric tests and the estimation of three discrete time proportional hazard models. The advantages of our estimation methods, as compared to previous analysis of persistence in exporting behaviour, 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 exporting spell. In addition, the estimation of both parametric and non-parametric unobserved individual heterogeneity survival models has allowed a robust test for the presence of unobserved individual heterogeneity. We have used for this purpose a representative sample of the population of

[17] The lower number of failures (140) in this shorter data set does not allow us to estimate fully non-parametrically the distribution of the unobserved individual heterogeneity component. For this reason we do not have estimates for the *cloglog* model using Jenkins´s *hshaz* program. As Jenkins (2001, 2004) points out there is a potential fragility of models incorporating (mainly non-parametrically) unobserved individual heterogeneity.

Spanish manufacturing for the period 1990 to 2000. The dataset has been drawn from the *Encuesta sobre Estrategias Empresariales*, a survey carried out annually since 1990 which provides detailed information at the firm level.

Our findings may be considered as giving support to the two main hypotheses raised in this paper. First, our results indicate that the longer the period of time in which a firm continuously exports, the longer it will remain exporting, i.e., we find strong evidence supporting the hypothesis of negative duration dependence. This result may be considered as giving support to the theory of *active learning* after entry in a new market (e.g. Ericson and Pakes, 1992, 1995; Pakes and Ericson, 1998; and Baldwin and Rafiquzzaman, 1995). Secondly, we also find strong evidence in favour of the hypothesis that firms exporting to "closer" markets generally last longer in these exporting markets than firms exporting to more unknown and uncertain markets. In this sense, Spanish firms exporting to the European Union and to the rest of the OCDE countries endure a lower risk of ending an exporting spell than Spanish firms exporting to countries in the rest of the world. Finally, other firm characteristics such as size, productivity, export intensity, R&D intensity and producing in a final consumption industry affect positively the continuity in exporting to foreign markets.

These findings contribute to better understand the determinants of the firm's survival in export markets and have implications for export promotion policies. On the one hand, policies oriented to improve information and access to foreign markets by providing exporting infrastructures could reduce the sunk costs of entry. On the other hand, policies directed at increasing productivity or stimulating R&D investments would have a positive impact on the spell length in export markets.

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# Tables

| Table 1: Variables definition. | |
|---|---|
| Duration | Spell duration in years. |
| *Firm characteristics* | |
| Size group | Dummy variable that takes the value of 1 if the firm has more than 200 workers, and 0 otherwise. |
| Productivity | Variable that takes the value of 1 if the firm´s labour productivity belongs to the first third of the sample labour productivity distribution, the value of 2 if the firm´s labour productivity belongs to the second third of the productivity distribution, and the value of 3 if the firm´s productivity belongs to the last third of the labour productivity distribution. |
| Productivity1 | Dummy variable that takes the value of 1 if the firm´s labour productivity belongs to the first third of the sample labour productivity distribution, and 0 otherwise. |
| Productivity2 | Dummy variable that takes the value of 1 if the firm´s labour productivity belongs to the second third of the sample labour productivity distribution, and 0 otherwise. |
| Productivity3 | Dummy variable that takes the value of 1 if the firm´s labour productivity belongs to the upper third of the sample labour productivity distribution, and 0 otherwise. |
| Export intensity | Dummy variable that takes the value of 1 if the firm´s export intensity (exports over sales ratio in %) is greater than 5%, and 0 otherwise. |
| Foreign | Dummy variable that takes the value of 1 if the firm has foreign capital participation, and 0 otherwise. |
| R&D intensity | Variable that takes the value of 1 if the firm does not invest in R&D, the value of 2 if the firm´s R&D intensity (R&D expenditure over sales in %) is greater than 0% and lower than or equal to 1%, the value of 3 if the firm´s R&D intensity is greater than 1% and lower than or equal to 2.5%, and takes the value of 4 if the firm´s R&D intensity is greater than 2.5%. |
| R&D intensity1 | Dummy variable that takes the value of 1 if the firm does not invest in R&D, and 0 otherwise. |
| R&D intensity2 | Dummy variable that takes the value of 1 if the firm's R&D intensity is greater than 0% and lower than or equal to 1, and 0 otherwise. |
| R&D intensity3 | Dummy variable that takes the value of 1 if the firm's R&D intensity is greater than 1% and lower than or equal to 2.5%, and 0 otherwise. |
| R&D intensity4 | Dummy variable that takes the value of 1 if the firm's R&D intensity is greater than 2.5%, and 0 otherwise. |
| *Product characteristics* | |
| Final consumption | Dummy variable that takes the value of 1 if the firm belongs to an industrial sector classified such as of final consumption, and 0 otherwise. |
| *Export market characteristics* | |
| Recessive demand | Dummy variable that takes the value of 1 if the firm claims to face a recessive demand on the market and the firm exports more than 50% of its sales, and 0 otherwise. |
| Exporting area | Variable that takes the value of 1 if the firm´s main exporting area is the European Union, the value of 2 if the firm´s main exporting area is the OCDE, and the value of 3 if the firm´s main exporting area is the rest of the world. |
| European Union | Dummy variable that takes the value of 1 if the higher proportion of exports by the firm are oriented to the European Union markets, and 0 otherwise. |
| OCDE | Dummy variable that takes the value of 1 if the higher proportion of exports by the firm are oriented to the OCDE markets, and 0 otherwise. |
| Rest | Dummy variable that takes the value of 1 if the higher proportion of exports by the firm are oriented to markets other than the European Union and OCDE markets, and 0 otherwise. |
| *Business Cycle* | |
| Year dummies | Dummy variables that take the value of 1 for the corresponding year and zero otherwise. |

Table 2: Industry classification according to final consumption goods and others.

| Industry | Classification |
|---|---|
| Meat industry | Final consumption |
| Food and tobacco | Final consumption |
| Beverages | Final consumption |
| Textiles | Final consumption |
| Leather and shoes | Final consumption |
| Wood | Other (intermediate goods) |
| Paper | Other (intermediate goods) |
| Printing | Other (intermediate goods) |
| Chemical products | Other (intermediate goods) |
| Rubber and plastic | Other (intermediate goods) |
| Non metallic miner | Other (intermediate goods) |
| Metallurgy | Other (intermediate goods) |
| Metallic products | Other (intermediate goods) |
| Machinery and mech. eq. | Other (equipment goods) |
| Office machines | Other (equipment goods) |
| Electronic | Other (equipment goods) |
| Motors and cars | Final consumption |
| Other transport material | Other (intermediate goods) |
| Furniture | Final consumption |
| Other manufacturing goods | Final consumption |

Table 3: Non-parametric tests of equality of survival functions and mean duration by explanatory variables.[1, 2, 3, 4]

| | Log-rank | Wilcoxon | Mean Duration |
|---|---|---|---|
| *Firm characteristics* | | | |
| Size group | 8.68<br>(0.003) | 9.67<br>(0.002) | Size=0 6.05<br>Size=1 8.04 |
| Productivity (Pro) | 13.20<br>(0.001) | 13.04<br>(0.001) | Pro=1 5.17<br>Pro=2 6.14<br>Pro=3 7.61 |
| Export intensity (EI) | 7.92<br>(0.005) | 2.62<br>(0.106) | EI=0 5.71<br>EI=1 7.06 |
| Foreign (Fore) | 1.92<br>(0.166) | 0.71<br>(0.400) | Fore=0 6.19<br>Fore=1 7.29 |
| R&D intensity (R&D) | 9.46<br>(0.024) | 8.64<br>(0.034) | R&D=1 6.06<br>R&D=2 7.14<br>R&D=3 5.41<br>R&D=4 8.24 |
| *Product characteristics* | | | |
| Final consumption (FC) | 3.38<br>(0.066) | 2.87<br>(0.090) | FC=0 5.97<br>FC=1 6.79 |
| *Export market characteristics* | | | |
| Recessive demand ($\nabla$D) | 0.64<br>(0.423) | 0.02<br>(0.887) | $\nabla$D=0 6.32<br>$\nabla$D=1 3.25 |
| Exporting area (Des) | 23.81<br>(0.000) | 21.00<br>(0.000) | Des=1 7.03<br>Des=2 6.75<br>Des=3 4.86 |

Notes:

1. See Table 1 for variable definitions.
2. 1414 observations, 407 firms, and 167 exits.
3. P-values in parenthesis.
4. Mean duration is reported, without accounting for censoring, for each group according to each explanatory variable.

Table 4. Maximum likelihood estimates for the discrete time proportional hazard models.

| | Cloglog without individual unobserved heterogeneity | | Cloglog with Gamma individual unobserved heterogeneity | | Cloglog with non-parametric individual unobserved heterogeneity (2-mass points) | |
|---|---|---|---|---|---|---|
| | Hazard rate | *p*-value | Hazard rate | *p*-value | Hazard rate | *p*-value |
| *Firm characteristics* | | | | | | |
| Size group | 0.455 | 0.025 | 0.454 | 0.021 | 0.455 | 0.020 |
| Productivity2 | 0.802 | 0.226 | 0.800 | 0.250 | 0.802 | 0.226 |
| Productivity3 | 0.441 | 0.001 | 0.439 | 0.003 | 0.441 | 0.001 |
| Export intensity | 0.616 | 0.016 | 0.615 | 0.014 | 0.616 | 0.012 |
| Foreign | 1.075 | 0.818 | 1.074 | 0.823 | 1.075 | 0.818 |
| R&D intensity2 | 0.957 | 0.874 | 0.956 | 0.870 | 0.957 | 0.872 |
| R&D intensity3 | 1.090 | 0.814 | 1.091 | 0.798 | 1.090 | 0.799 |
| R&D intensity4 | 0.469 | 0.084 | 0.469 | 0.084 | 0.469 | 0.084 |
| *Product characteristics* | | | | | | |
| Final consumption | 0.670 | 0.021 | 0.671 | 0.024 | 0.670 | 0.020 |
| *Export market characteristics* | | | | | | |
| Recessive demand | 2.991 | 0.243 | 2.967 | 0.198 | 2.989 | 0.178 |
| Exporting to UE | 0.363 | 0.000 | 0.361 | 0.000 | 0.363 | 0.000 |
| Exporting to OCDE | 0.389 | 0.071 | 0.386 | 0.096 | 0.389 | 0.076 |
| *Bussiness cycle* | | | | | | |
| Year 1992 | 20.182 | 0.000 | 20.295 | 0.000 | 20.170 | 0.000 |
| Year 1993 | 16.046 | 0.000 | 16.144 | 0.000 | 16.036 | 0.000 |
| Year 1994 | 11.177 | 0.000 | 11.223 | 0.000 | 11.168 | 0.000 |
| Year 1995 | 7.452 | 0.000 | 7.470 | 0.000 | 7.446 | 0.000 |
| Year 1996 | 9.964 | 0.000 | 9.977 | 0.000 | 9.955 | 0.000 |
| Year 1997 | 11.217 | 0.000 | 11.232 | 0.000 | 11.207 | 0.000 |
| Year 1998 | 16.332 | 0.000 | 16.407 | 0.000 | 16.320 | 0.000 |
| Year 1999 | 6.060 | 0.001 | 6.076 | 0.001 | 6.055 | 0.001 |
| *Duration dependence* | | | | | | |
| d1 | 0.077 | 0.000 | 0.077 | 0.000 | 0.076 | 0.058 |
| d2 | 0.059 | 0.000 | 0.060 | 0.000 | 0.058 | 0.033 |
| d3 | 0.054 | 0.000 | 0.054 | 0.000 | 0.053 | 0.026 |
| d4 | 0.029 | 0.000 | 0.029 | 0.000 | 0.028 | 0.007 |
| d5 | 0.021 | 0.000 | 0.021 | 0.000 | 0.020 | 0.004 |
| d6 | 0.015 | 0.000 | 0.015 | 0.000 | 0.015 | 0.004 |
| d7 | 0.021 | 0.000 | 0.021 | 0.000 | 0.021 | 0.008 |
| d8 | 0.018 | 0.000 | 0.019 | 0.001 | 0.018 | 0.014 |
| Log likelihood | -398.896 | | -398.896 | | -398.897 | |
| N. of observations | 1365 | | 1365 | | 1365 | |
| N. of spells | 407 | | 407 | | 407 | |
| Test for unobserved individual heterogeneity | | | LR test of Gamma variance=0<br>Chibar2(01)= 0.001<br>*p*-value =0.487 | | Mass point 1 = 0<br>Mass point 2 = 0.071<br>*p*-value=0.989 | |

## Figures

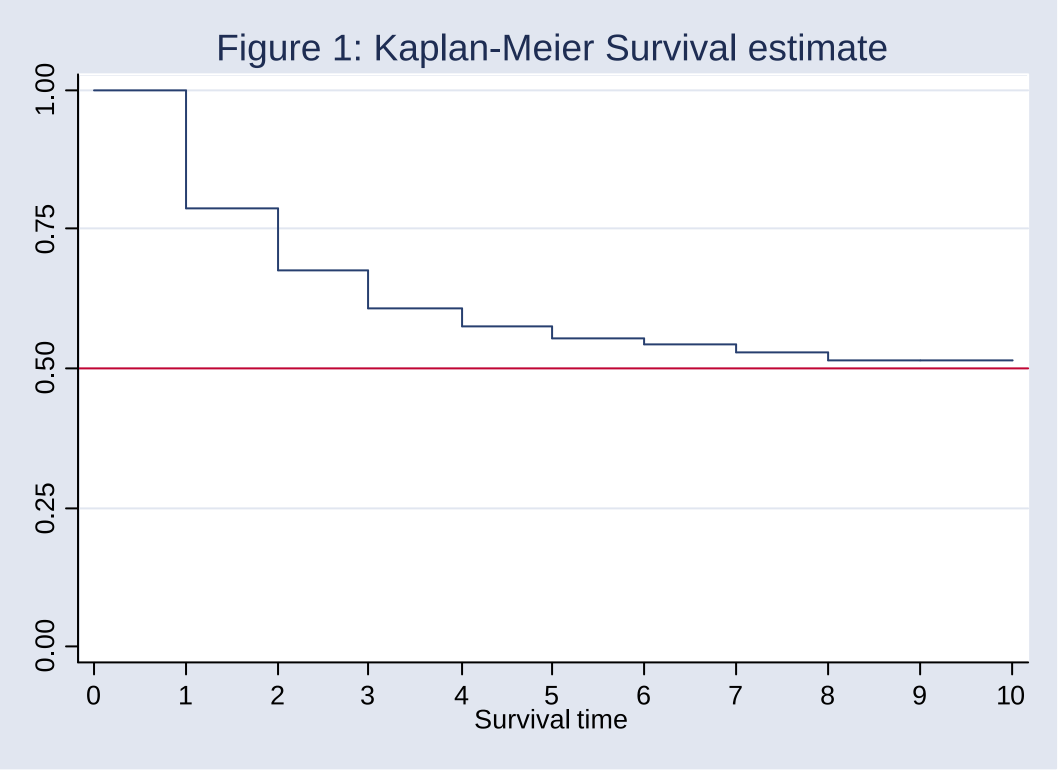

Figure 1: Kaplan-Meier Survival estimate

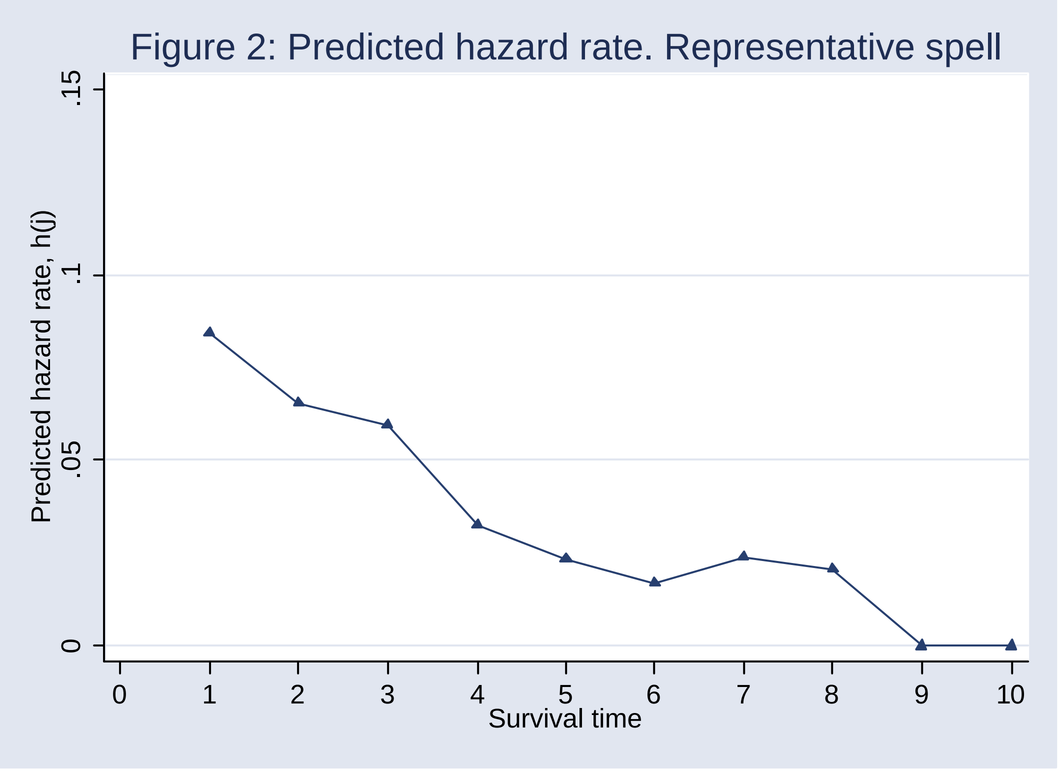

Figure 2: Predicted hazard rate. Representative spell

Figure 3: Survivor function. Representative spell