

## 6. Sunk costs, industry dynamics and firm productivity.

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### INTRODUCTION

This chapter examines whether the level of sunk costs is associated with productivity differences across cohorts of continuing firms. To organize this empirical question, we rely on the theoretical literature that seeks to account for the heterogeneous productivity observed across individual producers. The analysis of this heterogeneity has been addressed through models of industry dynamics, such as those in Jovanovic (1982), Hopenhayn (1992) and Ericson and Pakes (1995). In these models, the path of growth and failure that characterizes firm data sets is driven to a large extent by differences in productivity. In particular, we rely on the Hopenhayn (1992) model, which emphasizes the notion of sunk cost to explain productivity differences. On the empirical side, Tybout (1996), Caves (1998), Bertelsman and Doms (2000), Haltiwanger (2000) and Foster, Haltiwanger and Krizan (2001) provide excellent reviews of the literature. Our analysis of productivity differences between firms is similar to the approach used by Aw, Chen and Roberts (2001) and Aw, Chung and Roberts (2002).

The purpose of this chapter is to explore whether sunk entry costs are related to productivity differences at the firm level, as suggested by models of industry dynamics. We take a sample of Spanish manufacturing firms as our reference. The chapter uses the methodology proposed by Delgado, Fariñas and Ruano (2002) that compares the entire distribution of firm productivity rather than just marginal moments, typically means. In particular, we compare the cumulative distribution function of total factor productivity for groups of firms with different sunk costs. The chapter implements a testing procedure based on the concept of stochastic dominance

for ranking differences between productivity distributions. Furthermore, the paper tests whether sunk costs, measured at the firm level, influence the distribution of productivity levels across incumbent firms. Fariñas and Ruano (2005) examine this question at the aggregate level for a sample of Spanish manufacturing firms; in this paper, we extend the analysis to six industries defined at the two-digit level of the NACE classification.

The literature examining the relationship between sunk costs and firm productivity has confirmed the existence of this association empirically. Aw, Chung and Roberts (2002) reports evidence on manufacturing firms in Taiwan and Korea. Their analysis reveals a set of productivity differences between firms from both countries that are consistent with institutional characteristics, making sunk entry costs higher in Korea than in Taiwan. Results reported by Foster, Haltiwanger and Krizan (2001) for the service sector confirm that a large part of productivity growth comes from net entry. This reflects more market selection, due to the fact that sunk entry costs are lower for the service sector than for manufacturing industry.

The empirical evidence we provide in this paper partially confirms that the level of sunk costs is associated with productivity differences across cohorts of continuing firms. In one industry out of the six –the textile industry (NACE 17,18)– we confirm that firms operating in markets with high sunk costs have lower productivity than firms operating in markets with low sunk costs. In three other industries –non-metallic mineral products (NACE 26), rubber and plastic (NACE 25), and chemicals (NACE 24)– the relationship between firm productivity and sunk costs is as expected but the magnitude of the productivity differences is rather low and not statistically significant. Finally, in two industries –electrical equipment (NACE 31,32) and paper, publishing and printing (NACE 21,22)– productivity differences cannot be ranked according to the criterion of first-order stochastic dominance.

The chapter is organized as follows. Section 2 describes a theoretical framework relating sunk costs to productivity levels. Section 3 presents the testing procedure that has been implemented, and also discusses issues connected with the measurement of firm productivity and sunk costs. Section 4 presents the main empirical results. Finally, section 5 concludes.

## **SUNK COSTS AND FIRM PRODUCTIVITY: A FRAMEWORK FOR ANALYSIS**

Models of firm and market dynamics, as developed by Jovanovic (1982) and Hopenhayn (1992), provide a framework for analyzing the relationship between firm productivity and sunk costs. These models characterize the

long-run equilibrium properties of industries composed of a large number of price-taking firms that produce a homogeneous output. In particular, using Hopenhayn's model (1992) as a reference, firm output is a function of input quantities and a random variable, which can be interpreted as a firm-specific productivity shock. As firms observe their productivity shocks, they decide about the output level that maximizes their expected discounted profits.

The initial productivity shock has two characteristics. On one hand, the shock is assumed to be drawn from the same distribution function for all firms. On the other hand, the productivity shock follows a Markov process that implies that the higher the current productivity is, the better the distribution of future productivity shocks. Therefore, firms with a high current productivity are more likely to experience high productivity levels in the future.

One of the basic results coming out of this model is that there is a reservation level for the productivity shock,  $\theta^*$ , which defines the decision rule for the firm to continue or to abandon the market. Firms with  $\theta < \theta^*$  will exit the market and firms with  $\theta \geq \theta^*$  will continue their activity. The existence of this failure boundary in the distribution of firm productivity levels is a basic prediction of models of industry dynamics. This boundary is the lowest level of productivity that will enable firms to have positive discounted expected profits over future periods. As firms with productivity levels less than  $\theta^*$  will exit the market and firms with productivity levels greater than  $\theta^*$  will remain in the market, the failure boundary  $\theta^*$  must define a separating line between the productivity distribution function of surviving firms and the productivity distribution of exiting firms. Figure 6.1 illustrates what the positions of the productivity distributions of the group of exiting and continuing firms should be when a failure boundary at  $\theta^*$  is in operation.

Many studies find that exiting firms have significantly lower productivity (multifactor or labor) than continuing firms –see Caves (1998), Bartelsman and Doms (2000) and Foster, Haltiwanger and Krizan (2001) among others. In a previous paper that used a micro panel data set of Spanish manufacturing firms, Fariñas and Ruano (2005) also found evidence indicating that the productivity of incumbent firms is greater than the productivity of exiting firms. The paper made estimates of the productivity distributions of continuing and exiting firms that confirm that the productivity distribution of continuing firms stochastically dominates the distribution of exiting firms. Figure 6.2 reproduces the regularity that we obtain when comparing the productivity distributions of continuing firms and different cohorts of exiting firms. The position of the cumulative distribution of continuing firms is to the right of the distribution of exiting firms. The position of both distributions indicates that continuing firms have higher productivity than exiting firms. When these differences between both distributions are formally tested, the hypothesis that the distribution of continuing firms stochastically dominates

the distribution of exiting firms cannot be rejected. This result is basically consistent with models of industry dynamics.

However, as Figure 6.2 indicates, the distribution of exiting and continuing firms overlaps over a large range of productivity levels. The position of both distributions suggests that the failure boundary separating the productivity distributions of continuing and exiting firms (as in Figure 6.1) is not operating at all, which seems to be in contradiction with the existence of a failure boundary, as models of industry dynamics predict. In the rest of this section, we explore an explanation for this empirical fact that is based on the existence of different sunk entry costs.

Sunk costs play an important role in the failure process according to models of firm and industry dynamics. In particular, one of the implications of the Hopenhayn (1992) model is that a higher sunk entry cost ( $c_e$ ) will lower the minimum level of productivity,  $\theta^*$ , needed for incumbent firms to survive. As these costs provide a barrier to the entry of new firms, a high level of entry costs reduces the intensity of market selection. The insulation of incumbent firms from the effects of market selection will result in a distribution of surviving firms with a higher proportion of low productivity units. From this perspective, sunk entry costs are a key determinant of the distribution of productivity levels across incumbent firms in the market.

Figure 6.3 considers the case of two failure boundaries:  $\theta^*(c_e^H)$  is the boundary for firms with high sunk entry costs, and  $\theta^*(c_e^L)$  is the boundary for firms with low sunk entry costs. The model predicts that the critical level of productivity corresponding to high sunk costs is to the left of the productivity level corresponding to low sunk costs firms:  $\theta^*(c_e^H) < \theta^*(c_e^L)$ . According to models of industry dynamics, each boundary defines a separating line for the productivity distributions of both surviving and exiting firms. As illustrated for the group of firms with low sunk entry costs, the productivity distribution of surviving firms is to the right of the boundary and the distribution of exiting firms is to the left of the boundary. The same can be said for the group of firms with high sunk entry costs.

Figure 6.3 suggests that the productivity distributions of surviving and exiting firms, as they are drawn in Figure 6.2, are the result of an aggregation process over many productivity distributions that correspond to groups of firms with different sunk entry costs and various boundary failures. The aggregation over these groups of firms may explain why the distributions of surviving and failing firms overlap over a large range of productivity levels, covering the effects of the failure boundaries. Models of firm dynamics that seek to account for heterogeneity across individual productivity point to the heterogeneity of sunk entry costs as one of the idiosyncratic factors that determine the distribution of efficiency levels across incumbent firms. On the basis of these arguments, the paper explores whether aggregation over productivity distributions with different  $\theta^*$  levels is consistent with the fact

that productivity distributions of incumbent and exiting firms overlap over a large range of values.

As productivity thresholds,  $\theta^*$ , are not directly observable, it is difficult to test for aggregation over productivity distributions with different  $\theta^*$  levels. However, we can take advantage of the fact that critical levels of productivity are related to the magnitude of sunk costs. Therefore, the ranking of productivity distributions for the groups of surviving firms and exiting firms must be related to the magnitude of sunk entry costs. This makes it possible to apply the following strategy: to test whether the productivity distributions of incumbent and exiting firms can be ranked according to the magnitude of sunk costs. Figure 6.2 can be used to illustrate this strategy for the case of two productivity thresholds. As we have mentioned above, the critical level  $\theta^*$  ( $c_e^H$ ) corresponds to the group of firms with high sunk entry costs and  $\theta^*$  ( $c_e^L$ ) to the group of firms with low sunk costs. Consequently, the distribution  $F(\theta | \theta \geq \theta^* (c_e^H))$  denotes the productivity distribution of surviving firms with high sunk entry costs, and  $F(\theta | \theta \geq \theta^* (c_e^L))$  denotes the distribution of surviving firms with low sunk entry costs. The prediction of Hopenhayn's model is:  $F(\theta | \theta \geq \theta^* (c_e^H)) \geq F(\theta | \theta \geq \theta^* (c_e^L))$ , which states that the productivity distribution of surviving firms with low sunk entry costs stochastically dominates the distribution of firms with high entry costs. A more general statement of the previous condition can be formulated as follows: the productivity distribution of surviving firms  $F(\theta | \theta \geq \theta^* (c_e))$  is non-decreasing with sunk entry costs.

The previous condition has been formulated for the group of surviving firms, but it can be stated similarly for the cohort of exiting firms. In a given year, the productivity distribution of the cohort of exiting firms can be ranked in accordance with similar criteria: the productivity of exiting firms in markets with low sunk entry costs is higher than that of high-cost exiting firms. The reason for this result, in the case of exiting firms, is the same as for surviving firms. High entry costs reduce the intensity of market selection and this will result in a distribution of exiting firms with a higher proportion of low productivity units. When we compare firms exiting in markets with high sunk entry costs and firms exiting in markets with low sunk costs, the latter group must stochastically dominate the former.

The rest of the chapter explores the implications of industry dynamic models with respect to the relationship between sunk costs and firm productivity. In particular, we test whether the productivity distributions of surviving firms can be ranked according to the magnitude of sunk entry costs.

## ESTIMATION AND MEASUREMENT ISSUES

In this section, we present the estimation procedure and the issues that are related to the measurement of productivity and sunk costs.

### Estimation Procedure

The testing procedure used compares the productivity distributions corresponding to two groups of firms. The procedure is based on non-parametric techniques, which have been used previously by Delgado, Fariñas and Ruano (2002) and Fariñas and Ruano (2005). See both references for more details.

To perform the comparison between two productivity distributions, we use a procedure that relies on the notion of first-order stochastic dominance. Let us define two cumulative distribution functions such that the first one corresponds to the productivity distribution of firms with small sunk costs, which we denote by  $F$ , and the second one corresponds to the group of high sunk costs, denoted by  $G$ . According to models of industry dynamics, the productivity distribution of firms with small sunk costs,  $F$ , should dominate the distribution of high cost firms,  $G$ . Stochastic dominance of  $F$  relative to  $G$  requires that two statistical conditions be satisfied: first, both distributions are not identical (i.e., the null hypothesis  $H_0: F(z)-G(z) = 0$  can be rejected); second, the sign of the difference is as expected (i.e. the null hypothesis  $H_0: F(z)-G(z) \leq 0$  cannot be rejected). These two-sided and one-sided tests can be performed respectively by the following Kolmogorov-Smirnov test statistics:

$$\delta_N = \sqrt{\frac{n \times m}{n + m}} \sup_{z \in Z} |F_n(z) - G_m(z)|$$

$$\eta_N = \sqrt{\frac{n \times m}{n + m}} \sup_{z \in Z} (F_n(z) - G_m(z))$$

where  $n$  and  $m$  correspond, respectively, to the size of the sample of firms in distribution  $F$ , the small sunk cost group, and to the size of the sample drawn from distribution  $G$ . The limiting distributions of both test statistics are known under independence between the sample of firms drawn from distributions  $F$  and  $G$  (see Delgado, Fariñas and Ruano, 2002).

### Productivity Measurement

Productivity is measured with an index of total factor productivity. The proposed index follows the framework developed by Aw, Cheng and Roberts (2001) and it is an extension of the multilateral total factor productivity index

proposed by Caves, Christensen and Diewert (1982) and Good, Nadiri and Sickless (1996). The index takes a hypothetical firm as reference and measures productivity for each firm relative to this reference firm. In particular, the index uses as the reference the average firm of the size group to which the firm belongs, and then chain-links the reference points to preserve transitivity between firms of different size groups within the same industry. The index has been used previously in Delgado, Fariñas and Ruano (2002) and Fariñas and Ruano (2003, 2005).

The expression of total factor productivity for firm  $f$  is:

$$\ln \lambda_f = \ln y_f - \overline{\ln y_\tau} - \frac{1}{2} \sum_{k=1}^m (\overline{\varpi}_{kf} + \overline{\varpi}_{k\tau}) (\ln x_{kf} - \overline{\ln x_{k\tau}}) + \frac{\overline{\ln y_\tau} - \overline{\ln y}}{\overline{\ln y_\tau} - \overline{\ln y}} - \frac{1}{2} \sum_{k=1}^m (\overline{\varpi}_{k\tau} + \overline{\varpi}_k) (\overline{\ln x_{k\tau}} - \overline{\ln x_k})$$

where  $y_f$  is the output of firm  $f$ ,  $x_{kf}$  is the quantity of input  $k$  corresponding to firm  $f$ , and  $\overline{\varpi}_{kf}$  is the cost share of input  $k$  for firm  $f$ . The index  $\tau$  identifies two size groups of firms: the first group corresponds to small firms employing between 10 and 200 employees; and the second group corresponds to large firms with more than 200 employees.

The index measures the proportional difference of total factor productivity for firm  $f$  relative to a reference firm. This reference is defined as a firm such that the output and the inputs are, respectively, equal to the geometric means of a firm's outputs and inputs in the same industry, and the cost shares of inputs are equal to the arithmetic mean of a firm's input shares in the industry. To be more precise, the first line on the right-hand side compares firm productivity with the productivity of the average firm of the same size group. Therefore, comparisons between observations corresponding to the same size group are transitive. The set of terms in the second line on the right-hand side measures productivity differences between the reference firm of a size group and a common reference defined by the average firm of the entire sample of small and large firms in the industry. This second term preserves transitivity between small and large firms. The approach used to define the index has two advantages. First, if the testing procedure is applied both in the group of small and large firms, it allows us to control for differences in productivity between firms that are associated with the size of firms. Second, as transitivity between all firms in the same industry is preserved by the second term, overall comparisons between large and small firms can also be performed.

The information used to calculate the index of total factor productivity for each firm is drawn from the *Encuesta sobre Estrategias Empresariales* (Survey on Business Strategies) (ESEE). The output  $y_f$  is measured by gross production using individual price indexes. The estimation considers three

inputs ( $k=1,2,3$ ): labor, materials and the stock of capital. Labor inputs are measured by the number of effective hours of work per year. Material inputs are measured by the cost of intermediate inputs, expressed in real terms using an individual price index for each firm. The stock of capital is calculated using the perpetual inventory formula for each firm. Cost shares have been computed using individual information drawn from the ESEE. Total costs are the sum of labor costs, intermediate inputs and the cost of capital. The cost of labor is measured by the sum of wages, social security contributions and other labor costs paid by the firm. The cost of capital for each firm is computed by defining a user cost of capital that we measure by the cost of the long-term external debt of the firm plus the depreciation rate minus the variation of the price index for capital goods.

### **Sunk Cost Measurement**

To provide an explanatory assessment of the relationship between firm productivity levels and sunk costs, an empirical measure of this variable is needed. We adopt the methodology outlined in Kessides (1990). Ghosal (2002) and Fariñas and Ruano (2005), among others, have previously used this methodology.

The measure of sunk costs is based on the theory of contestable markets. Kessides (1990) draws on this literature to stress the idea that the share of sunk capital investment committed by the entrant firm is a function of three capital characteristics: the level of durability, the degree of specificity and the level of mobility. These characteristics are unobservable to a certain extent, but Kessides (1990) provides meaningful proxies that can be measured with the ESEE.

The first proxy is based on the conjecture that the share of sunk capital expenditures will be low for firms using capital that depreciates very rapidly. We define the variable *DEPRECIATION* as the ratio of depreciation charges during the year to the capital stock in fixed assets. If the entrant's capital depreciates by  $d$  percent per year, at the end of the period,  $(1-d)$  percent of the entry investment can be partially sunk. Therefore, the higher  $d$  (*DEPRECIATION*) is, the lower the amount of the entry investment that cannot be recovered (i.e. the lower the level of potential sunk costs is).

Given that a certain proportion of the value of the entrant's capital is undepreciated, its degree of sunkness will depend on the characteristics of the second-hand market for capital. Therefore, the second proxy is a measure of the intensity of the second-hand market for the capital employed by the firm. The ESEE provides information on the value of sales of used capital equipment, and the ratio between these sales and the value of the capital stock, denoted by *USED CAPITAL*, is the second proxy. Thus, the higher the variable *USED CAPITAL* is, the lower sunk costs are.

Furthermore, the degree of sunkness for the undepreciated stock of capital will depend on the extent to which such capital is firm-specific. Therefore, the third proxy captures capital mobility and refers to the extent to which the capital equipment used by the firm can be rented. The ESEE provides information on this characteristic as it indicates those firms partially renting their capital equipment. This is a zero/one variable that takes the value one for firms partially renting their capital and zero otherwise and is denoted by LEASED CAPITAL. The level of sunk cost will be lower for firms using capital that can be leased.

The three proxies are used to classify firms in two sets: the group of high sunk cost firms and the group of low sunk cost firms. The classification criteria are as follows:

- Firms with a DEPRECIATION value  $\geq$  50th percentile are classified in the group of low sunk cost firms, and firms with a value  $<$  50th percentile are classified in the high cost group.
- Firms with LEASED CAPITAL equal to one are classified in the group of low sunk costs.
- Firms with a value of USED CAPITAL  $\geq$  50th percentile are classified in the group of low sunk cost firms; when the value is  $<$  50th percentile, the firm is classified in the group of high sunk costs.
- Finally, we produce a COMBINED CRITERIA that classifies firms in the group of low sunk costs if DEPRECIATION or LEASED CAPITAL or USED CAPITAL fulfill the previous conditions.

The median level of the first and third variables –DEPRECIATION and USED CAPITAL– have been computed for each industry using the weighted empirical distribution. This nonparametric estimator of the distribution function takes into account the sampling proportions for small firms (10-200 employees) and large firms (more than 200 employees) in the ESEE. In the large-size category, the sample of firms in the ESEE represents approximately 70 percent of the population of manufacturing firms, and in the small-size category firms were chosen randomly up to a rate of participation of nearly 4 percent of the number of firms in the population. These percentages have been used to scale the absolute frequencies associated with the level of the sunk cost when estimating the median of the distribution.

## EMPIRICAL RESULTS

This section presents the results on productivity differentials between the groups of high and low sunk cost firms. The dataset we analyze consists of a

sample of Spanish manufacturing firms based on the *Encuesta sobre Estrategias Empresariales* (Survey on Business Strategies) (see Fariñas and Jaumandreu (1999) for more details). The empirical exercise and the testing procedure apply to firm-level information corresponding to the year 1997. To check for robustness, a similar exercise is applied to data corresponding to the year 1993 at the end of this section. The results are reported for six industries that are defined in terms of the two-digit codes of the NACE classification. These industries are as follows:

- Manufacture of textiles and textile products (NACE 17,18)
- Manufacture of other non-metallic mineral products (NACE C26)
- Manufacture of rubber and plastic products (NACE 25)
- Manufacture of chemicals and chemical products (NACE 24)
- Manufacture of electrical equipment (NACE 31,32)
- Manufacture of pulp, paper and paper products; publishing and printing (NACE 21,22)

Data availability has been the main restriction on the selection of these industries. First, some industries were discarded because the number of observations were not sufficient to apply the testing procedure defined in section 3.1. On the basis of this criterion, 9 industries out of a total number of 23 two-digit NACE manufacturing industries were selected. Second, more narrowly defined industries (i.e. three or four-digit NACE codes) would have been preferred for the purpose of testing productivity differences between low and high sunk costs. However, the information available in the data base makes this impossible. Furthermore, market dynamic models, such as the one developed by Hopenhayn (1992), characterize the properties of industries consisting of a large number of price taking firms that produce homogeneous products. From this point of view, some of the industries in the lists accommodate these characteristics better than others. We would have preferred to select industries in accordance with the above characteristics, but data restrictions did not allow us to do so.

The testing procedure defined in section 3.1 is applied within each of the six industries. Total factor productivity is measured for each firm taking as a reference an average firm of the same industry according to the index defined in section 3.2. Furthermore, the criterion that classifies firms in two groups of high and low sunk cost units has been applied within each of the six industries. We are assuming that within these broad industries our measures of sunk costs are able to group firms according to the level of sunk entry costs characterizing the markets in which they operate. Therefore, in the group of high sunk costs, we group firms operating in markets with this characteristic and we do the same for the group of low sunk cost firms.

Tests are applied within each industry separately for the group of small firms and the group of large firms. Statistics are given independently for both

groups of firms in order to be consistent with the data set used. As we have mentioned in the section above, firms were chosen according to a selective sampling scheme with probabilities of firm participation in the survey (*Encuesta sobre Estrategias Empresariales*) that depended on the size category of the firm. Therefore, within each industry, the samples of small and large firms can be considered random realizations of both subsets of the population of firms. Consequently, it is optimal to apply the testing procedure separately for small and large firms. The disadvantage of this procedure is that it produces two different results for the same industry. To alleviate this disadvantage and to further illustrate the comparison between high and low cost firms, we have plotted estimates of the distribution functions. The purpose is to produce a graph that represents the productivity difference between the group of low and high sunk cost firms for the whole population of firms (small and large firms) within each industry. Formally, they have been estimated as a mixture of the conditional distribution function for the groups of small and large firms. The parameters of the mixture are the probability of being either a small or a large firm in the populations of low and high sunk cost firms. The estimations are performed using a smooth sample distribution function that produces a graphical representation of the differences between low and high sunk costs. These differences can be interpreted as differences for the entire population of firms. More details about this procedure can be found in Fariñas and Ruano (2005).

Figure 6.4 separately reports the productivity distributions of the groups of high and low sunk cost firms for the six industries considered. Table 6.1 shows the hypothesis test statistics for the year 1997. The statistics summarized in Table 6.1 permit us to test whether the productivity of high sunk costs stochastically dominates the productivity distribution of high sunk costs. Tests are performed separately for each of the four sunk cost measures described in section 6.3, in both the samples of small and large firms. First, we state the results for the textile industry (NACE 17,18) and then we discuss the rest of the industries.

Figure 6.4 illustrates productivity differences between firms with high and low sunk costs. The first industry reported is Manufacture of textiles and textile products (NACE 17,18). The graph corresponds to the weighted kernel estimate of the cumulative distribution function of both small and large firms. The position of the productivity distribution of low sunk cost firms is to the right of the high sunk cost distribution, indicating that for any quantile of the distribution, the productivity of low sunk cost firms is higher than that of high sunk cost firms. At the median of the distribution, low sunk cost firms have a total factor productivity that is 8 percent higher than the productivity of high sunk cost firms. Therefore, the position of both distributions suggests that the productivity of low sunk cost firms stochastically dominates the distribution of high sunk costs.

Given the assessed difference between high and low sunk cost firms, we now apply the testing procedure to the sample of firms in the textile industry. The first part of Table 6.1 summarizes the hypothesis test statistics for this industry. As indicated above, tests are applied separately to the groups of small and large firms. First, for the group of small firms, the null hypothesis that the productivity distributions of high and low sunk costs firms are not equal can be rejected at usual levels for all sunk cost measures excluding LEASED CAPITAL. For the same group of small firms, the null hypothesis that the difference is as expected –higher productivity for low sunk cost firms with respect to high sunk costs– cannot be rejected at any reasonable significance level. Second, for the group of large firms, the null hypothesis that the sign is as expected (i.e. favorable to low sunk costs) cannot be rejected at any usual level of significance. However, test statistics do not make it possible to reject the equality between both distributions (the variable that produces the best result is DEPRECIATION, which makes it possible to reject the null hypothesis of equality between both distributions at 16.4 percent). Therefore, in the group of large firms, productivity differences are confirmed in the expected direction but the magnitude of the difference is rather small and this makes it statistically difficult to confirm dominance in the textile industry for the group of large firms. However, the plot of the productivity distributions in Figure 6.4 suggests that low sunk cost firms stochastically dominate high sunk costs firms. The plotted distributions have been weighted by the proportions of small (0.966) and large (0.034) firms in the population of firms in the textile industry. Both the results presented in Table 6.1 and the distributions plotted in Figure 6.4 can be interpreted as favorable to the hypothesis that the productivity distribution of firms operating in markets with small sunk entry costs stochastically dominates the distribution of firms operating in markets with high sunk costs. Overall, the results for the textile industry confirm that high sunk costs firms are concentrated among the least productive units.

The results for the other industries are not so favorable to the hypothesis of an inverse relationship between sunk costs and firm productivity as in the case of the textile industry. Figure 6.4 indicates that for three industries, Manufacture of other non-metallic mineral products (NACE 26), Manufacture of rubber and plastic products (NACE 25), and Manufacture of chemicals and chemical products (NACE 24), the difference between the productivity distributions of high and low sunk costs firms is always as expected. The distribution of low sunk cost firms is always to the right of the distribution of high sunk cost firms. These relative positions are consistent with the hypothesis arising from models of industry dynamics that predict a lower productivity for firms with a higher level of sunk costs. At the median of the distribution, the productivity differences between low and high cost firms is 5, 7 and 4 percent in non-metallic products (NACE 26), rubber and plastics (NACE 25), and chemicals (NACE 24), respectively.

In the remaining two industries, Manufacture of electrical equipment (NACE 31, 32) and Manufacture of paper, publishing and printing (NACE 21, 22), the productivity distribution of low and high sunk cost firms crosses at the 0.25 and 0.1 percentiles, respectively. Therefore, both distributions cannot be ranked according to the criterion of first-order stochastic dominance.

Table 6.1 reports test statistics for these industries. First, one-sided tests confirm the general pattern that productivity differences are always favorable to low sunk cost firms. Reported p-values for this hypothesis do not allow it to be rejected at reasonable significance levels. There is only one exception to this general rule for LEASED CAPITAL in the group of large firms, and for the non-metallic industry. Second, two-sided tests of the null hypothesis of equality between the distributions of high and low sunk costs are rejected only for small firms in the rubber and plastic industry (NACE 25) when USED CAPITAL is the sunk cost indicator. For large firms, they are also rejected in the electrical equipment industry (NACE 31, 32) and paper, publishing and printing industry (NACE 21, 22) when DEPRECIATION is the sunk cost indicator. In all other cases, the null hypothesis of equality of the productivity distribution of high and low sunk costs is not rejected. Overall, test statistics indicate that the productivity of low sunk cost firms is higher than that of high sunk cost firms. One sided-tests and Figure 6.1 confirm this conclusion. However, the magnitude of these productivity differences is rather low and two-sided tests do not make it possible to reject the equality of the productivity distributions. According to Figure 6.1, productivity differences are slightly higher for the non-metallic products industry (NACE 26), rubber and plastics (NACE 25) and chemical industry (NACE 24) than for the two remaining industries.

Finally, Table 6.2 repeats the testing scheme of Table 6.1 for a different year: 1993. The objective is to check the robustness of results documented for the year 1997. Test statistics and the corresponding p-values reported in Table 6.2 confirm the basic results reported for the year 1997. In the textile industry, stochastic dominance of low sunk cost firms cannot be rejected for the group of small firms. A similar conclusion cannot be applied to the group of large firms. In the rest of the industries, as in the year 1997, stochastic dominance of low sunk cost firms can be rejected for both the group of small and the group of large firms.

## CONCLUSIONS

This chapter examines whether or not the level of sunk costs is associated with productivity differences across cohorts of continuing firms. In particular, the hypothesis we are interested in indicates that firms operating in markets with high sunk entry costs should have, on average, lower

productivity than firms operating in markets with low sunk costs. An increase in the level of sunk costs lowers the minimum productivity level required for incumbent firms to survive. As a consequence, firms operating in markets with high sunk entry costs are subject to less market selection and this means that the productivity distribution of low sunk entry cost firms stochastically dominates the productivity distribution of high sunk cost firms. In a previous chapter, Fariñas and Ruano (2005), we tested this prediction for a large sample of Spanish manufacturing firms. In this chapter, we use a similar approach to examine whether the hypothesis can be confirmed for six different manufacturing industries.

The evidence this paper provides partially confirms the hypothesis of an inverse relationship between the level of sunk entry costs and firm productivity. In the textile industry (NACE 17,18), we confirm stochastic dominance of low sunk entry cost firms over high sunk entry cost firms. In three other manufacturing industries, non-metallic mineral products (NACE 26), rubber and plastic (NACE 25), and chemicals (NACE 24), test statistics indicate that low sunk cost firms have higher productivity than high cost firms. However, the magnitude of these differences is rather low and the equality between the productivity distributions of high and low sunk cost firms cannot be rejected. Finally, in two industries —electrical equipment (NACE 31,32), and paper, publishing and printing (NACE 21,22)— the distribution of both groups of firms crosses each other and they cannot be ranked according to the criterion of first-order stochastic dominance.

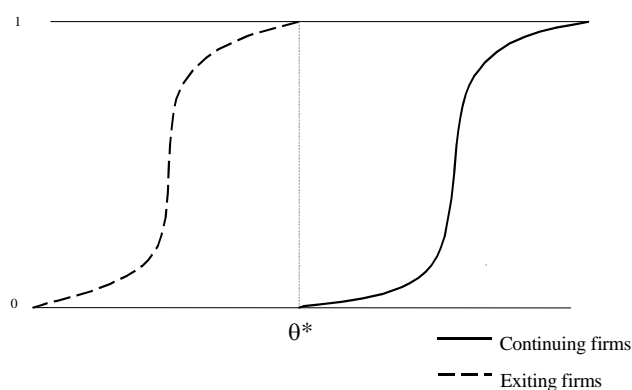


Figure 6.1 The productivity distributions of continuing and exiting firms at the exiting rule defined by  $\theta^*$

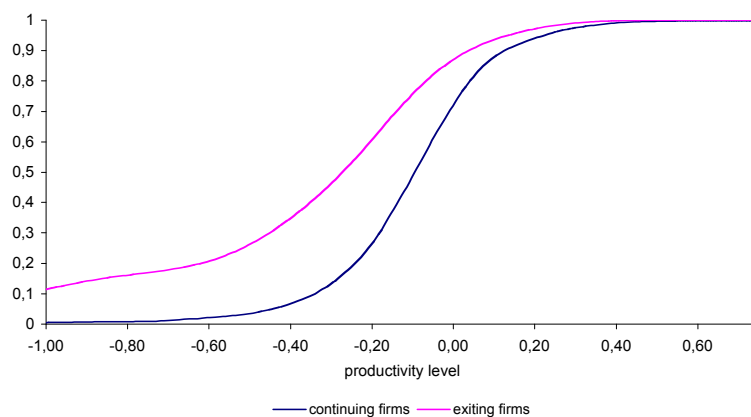


Figure 6.2 Productivity differences of exiting firms versus continuing firms (smooth sample distribution functions)

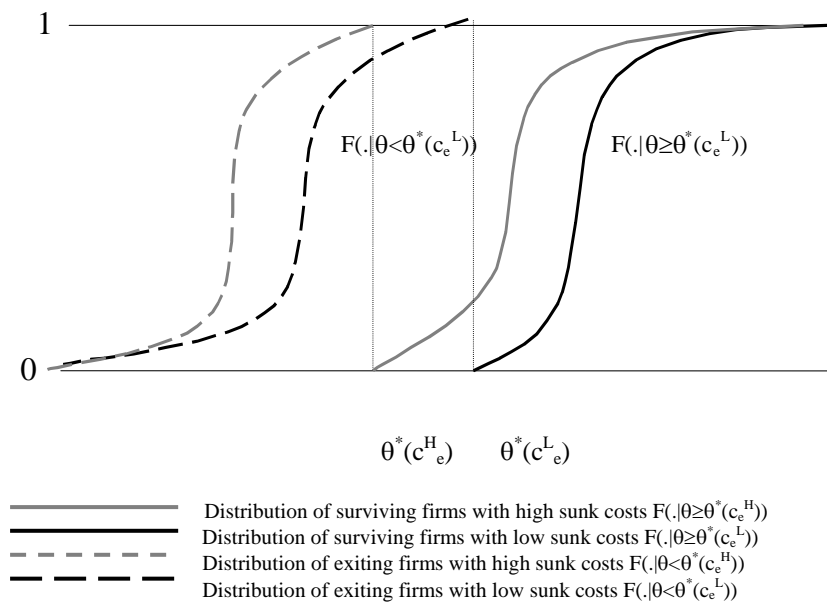
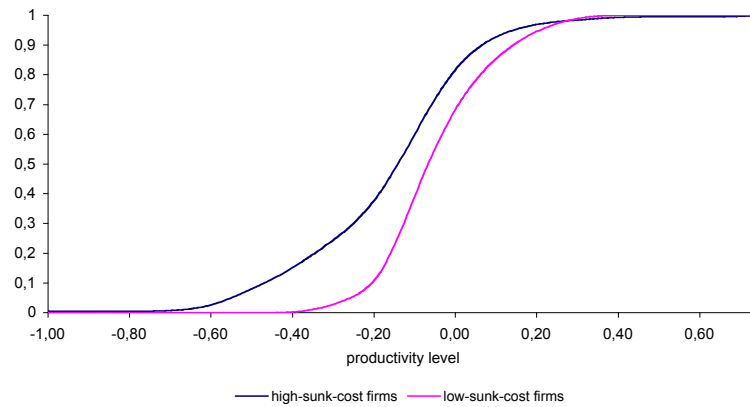
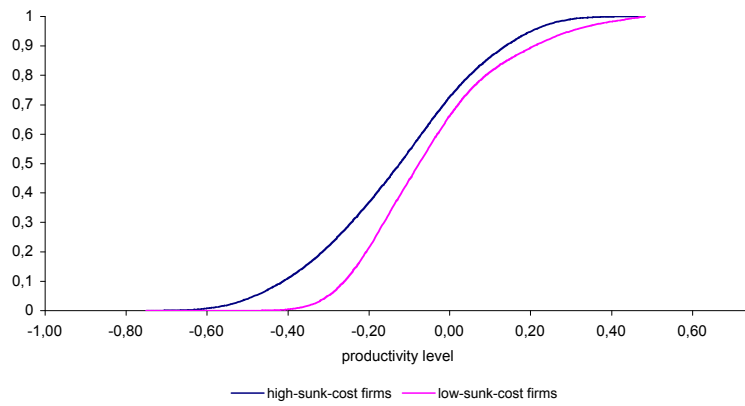


Figure 6.3 Productivity distributions and sunk entry costs

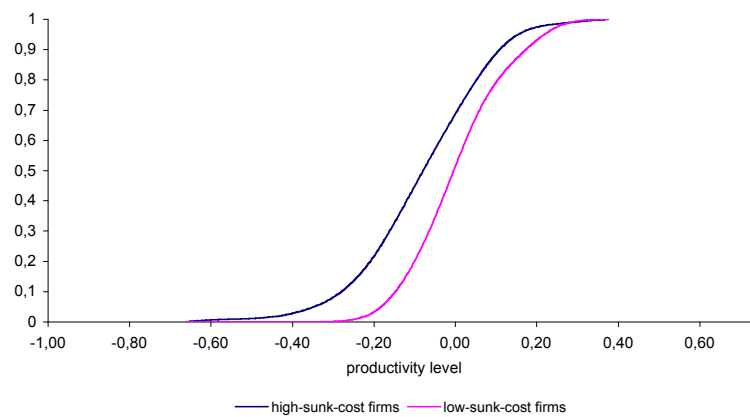
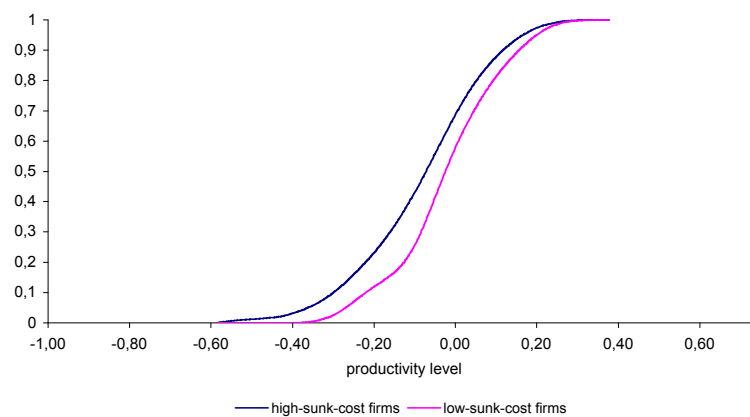
*Manufacture of textiles and textile products (NACE 17,18)*



*Manufacture of other non-metallic mineral products (NACE 26)*

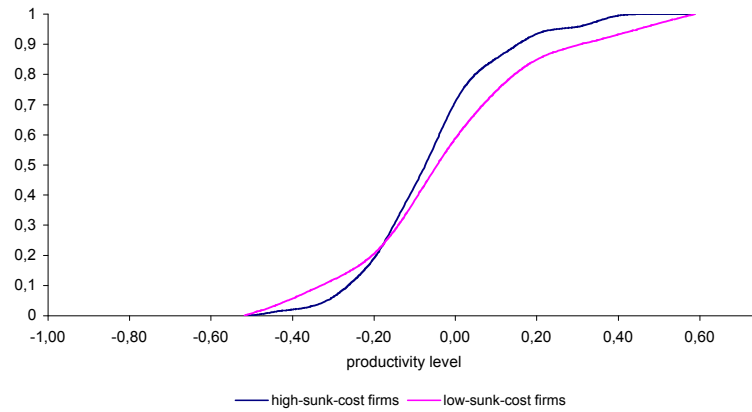


*Figure 6.4 Continuing firms with low sunk costs versus high sunk costs: productivity differences for six industries (smooth sample distribution functions)*

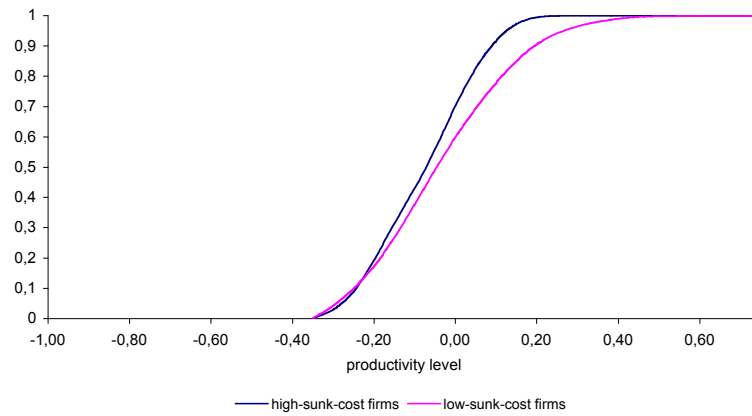
*Manufacture of rubber and plastic products (NACE 25)**Manufacture of chemicals and chemical products (NACE 24)*

*Figure 6.4 (continued) Continuing firms with low sunk costs versus high sunk costs: productivity differences for six industries (smooth sample distribution functions)*

*Manufacture of electrical equipment (NACE 31, 32)*



*Manufacture of paper and paper products; publishing and printing (NACE 21,22)*



*Figure 6.4 (continued) Continuing firms with low sunk costs versus high sunk costs: productivity differences for six industries (smooth sample distribution functions)*

Table 6.1 Productivity differences between low and high sunk cost firms: year 1997. Hypotheses test statistics

Industry/Sunk-cost measure	Small low cost firms vs. small high cost firms						Large low cost firms vs. large high cost firms					
	Number of observations*		Equality of distributions		Differences favorable to low cost firms		Number of observations*		Equality of distributions		Differences favorable to low cost firms	
	$n_H$	$n_L$	Statistic	P-value	Statistic	P-value	$m_H$	$m_L$	Statistic	P-value	Statistic	P-value
<b>Manufacture of textiles and textile products (NACE 17,18)</b>												
DEPRECIATION	30	98	1.734	0.005	0.098	0.981	20	22	1.118	0.164	0.147	0.958
USED CAPITAL	23	105	1.786	0.003	0.142	0.960	21	21	0.463	0.983	0.309	0.827
LEASED	8	120	0.799	0.548	0.548	0.549	7	35	0.966	0.308	0.069	0.991
CAPITAL	47	126	1.436	0.046	0.483	0.996	34	40	0.334	1.000	0.044	0.996
COMBINED CRITERIA												
<b>Manufacture of other non-metallic mineral products (NACE 26)</b>												
DEPRECIATION	29	29	1.050	0.220	0.000	1.000	5	28	0.809	0.529	0.000	1.000
USED CAPITAL	14	44	0.508	0.959	0.222	0.906	16	17	0.950	0.328	0.338	0.796
LEASED	19	39	0.965	0.310	0.193	0.928	15	18	1.112	0.168	1.112	0.084
CAPITAL	43	53	0.477	0.977	0.000	1.000	27	33	0.272	1.000	0.130	0.967
COMBINED CRITERIA												
<b>Manufacture of rubber and plastic products (NACE 25)</b>												
DEPRECIATION	-	-	-	-	-	-	-	-	-	-	-	-
USED CAPITAL	15	54	1.320	0.061	0.063	0.992	12	13	0.673	0.756	0.641	0.440
LEASED	6	63	0.743	0.639	0.223	0.905	7	18	0.659	0.778	0.659	0.419
CAPITAL	20	69	0.970	0.303	0.057	0.994	17	25	0.172	1.000	0.172	0.942
COMBINED CRITERIA												
<b>Manufacture of chemicals and chemical products (NACE 24)</b>												
DEPRECIATION	23	30	0.706	0.701	0.706	0.369	19	27	0.534	0.938	0.430	0.691
USED CAPITAL	13	40	1.006	0.264	0.078	0.988	22	24	0.873	0.432	0.231	0.899
LEASED	7	46	0.536	0.936	0.536	0.563	17	29	0.777	0.582	0.279	0.856
CAPITAL	34	53	0.351	1.000	0.152	0.955	39	40	0.202	1.000	0.202	0.921
COMBINED CRITERIA												
<b>Manufacture of electrical equipment (NACE 31,32)</b>												
DEPRECIATION	22	42	0.666	0.767	0.428	0.694	18	32	1.473	0.026	0.130	0.967
USED CAPITAL	7	57	0.807	0.532	0.807	0.272	25	25	0.566	0.906	0.566	0.527
LEASED	11	53	0.802	0.540	0.228	0.901	12	38	0.702	0.708	0.252	0.881
CAPITAL	34	63	0.487	0.972	0.254	0.879	40	45	0.652	0.789	0.038	0.997
COMBINED CRITERIA												
<b>Manufacture of paper and paper products; publishing and printing (NACE 21,22)</b>												
DEPRECIATION	65	24	0.700	0.710	0.405	0.720	11	20	1.913	0.001	0.242	0.889
USED CAPITAL	22	67	0.563	0.909	0.563	0.530	15	16	0.556	0.916	0.556	0.538
LEASED	18	71	0.981	0.290	0.415	0.708	10	21	0.954	0.322	0.954	0.162
CAPITAL	79	86	0.161	1.000	0.161	0.950	24	29	0.437	0.991	0.078	0.988
COMBINED CRITERIA												

Notes: \*  $n_H$  and  $n_L$  denote the sample sizes for small high and low sunk cost firms, respectively; similarly  $m_H$  and  $m_L$  denote the same for large firms.

Table 6.2 Robustness check: productivity differences between low and high sunk cost firms; year 1993. Hypotheses test statistics

Industry/Sunk-cost measure	Small low cost firms vs. small high cost firms						Large low cost firms vs. large high cost firms					
	Number of observations*		Equality of distributions		Differences favorable to low cost firms		Number of observations*		Equality of distributions		Differences favorable to low cost firms	
	$n_H$	$n_L$	Statistic	P-value	Statistic	p-value	$m_H$	$m_L$	Statistic	P-value	Statistic	p-value
<b>Manufacture of textiles and textile products (NACE 17,18)</b>												
DEPRECIATION	31	113	1.277	0.077	0.000	1.000	11	22	1.126	0.158	0.739	0.336
USED CAPITAL	24	120	1.379	0.045	0.410	0.715	15	18	0.826	0.502	0.191	0.930
LEASED	10	134	0.651	0.790	0.273	0.861	5	28	0.942	0.338	0.942	0.170
CAPITAL	51	143	1.438	0.032	0.000	1.000	22	32	0.339	1.000	0.154	0.954
COMBINED CRITERIA												
<b>Manufacture of other non-metallic mineral products (NACE 26)</b>												
DEPRECIATION	65	9	0.630	0.823	0.327	0.808	11	12	1.579	0.014	0.399	0.727
USED CAPITAL	19	55	0.547	0.926	0.316	0.818	11	12	0.690	0.728	0.309	0.827
LEASED	22	52	0.697	0.721	0.296	0.840	7	16	0.828	0.500	0.197	0.925
CAPITAL	68	69	0.131	1.000	0.114	0.975	20	30	0.309	1.000	0.015	1.000
COMBINED CRITERIA												
<b>Manufacture of rubber and plastic products (NACE 25)</b>												
DEPRECIATION	-	-	-	-	-	-	-	-	-	-	-	-
USED CAPITAL	16	55	0.884	0.415	0.448	0.669	9	9	0.707	0.699	0.236	0.895
LEASED	13	58	1.240	0.092	0.147	0.958	6	12	0.500	0.964	0.333	0.801
CAPITAL	27	71	0.932	0.350	0.148	0.957	12	18	0.447	0.988	0.075	0.989
COMBINED CRITERIA												
<b>Manufacture of chemicals and chemical products (NACE 24)</b>												
DEPRECIATION	26	31	0.802	0.540	0.462	0.653	21	37	1.131	0.155	1.131	0.078
USED CAPITAL	5	52	1.298	0.069	0.041	0.997	28	30	0.471	0.979	0.471	0.641
LEASED	9	48	1.262	0.083	0.000	1.000	16	42	1.145	0.145	1.145	0.073
CAPITAL	44	57	0.619	0.838	0.105	0.978	42	54	0.489	0.971	0.489	0.620
COMBINED CRITERIA												
<b>Manufacture of electrical equipment (NACE 31,32)</b>												
DEPRECIATION	27	47	0.649	0.793	0.649	0.430	21	42	0.356	1.000	0.356	0.776
USED CAPITAL	10	64	0.533	0.939	0.533	0.561	31	32	1.064	0.208	0.524	0.577
LEASED	19	55	0.755	0.618	0.284	0.851	15	48	0.817	0.517	0.423	0.700
CAPITAL	43	74	0.241	1.000	0.241	0.890	48	59	0.392	0.998	0.140	0.962
COMBINED CRITERIA												
<b>Manufacture of paper and paper products; publishing and printing (NACE 21,22)</b>												
DEPRECIATION	63	24	0.827	0.501	0.199	0.924	17	17	1.200	0.112	0.343	0.790
USED CAPITAL	12	75	1.008	0.262	0.279	0.856	17	17	0.514	0.954	0.514	0.589
LEASED	20	67	0.580	0.890	0.580	0.510	10	24	0.554	0.919	0.310	0.825
CAPITAL	2	15	0.664	0.770	0.664	0.414	1	5	0.913	0.375	0.000	1.000
COMBINED CRITERIA												

Notes: \*  $n_H$  and  $n_L$  denote the sample sizes for small high and low sunk cost firms, respectively; similarly  $m_H$  and  $m_L$  denote the same for large firms.

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