Comparison of Firm Dynamics in High-Tech and Low-Tech Firms: The Role of Innovation on Survival

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Abstract

The impact of firm dynamics on the survival of firms is a topic that has been broadly studied for several decades. In fact, both firm survival and firm growth are fundamental factors that need to be considered in order to understand how economic growth is characterized in any industry. The influence of firm and industry dynamics on the survivability of firms in the Portuguese manufacturing industry has already been studied (Correia & Gouveia, 2016; Mata & Cabral, 2003; Mata & Portugal, 1994), but the literature on the matter that relates such dynamics to the effects of the technological intensity of the industry is lacking. As such, in order to fill this gap, the main objective of this dissertation is to study how the survival of firms in the Portuguese manufacturing industry is different for firms that are inserted in environments with high and low technological intensities, with a special emphasis put on the impact of investment in innovation. To perform this study, we use the Integrated Business Accounts System (*Sistema de Contas Integradas de Empresas* – SCIE) dataset, provided by the Portuguese Institute of Statistics. In order to study the survival of firms in our sample of interest, we estimate proportional hazards duration models, using a piecewise constant function, in which the baseline hazard was modelled in segments that we consider to be constant. We analyse some of the most relevant characteristics of firm survival, as discussed in the literature, such as the industry's technological intensity, firm age, current number of employees, number of employees at start-up, investment in innovation and investment in exports. We reveal that the impact of firm age in the exit hazard is described by an increase on the exit hazards during an initial period, which then decrease monotonically, following a theory called "the liability of adolescence". We also show that both for firms that present larger current number of employees and for firms that present larger number of employees at start-up, the hazards of exit are lower than when compared with their smaller counterparts. Our results also suggest that firms that are innovators present lower hazards of exit than those that are not innovators, and the same relation exists between firms who are exporters and those that are not. Regarding the impact of technological intensity, we find that firms in high-tech industries face lower hazards of exit than in low-tech ones. Furthermore, our results indicate that firms benefit more from

being innovators in high-tech industries than in low-tech ones. Lastly, we cannot ascertain if there exists a difference in the hazards of exit associated with the relationship between firm size and technological intensity. As we stated, the study of the impact that technological intensity has on firm survival has not been studied deeply in the Portuguese manufacturing industry, and the same applies for how the impact of firm dynamics is different for different levels of technological intensity. As such, we believe our results to be relevant, as we draw conclusions on these previously less studied topics.

Theoretical Framework

The literature regarding firm survival and growth focuses on several variables, both at firm and industry level. The variables which have been studied with greater detail include, mainly, age, firm size, start-up size and technological intensity.

Studies show that age is positively correlated with firm survival (Cefis & Marsili, 2006; Dunne & Hughes, 1994; Evans, 1987a). Many firms that enter an industry are not able to adapt to the adversities that they end up facing and are forced to leave soon after entry. However, the firms that adapt and survive will likely grow, and will have larger chances of survival (Jovanovic, 1982).

Both firm size and start-up size have also been shown to be positively correlated with firm survival (Audretsch et al., 2006; Cefis & Marsili, 2006; Dunne & Hughes, 1994; Evans, 1987a). Firms of larger scale usually have initial endowments that are ample enough to allow them to survive for longer periods of time (Fichman & Levinthal, 1991). As such, the cost disadvantage associated with the gap between a firm's level of output and the Minimum Efficient Scale level of output is larger for smaller firms, which means they will face higher hazard rates than their larger counterparts (Esteve-Pérez & Mañez-Castillejo, 2008).

A high level of technological intensity is often viewed as an industry characteristic that lowers the survival probabilities of firms in it. As technological uncertainty rises, the probability that a firm will be able to produce a viable and desirable product will decrease, along with their chances of survival (Audretsch & Mahmood, 1994). However, in technologically intensive industries small firms may be able to occupy strategic niches that are largely unexplored by large firms, boosting their survival chances (Porter, 1979).

Furthermore, two other topics whose impact on firm survival has been studied with emphasis are investment in innovation and exports. Studies suggest that investing in innovation allows firms to adapt to changes in the environment, and to better respond to the changing needs of their customers. As such, innovation strongly determines the survival of both new firms and incumbents, boosting their survival probabilities (Audretsch, 1995; Cefis & Marsili, 2006).

Lastly, when considering the investment in exports, the studies in the matter show that it is also positively correlated with firm survival. Firms that are able to successfully export were found to usually be more productive than their non-exporting counterparts, presenting larger sizes, being more profitable and more capital and technology intensive than their non-exporting counterparts (Baldwin & Yan, 2011; Bernard & Wagner, 1997).

Variables

Taking into consideration the findings discussed in the literature review, we chose the main variables to be analysed in this dissertation: Firm age at each period of time considered; Current firm size (logarithm of the number of employees at the firm) and firm start-up size (logarithm of the number of employees at firm entry) – we use the logarithms as it allows to analyse the impact of a 1% change in the number of employees has on survival; Technological intensity - based on the codes NACE Rev.2, that identify the technological intensity of firms. We grouped the firms into two categories, high-tech firms, and low-tech firms; Innovation investment (for which we consider the investments in intangible assets, R&D and software) and exports (the sum of the sales and services provided to the community and extra-community markets) – for both these variables we first calculate a sliding window mean, with a time span of three years, and divide the sum of the investments by the volume of sales of each firm, in order to help solve the issue of scale that exists when comparing small firms with large firms. Then we calculate the mean of investment for these variables for each of the 28 technological categories to which manufacturing firms can belong according to the NACE Rev.2 codes at the 2-digit level. Lastly, we consider that a firm is an innovator or exporter for each period, if their three-year period sliding window mean of investment in the variable is larger than the average investment of the technological category to which they belong. This way, we are comparing each firm only with firms with similar characteristics as their own, making for a fairer comparison.

Research hypotheses

Taking into account the literature review presented in the previous section, we now present our research hypotheses regarding firm survival and the role of technological intensity: **Hypothesis 1 (H1):** Firms in high-tech industries face higher hazard rates than in low-tech ones; **Hypothesis 2 (H2) :** Small firms face lower hazard rates in high-tech industries than in low-tech ones; **Hypothesis 3 (H3):** Firms benefit more from being innovators in high-tech industries than in low-tech ones; **Hypothesis 4 (H4):** Older firms face lower hazard rates than younger ones; **Hypothesis 5 (H5):** Larger firms face lower hazard rates than smaller ones; **Hypothesis 6 (H6):** Firms with larger start-up sizes face lower hazard rates than those with smaller start-up sizes; **Hypothesis 7 (H7):** Innovators face lower hazard rates than non-innovators; **Hypothesis 8 (H8):** Exporters face lower hazard rates than non-exporters.

Survival analysis and hazard model

Survival analysis is a type of statistical method that helps describe the occurrence and timing of events. This analysis involves the estimation of regression models, with the independent variable being a measure of time or rate of an occurrence. Survival analysis is particularly useful, as it gives the researcher the ability to handle right censoring, which occurs when some of the individuals in the sample do not experience the occurrence of the events we are interested in studying, which implies that an event time cannot be measured. Conventional statistical methods are not good choices for duration analysis, as they do not account properly for right-censoring, producing biased and inconsistent estimates. We are interested in studying firm duration and firm failure, in which information with respect to duration is typically incomplete, since at the time of the survey there persists a number of cases that did not fail, making it right-censored. Therefore, the right choice is to employ models specifically designed to take this problem into account, which leads us to the study of survival analysis and hazard models (Allison, 1984; Jenkins, 2005). We purpose to apply these models to study the instantaneous probability of a firm leaving the industry we are studying, which is commonly called the hazard.

The hazard model gives a risk of failure for each point in time, i.e., the conditional probability that a firm will exit the market in the next time interval, conditional on the firm having survived to the start of the time interval that is being studied. By defining the hazard rate as λ(t), we can write the hazard function as:

$$\lambda(t) = lim_{\Delta t \to 0^+} \frac{P(\, t \leq T \leq t + \Delta t \,|T \geq t)}{\Delta t} = \frac{f(t)}{S(t)}, \quad (1)$$

In this formula, T is a random variable representing failure time, f(t) is the probability density function of the event occurring and S(t) is the survival function, given by:

$$S(t) = P(T \geq t), \quad (2)$$

The notion of duration dependence is associated with the hazard rate. If the duration dependence is positive, the hazard rate will increase with time, which, in our model means that $d\lambda(t)/dt > 0$. On the other hand, if a negative duration dependence occurs, the hazard rate will decrease with time, which, in our model means that $d\lambda(t)/dt < 0$ (Mata & Portugal, 1994).

In order to fit survival models, there are three approaches that can be followed: parametric, semi-parametric, and non-parametric ones, each presenting advantages and disadvantages. The model that better allows us to fit the characteristics we desire for our study is the piecewise-constant exponential model. This parametric continuous-time duration model requires that we subdivide the time of our analysis into intervals, and we consider that the hazard is assumed constant within this pre-specified survival time intervals but that the constants may differ for different intervals. This assumption requires some flexibility, making weaker assumptions on the shape of the baseline hazard, minimizing the disadvantages inherent to this.

Sample construction

In order to analyse firm survival, we use the Integrated Business Accounts System (*Sistema de Contas Integradas de Empresas* – SCIE) dataset. The population of the dataset is composed by all the firms (societies, sole proprietors and independent workers) that have a production activity of goods and/or services, during that period, in the whole country. We only consider manufacturing firms, with the data available belonging to the years of 2007 to 2015. While our analysis time frame begins in 2007, we follow firms that were born in 2004 and after, though these observations are left-truncated. This delay entry means that some firms were already at risk of closure by the time our analysis begins (in our dissertation, we consider that firm closure occurs when there is a registered firm death in our dataset). From a different perspective, it means that some of the firms born in 2004 (or later) might not have survived until our analysis began, leading to a sample that is composed of survivors. Fortunately, the model we use easily accounts for the delayed entry issue.

We only considered the observations that correspond to "societies", since individual firm owners probably have very different behaviours from regular firms and may not be focused on making profit. Further, we excluded all the observations in the sample that did not have the year of birth of the firm and all the observations for the year 2015, as we do not have any information about firm closures in 2015, and both these variables would be vital to perform an analysis of firm survival. Additionally, we excluded firms for which the total number of sales and/or services provided is zero for all of the years they were present in the data set. For the particular case of firms that have their death documented in the dataset, but that re-enter the dataset once more on a later date, we discarded all the entries after the first death, so as to simplify the interpretation of the results. Lastly, we only consider firms for which the level of technological intensity never changes.

Results

In this section we present the results of the econometric analysis we performed and then discuss them in the light of the literature review. We tested the hypotheses that were previously formulated, by estimating six models, each with different combinations of the variables that we have been analysing so far. For all the models we also controlled for region and variations of unemployment rate and of GDP, from the years of 2007 to 2014.

Table 1 shows the marginal effects for the predicted hazard in each model, for all variables. A "predictive margin" is a statistic computed from predictions from a model while manipulating the values of the covariates, if some covariates are not fixed. The marginal effects are the differences in levels of margins if the covariate values are changed. As such, the values in Table 12, for discrete variables represent the average difference between the predicted hazard for each class and the base level of that variable, and for continuous variables represent the impact that a 1% change on the variable has on the hazard (since we are using them in logarithmic form). Therefore, values for the marginal effects lower than 0 are associated with lower hazard and longer survival times, and values greater than 0 are associated with increased hazard and shorter survival times.

Table 1 - Marginal effects for the exponential model, for all firms

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Age: 2 to 4 years	0.052*** (0.002)	0.054*** (0.002)	0.035*** (0.003)	0.036*** (0.003)	0.046*** (0.003)	0.048*** (0.003)
Age: 5 to 6 years	0.060*** (0.003)	0.062*** (0.003)	0.035*** (0.004)	0.036*** (0.004)	0.047*** (0.004)	0.050*** (0.004)
Age: 7 years and older	0.048*** (0.003)	0.049*** (0.003)	0.019*** (0.006)	0.021*** (0.006)	0.031*** (0.006)	0.033*** (0.006)
Log of current size	-0.029*** (0.001)				-0.060*** (0.002)	
Firm size: 2 to 5 employees		-0.073*** (0.003)				-0.116*** (0.005)
Firm size: 6 or more employees		-0.083*** (0.003)				-0.140*** (0.005)
Log of start-up size			-0.007*** (0.001)		0.037*** (0.002)	
Start-up size: 2 to 5 employees				-0.030*** (0.002)		0.027*** (0.003)
Start-up size: 6 or more employees				-0.016*** (0.003)		0.097*** (0.007)
Innovator (binary)	-0.012** (0.004)	-0.012** (0.004)	-0.030*** (0.005)	-0.029*** (0.005)	-0.028*** (0.005)	-0.027*** (0.005)
Exporter (binary)	-0.019*** (0.003)	-0.023*** (0.003)	-0.037*** (0.004)	-0.039*** (0.004)	-0.026*** (0.004)	-0.029*** (0.004)
High-tech firm (binary)	-0.012*** (0.004)	-0.015*** (0.004)	-0.001 (0.004)	-0.001 (0.005)	-0.004 (0.005)	-0.007 (0.005)
Log-likelihood	-16809.402	-16655.818	-14066.869	-14013.128	-13578.719	-13461.624
Number of firms	22198	22198	17962	17962	17962	17962
Number of observations	22198	22198	17962	17962	17962	17962

Statistics computed using only the last observation of each firm, using the exponential model. All estimations control for rate of yearly change of GDP, unemployment rate per year and region. For categorical variables the base levels are not presented (age = 1 year; current size = 1 employee; start-up size = 1 employee; non-exporters; non-innovators; low-tech firms). Standard errors presented in brackets.
* significant at 10%; ** significant at 5%; *** significant at 1%

The results displayed in Table 1 indicate that when considering technological intensity, Models 1 and 2 show that high-tech firms face lower hazard than their low-tech counterparts. For all other models, we did not obtain significative results for this variable. As such, our findings do not support H1.

When looking at all of the age classes, the results show that the marginal effects are larger than 0, for all models, which means that firms with 1 year of age present the lowest hazard. The hazard increases from the class of age 2-4 years to age 5-6 years, but then, for all models, starts decreasing when it reaches the 7-year mark. These results seem to be in line with the theory of the “liability of adolescence”. This theory suggests that, for the initial period the hazard rate is low, and the end of adolescence is marked by a hazard maximum, followed by monotonically declining hazard rates (Bruderl & Schussler, 1990; Fichman & Levinthal, 1991). Due to this, our findings do support H4, with age and hazard being negatively correlated, but the most common theory of the “liability of newness” does not describe our sample.

Additionally, looking at Models 1 and 2, we see that current size has a negative impact on hazard. This suggests that larger firms face lower risk of exit than their smaller counterparts, as proposed by H5.

By looking at Models 3 and 4, we can see that start-up size has a negative impact on hazard, which suggests that these findings support H6. However, Model 4 indicates that firms with start-up size of between two to four employees face a hazard lower than those who start with 6 or more employees, which indicates that firms may in fact start too big. Models 5 and 6 include estimations for both start-up size and current size. We can see that, when considering the control of all variables, including current size, start-up size presents marginal effects greater than zero. These results indicate that considering the two variables at once in the same model leads to worse results than when they are included separately, since they are greatly correlated.

Lastly, for both innovators and exporters, all models without exception present marginal effects lower than zero for both variables, which is in line with the findings in the literature, supporting H7 and H8.

Furthermore, we took into consideration interaction effects between variables. An interaction effect is one in which the partial effect of the dependent variable with respect to an explanatory variable may depend on the effect of yet another explanatory variable. As such, this analysis allows us to understand the effect that the variables can have upon other variables.

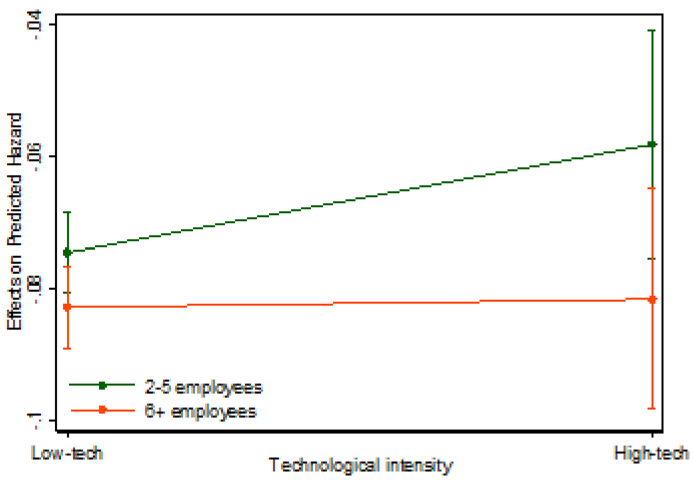

Figure 1 - Marginal effects for the interaction between each current firm size class and both levels of technological intensity

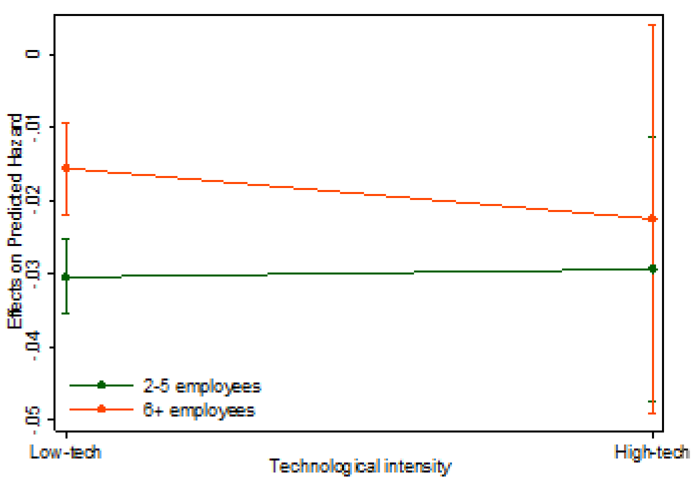

Figure 2 - Marginal effects for the interaction between each start-up size class and both levels of technological intensity

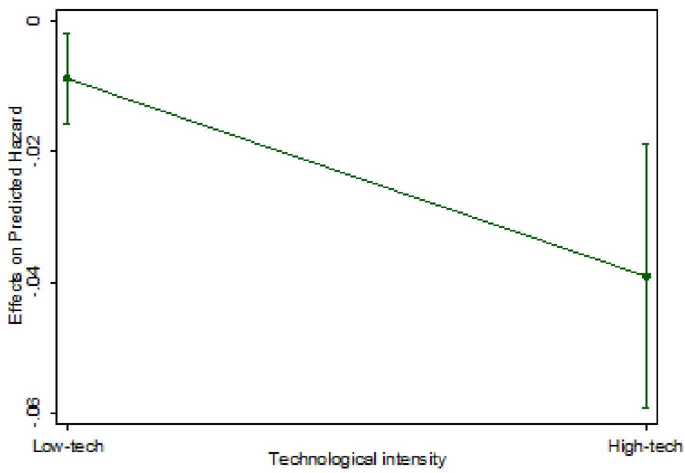

Figure 3 - Marginal effects for the interaction for between innovators and both levels of technological intensity

We can see that only for the case of the interaction between the variables innovator and technological intensity (displayed in Figure 3) are the results significatively different between high-tech and low-tech firms (because the bands representing the 95% confidence interval do not overlap their values for this variable). The results for both technological intensities are negative, which means that both high-tech and low-tech innovators face lower hazard than their non-innovator counterparts. Furthermore, since high-tech firms obtain a larger decrease in predicted hazard than low-tech ones, we can affirm that high-tech firms benefit more from being innovators than their low-tech counterparts, confirming H3.

On the other hand, by looking at Figures 1 and 2, the results do not allow us to confirm if the hazard is significatively different for any size class, neither regarding current firm size nor regarding start-up size. As such, we are unable to confirm H2, since we cannot tell with certainty if there exists a difference in hazard for high-tech and low-tech firms, for any of the size classes.

Conclusions

In this study we analyse the impact that firm dynamics have on firm survival, comparing firm dynamics of high-technology and low-technology firms, with a special emphasis put on the impact of innovation. To do so, we perform an econometric analysis to our sample of interest, considering a proportional hazards model for which we used a flexible piecewise constant specification of the baseline hazard function. For this analysis, the variables we studied were technological intensity, firm age, current firm size, firm start-up size, innovation investment and exports. By performing this analysis, we aimed to understand how these variables impact firm survival, considering these to be the factors that most influence the hazard of exit. The results we present confirm most of the hypotheses in our dissertation, going in accord with what was expected taking into account the literature review. We show that firm size, firm start-up size, innovation investment and exports have a positive impact on firm survival, lowering the hazards of exit, which goes in accord to the main results presented in the relevant literature.

We also suggest that small firms have higher survival chances in high-tech environments than in low-tech ones.

On the other hand, when considering the variables related with age and technological environment, our results differ from the hypotheses presented. When age is considered, the most common scenario is that of monotonically decreasing hazard rates with age, following what is usually called the "liability of newness". However, our results suggest that hazard rates increase during the initial period of activity of a firm, and only start decreasing later on in their lives. This scenario is not uncommon, being usually called the "liability of adolescence". What makes our results different from the common scenario is that it takes nearly seven years for the hazard to start decreasing, while the results presented in the literature show a much shorter time window before the hazard decreases. Although it is not unheard of for such a long period to exist, it is still uncommon, and is a characteristic of the Portuguese manufacturing industry that should be further studied.

When technological environment is considered, we suggest that firms in high-tech environments present lower hazard rates than the ones in low-tech environments, which does not go in accord with most findings in the literature. Additionally, we state that firms benefit more from being innovators in high-tech industries than in low-tech ones. Lastly, we cannot draw any conclusions regarding the existence of a difference associated with the relationship between firm size and technological intensity.

Overall, our findings suggest that investment in international trade and exports and investment in innovation will increase the survival chances of firms. As such, incentives for such investments could lead to an increase in firm survival and growth and should be taken into consideration in order to lead to a possible increase in economic growth. We hope the findings in this dissertation are useful for future studies on the manufacturing industry.

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