The Dynamics of Productivity: A Decomposition Approach Using Distribution Functions

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ABSTRACT. In this paper we use a micro panel data set of Spanish manufacturing firms to measure the contributions of continuing firms and turnover to total factor productivity growth over the period 1990–1997. The paper proposes an approach to the decomposition of productivity growth that is based on the estimation of productivity distributions. We characterize the dynamics of productivity distributions defining counterfactual distributions and using non-parametric methods. The results we obtain indicate that incumbent firms are the main factor contributing to the change in the productivity distribution. Net entry contributes positively to TFP growth. Finally, changes in the relative weights of incumbent, entering and exiting firms produce a counter-cyclical movement of productivity.

1. Introduction

This paper uses a micro panel data set of Spanish manufacturing firms to measure the contributions of incumbent firms and turnover to total factor productivity growth over the period 1990–1997. Our analysis parallels recent studies that decompose productivity growth in several countries and with slight differences in the methodology of the reported decompositions. Papers reporting decompositions of productivity growth include Baily, Hulten and Campbell (1992) for the United States, Griliches and Regev (1995) for Israel, Baldwin (1995) for Canada, Liu and Tybout (1996) for Chile and Colombia, among others. Tybout (1996), Caves (1997), Bartelsman and Doms (2000) and Foster, Haltiwanger and Krizan (2001) provide excellent reviews of the literature.

The existing work on the manufacturing industry has found, first, that productivity growth of incumbent firms is typically the largest component of aggregate productivity growth. Second, reallocation effects via changes in shares across incumbent firms contribute positively to total factor productivity growth. Third, entry and exit of firms have a positive contribution to aggregate productivity and this contribution increases with the time horizon over which the change is measured. Finally, under certain conditions, reallocation effects via net entry play the most important role in productivity growth: under conditions of regulatory reform, Olley and Pakes (1996); for the service sector, Foster, Haltiwanger and Krizan (2001) and (2002); under institutional environments with low sunk entry and exit cost that favor the role of entry and exit in productivity growth as suggested by Aw, Chen and Roberts (1997) and Aw, Chung and Roberts (2000).

The main purpose of this paper is to measure the within contribution of incumbent firms and the contribution of reallocation effects on total factor productivity growth in the manufacturing sector. For this purpose we use an unbalanced panel of Spanish manufacturing firms. The panel of firms we work with is a statistically representative sample of Spanish manufacturing firms that provides a suitable setting to approximate the contributions of continuing, entering and exiting firms to productivity growth.

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The paper makes two contributions to the literature. First, we add another national perspective to the literature reporting decompositions of productivity growth. Second, we propose an approach to the decompositions of productivity growth that is based on the estimation of productivity distributions. The proposed decomposition differs from previous decomposition methods in some important ways (see Haltiwanger (2000) for a revision of decomposition methodologies). The use of productivity distributions does not permit an estimation of the between-firm component that reflects changing shares across incumbent firms. However, our approach uncovers patterns of productivity growth that standard methods cannot identify as, for example, the existence of productivity changes that are not homogeneous along the distribution function. Our approach complements previous work on the analysis of productivity differences between groups of firms, Delgado, Fariñas and Ruano (2002) and Fariñas and Ruano (2002).

The evidence we report is in line with results reported by the literature on productivity decompositions. First, incumbent firms are the main factor contributing to the change in the productivity distribution. Second, the replacement of exiting firms by entering firms contributes positively to TFP growth. At the median of the distribution the contribution of this component is 10% of the change in productivity over a span of seven years. In the first quartile of the distribution the effect is higher with net entry contribution approaching 20% of productivity growth. Third, changes in the relative weight of incumbent, entering and exiting firms produce a countercyclical movement of productivity distributions.

The paper is organized as follows: Section 2 describes the characteristics of the data set used in the analysis and presents the procedures followed for the estimation of the distribution functions and for the measurement of total factor productivity at the firm level. Section 3 presents the results obtained applying a standard decomposition method. In particular, we use the decomposition of Baily, Hulten and Campbell (1992), applying this procedure to the same data set that is used with our method. The objective of this analysis is to perform an estimation that gives us a reference for the decomposition presented in the next section. Section 4 presents the analysis based on the decomposition of productivity growth using productivity distributions, and Section 5 summarizes the main conclusions.

2. Measurement and estimation issues

This section deals with measurement and estimation issues. The section contains three parts: in the first part we describe the characteristics of the data set: the second part presents an index for measuring firm productivity; the third part explains the approach that has been followed for the estimation of distribution functions.

2.1. *Characteristics of the data set*

The data that we employ is a longitudinal survey of Spanish manufacturing firms that comes from the Encuesta sobre Estrategias Empresariales (ESEE). The data is collected by the Fundación Empresa Pública and sponsored by the Spanish Ministry of Industry. This database contains a longitudinal sample of firms from 1990 to 1997. The information collected every year is consistent with previous years. Over the period 1990–1997, the panel of firms contains 15,087 observations that correspond to an average number of 1,887 firms per year.

A characteristic of the data set is that firms participating in the survey were chosen according a selective sampling scheme. The sample of firms includes almost the universe of Spanish manufacturing firms with more than 200 employees (large firms) in 1990. In fact, the rate of participation of firms in this size category was the 67.6% of the population of large firms in 1990. Firms employing between 10 and 200 employees (small firms) were chosen according to a stratified random sample representative of the population of small firms. The 3.9% of the population of firms within this size category were randomly sampled in 1990. Table I reports the number of firms in the sample and the number of firms in the population, distinguishing between small and large firms.

Given the procedure used to select firms participating in the survey, both samples of small and large firms can be considered as samples that permit to estimate the distribution of any of the characteristics of the population of Spanish

TABLE I
Summary statistics for the sample of manufacturing firms

	Small firms (10–200 employees)	Large firms (more than 200 employees)
Number of firms in the sample	1,478	710
Number of firms in the population	37,453	1,050
Sampling proportion (%)	3.9	67.6
Population distribution:		
Number of firms (%)	97.3	2.7
Output (%)	53.6	46.4

manufacturing firms with available information in our data set. Section 2.3 explains the procedure that has been followed for the estimation of these distributions. Similarly, the decomposition approach that has been applied to the analysis of productivity growth takes into account the sampling properties of large and small firms.

The data set attempts to maintain the representativeness of the manufacturing sector over time as in the initial year 1990. On one hand, every year new firms are included in the sample from the universe of newly created firms. These new firms have been selected and surveyed with the same selection criteria as firms were surveyed in the original sample. Therefore, each year a number of entering firms were selected according to a random sampling procedure among the whole population of entering firms. This selection was conducted using the same proportions as in the original sample. On the other hand, failing firms that exit production entirely each year are recorded by the survey. Consequently, firms of similar size and industry that enter production replace exiting firms. Therefore, the ESEE is an unbalanced panel of firms that captures entry and exit in the Spanish manufacturing sector over the period 1990–1997 (see Fariñas and Jaumandreu (1999) for technical details on the evolution and characteristics of the sample).

The sample allows a classification of firms according to their trajectories over any time interval. In the period 1990–1997, three groups of firms can be defined. First, the group of entering firms between 1990 and 1997. This group is composed of new firms that enter production after year 1990 and they are still in operation in year 1997. Second, the group of exiting firms leaving the market between 1990 and 1997. This group of failing firms is composed of firms staying in business in 1990 and exiting production after year 1990. The third group of incumbent firms corresponds to those units producing in 1990 and continuing in business in 1997. As a consequence of these definitions, firms entering and exiting the market within the period 1990–1997 are not considered in the performed decomposition. Furthermore firms that ceased to participate in the survey are excluded from the decompositions. We test for the existence of some form of attrition bias due to the elimination of this latter group of firms. We do not find any systematic evidence of biases.

Table II reports the shares of entering, exiting

TABLE II
Shares of incumbent, entering and exiting firms. Average annual rates over period 1990–1997 (percentages)

	Number of firms			Output		
	Small firms	Large firms	Total	Small firms	Large firms	Total
Incumbent firms	90.7	99.0	90.9	95.6	98.7	97.0
Entering firms	6.1	0.7	6.0	2.4	0.8	1.7
Exiting firms	3.2	0.3	3.1	2.0	0.5	1.3
Total	100.0	100.0	100.0	100.0	100.0	100.0

and incumbent firms. The rate of entry defined as the number of new firms divided by the total number of firms at the beginning of each year is 6%. Entry rates for the groups of small and large firms are also reported. Entering firms are mainly small firms as suggest the fact that the entry rate for the group of small firms is more than eight times the rate for large firms. The average exit rate is 3.2% and the rate of participation of incumbent firms is 90.9%. The difference between entry and exit rates indicates that net entry is positive over the period 1990–1997 in the Spanish manufacturing industry. The rate of entry penetration defined as the output by entrants divided by total manufacturing output is 1.7% and 1.3% for the exit penetration rate. The difference between entry rates defined in terms of the number of firms and the entry output share arises from the fact that entrants are much smaller than incumbent firms.

The characteristics of the data set imply that the distributions of entering, exiting and continuing firms can be estimated. The appropriate way to estimate these distributions is to consider separately the distributions of small and large firms, for each of the three groups, and to weight these distributions using the sampling proportions summarized in Table I. Similarly, we can measure the contributions of incumbent firms and turnover to productivity growth over the period 1990–1997. In the following sections we explain the procedure that has been used to measure these contributions.

2.2. *Productivity measurement*

Using information drawn from the ESEE we construct an index of total factor productivity for each firm over the period 1990–1997. The index proposed follows the framework developed by Aw, Cheng and Roberts (1997) and it is an extension of the multilateral total factor productivity index proposed by Caves, Christensen and Diewert (1982). The index takes as reference a hypothetical firm and measures productivity in each year relative to this reference firm. In particular, our index uses as the reference point the average firm of the size group the firm belongs to, and then chain-links the reference points to preserve transitiveness between firms of different size groups within the same industry. A similar extension of the index can be found in Good, Nadiri and Sickless (1996).

The definition of the multilateral index we use takes into account the characteristics of the data set and particularly the fact that sampling proportions are different for the group of small and large firms. Let each firm f produce a single output y using the set of inputs x, the expression of total factor productivity for firm f at time t is

$$\begin{aligned} \ln \lambda_{ft(\tau)} = {} & \ln y_{ft} - \overline{\ln y_\tau} - \\ & \frac{1}{2}\sum_{r=1}^{R} (\varpi^r_{ft} + \overline{\varpi^r})(\ln x^r_{ft} - \overline{\ln x^r_\tau}) + \\ & \overline{\ln y_\tau} - \overline{\ln y} - \\ & \frac{1}{2}\sum_{r=1}^{R} (\overline{\varpi^r_\tau} + \overline{\varpi^r})(\overline{\ln x^r_\tau} - \overline{\ln x^r}); \qquad [1] \end{aligned}$$

where y_{ft} is the output of firm f at time t, x^r_{ft} is the quantity of input $r = 1, \ldots, 3$ corresponding to firm f at time t, and ϖ^r_{ft} is the cost share of input r. Firms are classified in two size groups of small and large firms, $\tau = 0, 1$. A bar over a variable indicates the arithmetic mean of the variable. In this case, when the variable has index τ the average refers to a given size group of firms, otherwise the average refers to the entire sample of small and large firms.

The index λ_{ft} measures the proportional difference of total factor productivity for firm f at time t relative to a given reference firm. The reference firm varies across industries and therefore when observations of different industries are pooled, productivity differences across industries are removed. Firms are classified in eighteen industries corresponding to the NACE-CLIO R25 classification. To be more precise about the meaning of expression [1], the two first elements of the right-hand side compares the productivity of firm f with the productivity of an average firm of the size group and industry firm f belongs to. Therefore, comparisons between observations corresponding to the same size group are transitive. The two last terms measure productivity differences between the reference firm for any size group and the average firm of the entire sample of small and large firms in industry r.

The information used to calculate the index of total factor productivity for each firm is drawn from the ESEE. The output y_{ft} is measured by the annual value of gross production of goods and services expressed in real terms using price indexes for each firm reported by the ESEE. The estimation of the index considers three inputs: labor, materials and the stock of capital. Labor inputs are measured by the number of effective hours of work per year, which is equal to normal hours plus overtime hours minus non-working hours. Material inputs are measured by the cost of intermediate inputs, including raw materials purchases, energy and fuel costs and other services paid by the firm. The value of material inputs is measured in real terms using individual price indexes on the three categories of intermediate inputs for each firm reported by the ESEE. The stock of capital is calculated according to the perpetual inventory formula for each firm:

$$k_{ft} = I_{ft} + k_{ft-1}(1 - d_{ft})\frac{P_t}{P_{t-1}},$$

where I_{ft} corresponds to the value of investment in equipment of firm f at time t, d_{ft} stands for depreciation rates and P_t is an aggregate price index for equipment investment published by the Spanish Institute of Statistics. Finally, input cost shares, w^r_{ft}, are defined as the fraction of the cost of each input in total input costs. Total input costs is defined by the sum of labor costs, intermediate input costs 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 intermediate inputs is measured by the sum of costs of raw materials purchases, energy and fuel costs and other services paid by the firm. The user cost of capital is measured for each firm by the cost of long-term external debt of each firm as reported by the ESEE plus the depreciation rate, d_{ft}, minus the variation of the aggregate price index for capital goods.

2.3. *The estimation of productivity distribution functions*

One of the goals of this paper is to decompose shifts of firms' productivity distribution functions over time into two elements: (1) the effect produced by changes in the productivity distribution of continuing firms; and (2) the effect produced by firm turnover. The latter effect operates through two different channels: the replacement of exiting firms by entering firms and the change in the relative weight of incumbent firms as a consequence of the existence of a net entry (or exit) flow of firms. This objective is achieved by comparing the productivity distributions for different time periods and groups of firms as will be explained in Section 4. In this section we present some general nonparametric techniques that have been used in Section 4 for the estimation of distribution functions.

The estimation process that we describe refers to a cumulative distribution function associated to a univariate random variable Z (say the level of firm productivity in year t). Let $F(z)$ denote this cumulative distribution function evaluated at a given value z, where $z \in \mathbb{R}$. The estimation will be based on a sample $Z_1, \ldots, Z_N$ of size N, that is the combination of two random samples of firms that corresponds to the groups of small and large firms. The sizes of both subsamples are N_0 and N_1 ($N_0 + N_1 = N$), respectively. Given that the rate of participation of firms in the survey varies across size categories, both subsamples of small and large firms cover different percentages of the corresponding subpopulations of firms.

The difference in sampling proportions for small and large firms do not permit a direct estimation of the productivity distribution for the whole population of firms. However, it is possible the estimation of conditional distribution functions in a given size category. Let τ be a dummy variable indicating the size category the firm belongs to, then the conditional distribution functions corresponding to small firms and large firms categories can be denoted as $F(.|\tau = 0)$ and $F(.|\tau = 1)$, respectively. The nonparametric techniques proposed to estimate the cumulative distribution function for the whole population of firms (small and large firms) are based on the idea that this function can be expressed as a mixture of the two conditional distributions $F(.|\tau = 0)$ and $F(.|\tau = 1)$ given by the following expression,

$$F(z) = P(\tau = 0) \times F(z|\tau = 0) + P(\tau = 1) \times F(z|\tau = 1), \quad z \in \mathbb{R}; \qquad [2]$$

where $P(\tau = 0)$ and $P(\tau = 1)$ are the probabilities of being a small firm and a large firm in the population, respectively. Expression [2] says that the cumulative distribution function for the whole population of firms is a mixture of the conditional distribution functions of small and large firms and the parameters of the mixture are the probabilities of being a small or a large firm in the population.

According to expression [2], the cumulative distribution function of the productivity level for the whole population of firms, evaluated at any given value $z \in \mathbb{R}$, can be estimated as a linear combination of the conditional distribution estimates corresponding to both size categories evaluated at this value. The parameters of the combination are the estimated probabilities of being a small or a large firm in the considered population. In particular, the expression of the (weighted) productivity distribution estimate is the following,

$$\hat{F}(z) = \hat{p} \times \hat{F}(z|\tau = 0) + (1 - \hat{p}) \times \hat{F}(z|\tau = 1) \qquad z \in \mathbb{R}; \qquad [3]$$

where $\hat{p}$ denotes the probability of being a small firm.[1] We consider two types of non-parametric estimators for distribution functions. First, to quantify differences between distribution functions we use the (weighted) empirical distribution function that is defined by expression [3]. To compute this weighted distribution function we estimate the empirical distribution functions that correspond to both size categories. The expressions of the empirical distribution function for small and large firms are as follow

$$F_{N_0}(z) = \frac{1}{N_0} \sum_{i=1}^{N} 1(Z_i \leq z) \times (1 - \tau_i)$$

and

$$F_{N_1}(z) = \frac{1}{N_1} \sum_{i=1}^{N} 1(Z_i \leq z) \times \tau_i$$

respectively, where 1(.) is the indicator function that takes the value 1 when the event in the parenthesis takes place and 0 otherwise; again, τ is a dummy variable that takes value 1 for large firms and 0 otherwise and N_0 and N_1 (such that $N_0 + N_1 = N$) denote the sample sizes for the groups of small and large firms, respectively.

Substituting both expressions in [3], we obtain the weighted empirical distribution function,

$$F_N(z) = \sum_{i=1}^{N} \omega_i \times 1(X_i \leq z), \qquad z \in \mathbb{R},$$

where the weights ω_i, satisfy $\sum_{i=1}^{N} \omega_i = 1$ and are given by the following expression,

$$\omega_i = \frac{\hat{p}}{N_0} \times (1 - \tau_i) + \frac{1 - \hat{p}}{N_1} \times \tau_i. \qquad (4)$$

Second, to further illustrate the comparisons between different distribution functions, we also provide graphical representations of these distributions. For this purpose we use kernel smoothing techniques. The (weighted) kernel distribution estimate is defined as in [3], but considering the following estimator for the categories of small and large firms

$$\hat{F}_h(z|\tau = \tau_0) = \int_{-\infty}^{z} \left[\sum_{i=1}^{N} \frac{1}{N_{\tau_0}} \times K\left(\frac{\nu - Z_i}{h}\right) \times 1(\tau_i = \tau_0) d\nu, \right. \qquad z \in \mathbb{R}, \quad \tau_0 = 0, 1;$$

where h is the bandwidth and $K(.)$ is the kernel function. The weighted kernel distribution estimate for the whole population of firms is defined by the following expression,

$$\hat{F}_h(z) = \sum_{i=1}^{N} \omega_i \int_{-\infty}^{z} K\left(\frac{\nu - Z_i}{h}\right) d\nu, \qquad z \in \mathbb{R};$$

where the weights are defined by expression [4], the kernel function is the standard normal and the bandwidth has been selected according to Silverman's rule-of-thumb (see Silverman 1986).

3. Aggregate productivity growth and turnover: applying the standard decomposition approach

In this section we decompose aggregate total factor productivity growth into the contributions of continuing, entering and exiting firms. Apart from examining micro patterns of productivity growth to gain a better understanding of aggregate productivity growth, we perform this exercise to have an estimation that gives us a reference for the decomposition using distribution functions that is presented in Section 4. The panel of firms we use is a statistically representative sample of Spanish manufacturing firms so it provides a suitable setting to approximate the contributions of continuing, entering and exiting firms to productivity growth in the population of Spanish manufacturing firms. Different authors have used various methods for computing the contributions of incumbent firms and turnover. Here we use the decomposition proposed by Baily, Hulten and Campbell (1992). Although other approaches have been proposed to decompose productivity growth, in particular the decompositions used by Griliches and Regev (1995) and Foster, Haltiwanger and Krizan (2001), we have not explored the sensitivity of our results to differences in the measurement methodology.

We begin by defining aggregate productivity for the manufacturing sector as the market-share weighted sum of the firm productivity levels,

$$\ln \lambda_t = \sum_{f=1}^{F} \theta_{ft} \ln \lambda_{ft};$$

where firm productivity, $\ln \lambda_{ft}$, is defined in equation [1] and θ_{ft} is the market share of firm f in total manufacturing sales in year t.

Considering that the participation of firms in our data set is different for the groups of small and large firms, we have defined weights according to the following criteria. First, we estimate weights for each firm within its size category. Firm market shares estimated in this way are good proxies for firm market shares in the populations of small and large firms. Second, weights for each individual firm, within a given size category, have been scaled by the relative weight of the size category in the whole population of firms. Therefore, we define the output share of firm f, which belongs to the size group τ, in a given period of time t, as:

$$\theta_{ft} = \frac{y_{ft}}{\sum_{i=1}^{N} [Y_{it} \times 1(\tau_i = \tau_f)]} \times \theta^{\tau}, \ \tau = \tau_f;$$

where Y_{it} is the output of firm i in year t; 1(.) is an indicator function of the event in the parenthesis and τ_ι is a dummy variable indicating the size group the firm belongs to; θ^{τ} is the output share of the size group which firm f belongs to.

Next, we define aggregate productivity growth as the change in $\ln \lambda_f$ between two time periods: $\ln \lambda_{ft_1} - \ln \lambda_{ft_0} = \Delta \ln \lambda_{ft_1}$. This change in productivity can be decomposed into the contributions due to the productivity growth of continuing firms, the reallocation of market shares among continuing firms and the replacement of exiting firms for entering firms. In particular, the change in productivity between years 1990 and 1997 can be decomposed into the contribution of incumbent firms that remain in operation in both years, denoted as $f \in I$, the contribution of entering firms between 1990 and 1997, denoted as $f \in E$, and the contribution of exiting firms between 1990 and 1997, denoted as $f \in X$. The change in productivity can be written as

$$\begin{aligned}\Delta \ln \lambda_{97} = & \sum_{f \in I} \theta_{f97}(\ln \lambda_{f97} - \ln \lambda_{f90}) + \\ & \sum_{f \in I} (\theta_{f97} - \theta_{f90}) \ln \lambda_{f97} + \\ & \left(\sum_{f \in E} \theta_{f97} \ln \lambda_{f97} - \sum_{f \in X} \theta_{f90} \ln \lambda_{f90} \right)\end{aligned}$$

This decomposition of productivity growth consists of three parts. The first term reflects the contribution of continuing firms due to improvements in each firm separately. The second term captures the reallocation of market shares in the group of incumbent firms. The third term summarizes the contribution due to differences in the productivity levels of the cohort of entering firms and the cohort of exiting firms.

Table III reports the results of the decomposition of total factor productivity growth for the period 1990–1997. Aggregate total factor productivity growth in the period is 6.5%. The first component of the decomposition indicates that the productivity growth of incumbent firms is the most significant source of productivity growth in the manufacturing sector. The contribution of this component represents 95% of the variation in total factor productivity. In contrast, we find that differences in productivity between entering and exiting firms have a much more modest contribu-

TABLE III
Decomposition of aggregate productivity growth: Period 1990–1997 (percentage points)

1. Incumbent firms	6.2
1.1. Share reallocation effect	2.4
1.2. Within-firm effect	3.8
2. Firm turnover	0.3
2.1. Entering firms	–0.8
2.2. Exiting firms	1.1
TFP growth	6.5%

tion to total factor productivity growth. The contribution of firm turnover represents 5% of the variation of productivity.

The contribution of incumbent firms indicates that the within-firm effect and the effect associated to share reallocation are both major sources of productivity growth. The share reallocation effect represents 37% of productivity growth over the period. Therefore, increasing output shares among high-productivity firms and decreasing output shares among low-productivity firms accounts for a significant part of productivity growth.

The contribution of entry and exit to productivity growth is rather small. Numbers reported in Table III have to be interpreted taking into account the index that has been used. The effect associated to entering firms is a year-end share weighted sum of the proportional difference between TFP of entering firms and TFP of an average firm of the same size and industry. Therefore, the negative contribution of entering firms indicates that the average TFP for this group of firms in 1997 is 0.8% lower than the average reference firm. Similarly, for the average exiting firm the average productivity level is 1.1% lower than the average reference firm. Therefore, the replacement of exiting by entering firms adds to aggregate TFP growth 0.3% point and this represents the 5% of the total change.

Overall, the results indicate that the largest contribution to TFP growth comes from the within component that represents 58% of the total change. The reallocation of output contributes with a 42% to TFP growth. The largest component of reallocation effects is via changes in shares across continuing firm that contributes with the 37% of the total change. The rest of the reallocation process is via net entry that contributes with a small fraction of 5% of the total change. Two applications to the analysis of productivity growth for the Spanish industry are Martin and Jaumandreu (1999) and Callejon and Segarra (1999). They apply regression techniques to the analysis of productivity growth and the coefficients attached to gross entry and exit are positive and significant.

4. Productivity dynamics: a decomposition approach based on distribution functions

In this section we examine the dynamics of productivity distribution functions for different groups of manufacturing firms in the period 1990–1997. Furthermore, we describe a procedure based on the estimation of counterfactual distribution functions that permits the decomposition into various components of changes in the distribution of firm productivity. In particular, we consider three sources for the variation in the productivity distribution: changes due to variations in the productivity distribution of continuing firms, the replacement of exiting firms by entering firms and, finally, changes in the relative weight of incumbents as a consequence of net entry (or exit) flows of firms in the population. We begin with the explanation of the procedure that has been used and, then, the main empirical results are presented.

Let F_t be the productivity distribution function for manufacturing firms at time t, then the evolution of productivity for this group of firms between t_0 and t_1 can be described by the comparison of distributions F_{t_0} and F_{t_1}. These functions can be estimated using non-parametric techniques described in section 2.3. Figure 1 presents the estimates of the productivity distribution of 1990 and 1997. The rightward shift in the distribution between 1990 and 1997 describes the change in TFP for the population of Spanish manufacturing firms. Our analysis refers to this change in the productivity distribution over the period and, in particular, we are interested in separating the part of the movement in the distribution that can be attributed to changes in the productivity levels of continuing firms from the part associated to firm turnover.

To derive an expression for the decomposition, let consider the variable G that allows to distinguish between three groups of firms in the population: the group of incumbent firms staying in business from 1990 to 1997 that we denote by $G = I$; the group of firms entering the market between 1991 and 1997, active firms in production in 1997 but not in 1990, that we denote by $G = E$; and, finally, the group of exiting firms, $G = X$, integrated by units that were active in production in 1990 but not in 1997.[2] The distributions of 1990 and 1997 can be expressed as a combi-

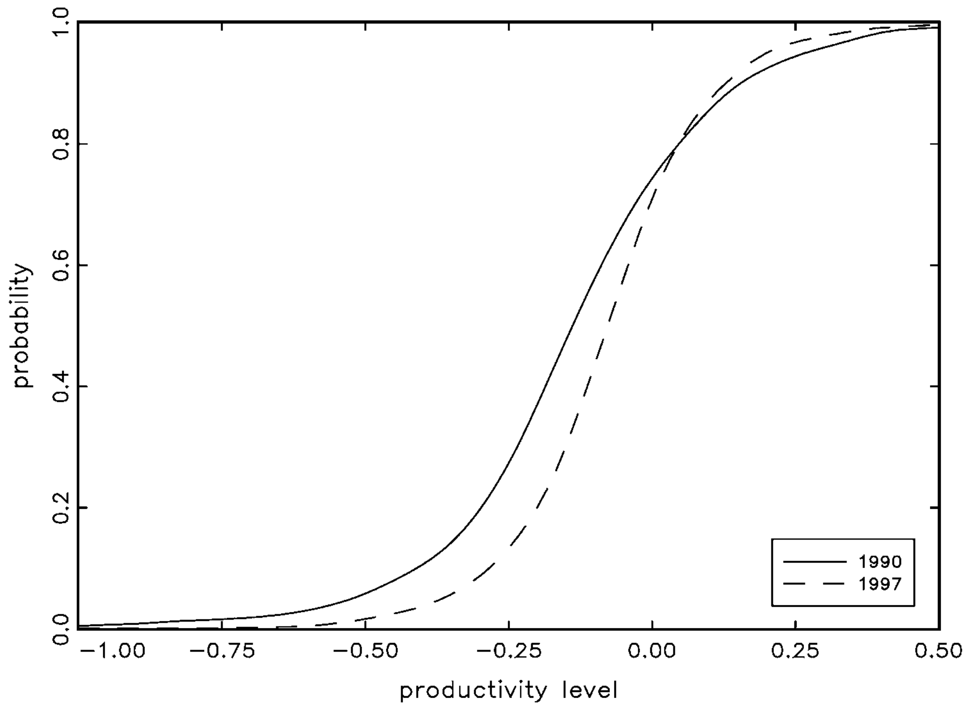

Figure 1. Distribution functions of total factor productivity for years 1990 and 1997 (weighted kernel distribution function estimates).

nation of some of these distributions. The productivity distribution corresponding to year 1990 can be expressed as follows,

$$F_{90}(.) = \Pr_{90}(G = I) \times F_{90}(.|G = I) + \Pr_{90}(G = X) \times F_{90}(.|G = X); \quad [5]$$

where $F_{90}(.)$ denotes the productivity cumulative distribution function corresponding to the population of firms in year 1990; $F_{90}(.|G = I)$ and $F_{90}(.|G = X)$ denote, respectively, the productivity level distribution in 1990 of continuing firms and the distribution in 1990 of productivity levels for exiting firms; finally $\Pr_{90}(G = I)$ and $\Pr_{90}(G = X)$ denotes, respectively, the probability of being an incumbent and an exiting firm in the population of firms in year 1990.

Similarly, the productivity distribution corresponding to year 1997, $F_{97}(.)$, can be expressed in terms of the productivity distributions corresponding to incumbent firm ($G = I$) and entering firms ($G = E$) in both cases the productivity level refers to year 1997. The distribution can be expressed as follows,

$$F_{97}(.) = \Pr_{97}(G = I) \times F_{97}(.|G = I) + \Pr_{97}(G = E) \times F_{97}(.|G = E). \quad [6]$$

Therefore, the shift in the productivity distributions from 1990 to 1997, i.e. the change from $F_{90}(.)$ to $F_{97}(.)$, can be expressed as a linear combination of the following four distribution functions: $F_{90}(.|G = I)$, the distribution in 1990 of incumbent firms; $F_{97}(.|G = I)$, the distribution in 1997 of incumbent firms; $F_{90}(.|G = X)$, the distribution in 1990 of exiting firms; and $F_{97}(.|G = E)$, the distribution of productivity in 1997 of entering firms.

Figure 2 provides (weighted) kernel estimates for the four defined productivity distributions. For the group of incumbent firms, the distribution of the productivity level in 1990 is to the left of the distribution of 1997. Therefore, the estimates show a substantial rightward shift over time indicating productivity improvements across the entire distribution of incumbent firms. Figure 2 also provides kernel estimates for the distributions of entering and exiting firms and shows that the distribution of entering firms is to the right of the distribution

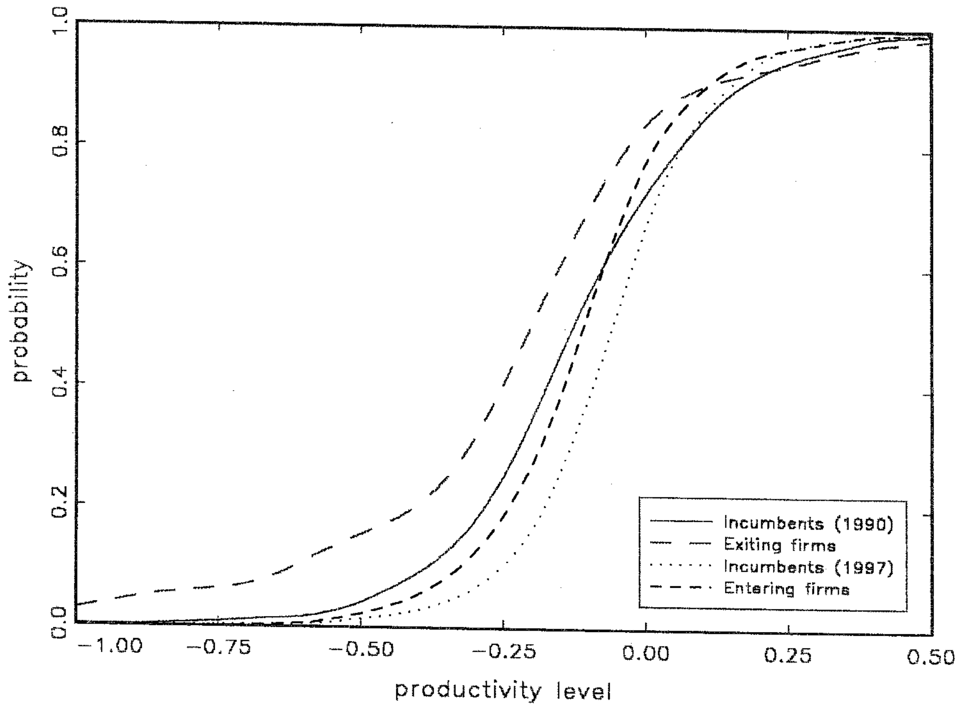

Figure 2. The productivity level distributions of incumbent firms in 1990 and 1997, and the distributions of entering and existing firms in period 1997–1997 (kernel distribution function estimates).

of exiting firms. These positions indicate the existence of a systematic productivity differential that is favorable for entering firms relative to exiting firms. The difference reflects the existence of learning and selection effects and it implies that the replacement of exiting firms by entering firms has a positive impact on productivity growth.

An alternative way of summarizing the movement of the four productivity distributions is to measure the quartiles of the weighted empirical distributions. Table IV reports the 25th, 50th and 75th percentiles of the distributions of incumbent firms (both in 1990 and 1997) and the distributions of entering and exiting firms. With respect to incumbent firms, the productivity levels clearly indicate that there is a systematic shift in the distribution. The change in productivity for the 25th percentile is 9% over the entire period, the median rises 7% and the 75th percentile increases only 2%. These differences in the rate of growth imply that the rightward shift in the distribution is accompanied by a slight change in the shape of the distribution. The interquartile range narrows slightly over time. The reduction of productivity differentials in the group of continuing firms has been produced by a reduction in the mass of low productivity firms. Since we cannot observe the movement of firms along the distributions over

TABLE IV
Percentiles of the distribution of total factor productivity for different groups of firms
(levels of TFP, ln λ)

Year	Productivity distributions:	25th Percentile	Median	75th percentile
1990	Incumbent firms	–0.24	–0.13	0.02
	Exiting firms	–0.32	–0.21	–0.07
1997	Incumbent firms	–0.15	–0.06	0.04
	Entering firms	–0.21	–0.11	–0.02

time, the exact reason of the reduction of productivity differentials cannot be identified. However, as suggested by Fariñas and Ruano (2002) this pattern may indicate the existence of convergence processes in productivity levels between young and small firms that are concentrated in the lower tail of the distribution and the rest of firms in the population. This behavior is consistent with the presumption that young surviving firms learn about their relative efficiency in their early years as suggested by the literature on firm dynamics, Audretsch (1995).

Table IV also reports the quartiles of the weighted empirical distributions for the group of entering and exiting firms. For the 25th percentile the level of productivity of entering firms is 11% higher than the productivity of exiting firms. In the median of the distribution the difference is 10% and for the 75th percentile the difference is 5%. These productivity differences indicate that the replacement of entering by exiting firms has contributed positively to the rightward movement of the productivity distribution over the period 1990–1997. Notice that the productivity level of entering firms corresponds to 1997 and for exiting firms the productivity level refers to 1990. Therefore, part of difference we observe between entering and exiting firms is due to a process of learning and selection that is higher the greater is the time horizon considered.

Apart from the movements in the productivity distributions of incumbent, entering and exiting firms, an additional element producing movements in the productivity distribution is the change in the relative weights of incumbent firms, as a consequence of the existence of a net entry (exit) flow of firms. Differences between $\Pr_{90}(G = I)$ and $\Pr_{97}(G = I)$ in expressions [5] and [6],[3] conditional on the inexistence of differences in the productivity distributions of incumbent, entering and exiting firms, will produce movements in the productivity distribution over time. This effect refers to changes in the relative number of firms in the population produced by turnover. If net entry is positive (negative) and incumbent firms have a productivity distribution that is to the right of both entering and exiting firms, then we would observe a shift in the productivity distribution over time in the direction of lower (higher) productivity. It should be noticed that this source of changes in the productivity distribution over time is different from the market-share reallocation effect that appears in the traditional decomposition approach that has been estimated in section 3. The comparison of distribution functions does not permit the estimation of the market-share reallocation effect.

Now we are in a position to consider a decomposition that is based on the use of productivity distributions. Our procedure for decomposing changes in the cumulative distribution of productivity is based on a comparison between productivity distributions for years 1990 and 1997 and counterfactual distributions. The decomposition requires defining two counterfactual distributions. Both functions correspond to the following expressions,

$$F^{C1}(.) = \Pr_{90}(G = I) \times F_{97}(.|G = I) + \Pr_{90}(G = X) \times F_{90}(.|G = X)$$

and

$$F^{C2}(.) = \Pr_{90}(G = I) \times F_{97}(.|G = I) + \Pr_{90}(G = X) \times F_{97}(.|G = E).$$

The counterfactual distribution F^{C1} indicates what the productivity distribution would have been in 1990 if continuing firms had had their productivity level at 1997. This distribution is therefore analogous to the distribution of year 1990, $F_{90}(.)$, but the distribution of incumbent firms in 1990, $F_{90}(.|G = I)$, has been substituted by the distribution of incumbent firms in 1997, $F_{97}(.|G = I)$. The second counterfactual distribution, F^{C2}, indicates what the productivity distribution would have been in 1997 if the relative weight of incumbent and entering firms had had the same levels as incumbent and exiting firms in 1990. F^{C2} is analogous to the productivity distribution of 1997 but the relative weights of continuing and entering firms in year 1997, $\Pr_{97}(G = I)$ and $\Pr_{97}(G = E)$, have been replaced by the relative weights of continuing and exiting firms in year 1990, $\Pr_{90}(G = I)$ and $\Pr_{90}(G = X)$.

With counterfactual distributions F^{C1} and F^{C2}, the movement from distribution $F_{90}(.)$ to distribution $F_{97}(.)$ can be decomposed by the following expression:

$$F_{97} - F_{90} = (F^{C1} - F_{90}) + (F^{C2} - F^{C1}) + (F_{97} - F^{C2}) \qquad [7]$$

Expression [7] decomposes the movement in the productivity distribution of manufacturing firms between 1990 and 1997 into three elements. First, the comparison between the counterfactual distribution F^{C1} and the observed distribution in 1990, F_{90}, isolates the change in the productivity distribution that can be attributed to the shift in the productivity distribution of continuing firms. Second, the comparison between the counterfactual distributions F^{C2} and F^{C1} identifies the effect on the productivity distribution generated by the replacement of exiting by entering firms. Finally, the comparison between the observed distribution in 1997, F_{97}, and the counterfactual distribution F^{C2} gives the part of the change in the productivity distribution that is due to changes in the relative number of continuing firms.

Figure 3 provides kernel estimates for the four distribution functions appearing in expression [7]:[4] F_{90}, F_{97}, F^{C1} and F^{C2}. The largest rightward shift in the distributions corresponds to the movement from distribution F_{90} to distribution F^{C1}. This result indicates that the change in the distribution of continuing firms is the most important source of productivity growth over the period. Incumbent firms are the main factor contributing to the change in the productivity distribution. The position of distribution F^{C2} is also to the right of the distribution F^{C1}. Both positions indicate that the net effect of entry and exit is positive. The magnitude of this replacement effect seems to be rather small relative to the magnitude of the incumbent effect. Finally, the distribution F^{C2} is to the left of F_{97}, indicating that the change in the relative number of continuing, exiting and entering firms has a negative contribution to productivity growth.

Our approach decomposes the overall change in the productivity distribution of Spanish manufacturing firms in three components associated to the behavior of the productivity distributions of incumbent, entering and exiting firms. The magnitude of the shift in the distributions can be measured by the estimation of the four (weighted) empirical distributions involved in the decomposition: F_{90}, F_{97}, F^{C1} and F^{C2}. Table V summarizes these contributions reporting the magnitude of the change at three points of the productivity distributions: the 25th , 50th and 75th percentiles.

At the median of the distribution the overall

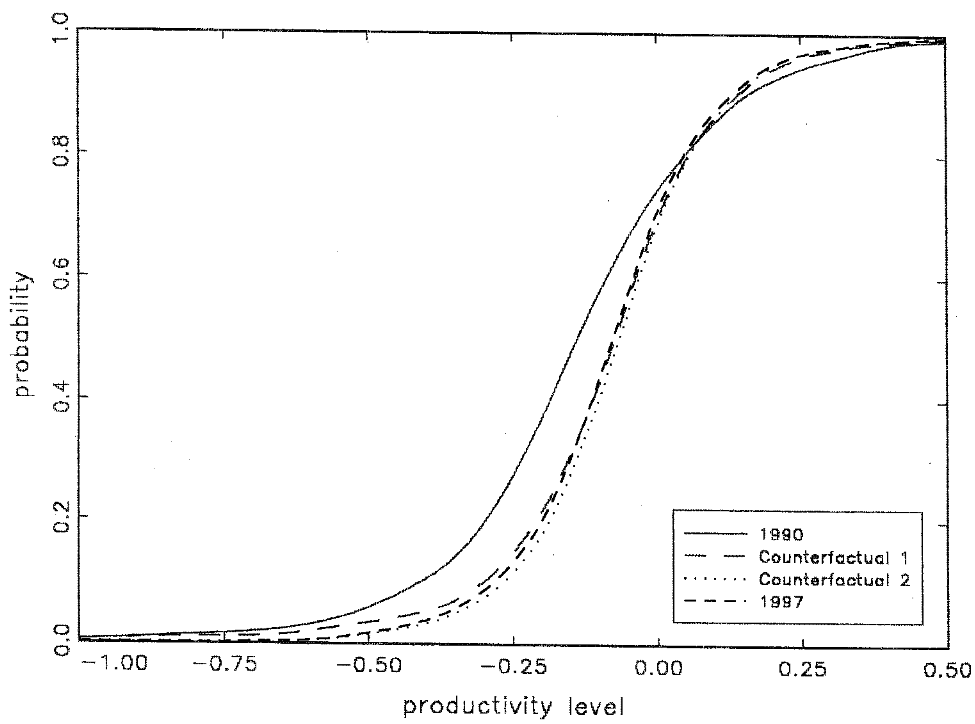

Figure 3. Decomposition of changes in the distribution of total factor productivity (kernel distribution function estimates).

TABLE V
Decomposition of TFP growth based on productivity distributions. Period 1990–1997
(productivity growth measured in percentage points)

	25th Percentile	Median	75th Percentile
Total change: 1990–1997	8.8	6.1	0.7
Change in the distribution of incumbent firms	7.9	6.4	0.9
Change due to the replacement of exiting firms by entering firms productivity distributions	1.6	0.7	0.5
Change in the relative weight of incumbent firms	–0.7	–1.0	–0.7

change in productivity in period 1990–1997 is 6.1%. The shift in the productivity of incumbent firms is 6.4%. The fraction of within-firm contribution is therefore 105% of the overall productivity growth between 1990 and 1997 at the median of the distribution. The replacement of exiting firms by cohorts of new entrants has a positive effect. The shift in the distribution due to this replacement effect is 0.7% and this change represents more than 10% of total factor productivity growth in the period. The component associated with changes in the relative numbers of continuing, entering and exiting firms has a negative impact on productivity growth. The shift in the distribution due to this effect is –1.0% and represents around 15% of the total change in productivity. Two factors have produced this negative contribution coming from changes in the relative weights of continuing, entering and exiting firms. On one hand, over the period net entry has been positive so that the relative weight of incumbent firms in the population is lower at the end of the period. On the other hand, the productivity distribution of incumbent firms at the end of the period is to the right of the distributions of exiting and entering firm (see Figure 2). Therefore, at the end of the period new entering firms with lower productivity levels than incumbent firms, increase their relative weight in the whole population of firms and have a negative contribution to productivity growth.

The results reported in Table V for other percentiles indicate that the magnitude of changes in productivity is not homogenous along the distribution function. Two points are worth to mention in connection with differences in productivity growth along the distribution function. First, the shift in productivity is higher for the lower tail of the distribution. The group of firms producing this behavior in the distribution is the group of incumbent firms. The change in the distribution of incumbent firms for the first quartile is 7.9%, for the second quartile is 6.4% and for the third 0.9%. As we have said before, this pattern is consistent with the fact that young and small surviving firms over the period have higher productivity growth than the rest of firms, which tend to concentrate in the upper tail of the distribution. The second point refers to the contribution of turnover to total factor productivity growth. At the lower tail of the distribution, the shift produced by the impact of entry and exit is higher than in the rest of the distribution: 1.6% in the first quartile, 0.7% in the second and 0.5% in the third quartile.

5. Conclusions

In this paper we use a micro panel data set of Spanish manufacturing firms to measure the contributions of continuing firms and entry-exit turnover to productivity growth. We apply a new decomposition approach for the analysis of productivity growth. Our methodology characterizes the dynamics of productivity distributions defining counterfactual distribution functions and using non-parametric methods.

The use of productivity distributions uncovers interesting aspects of productivity growth. One of these refers to the fact that the magnitude of changes in productivity is not homogenous through out the distribution function. The increase in productivity of incumbent firms in the first quartile of the distribution is higher than for the rest of firms in the distribution. Therefore, the rightward shift in the distribution during the period is accompanied by a slight change in the shape of the productivity distribution of surviving firms. This change implies a convergence in productivity between the group of firms in the first quartile and the rest of the distribution. Given that young and small surviving firms tend to concentrate on the lower tail of the distribution, the convergence process is consistent with the presumption that young incumbent firms learn about their relative efficiency in their early years.

The three main points drawn from the evidence on the factors contributing to the change in the productivity distributions can be summarized. First, incumbent firms are the main factor contributing to the change in the productivity distribution. At the median of the distribution, 105% of total factor productivity growth is due to continuing firms. Our approach does not permit us to identify reallocation effects coming from incumbent firms.

Second, the replacement of exiting firms by entering firms has a positive contribution to the dynamics of total factor productivity distribution. At the median of the distribution this contribution represents around 10% of the productivity growth. The magnitude of this reallocation effect corresponds to a time span of seven years, and it reflects a combination of selection and learning effects.

Third, between the years 1990–1997 changes in the relative weights of incumbent, entering and exiting firms have a negative contribution on productivity growth. In the second quartile of the distribution, the negative contribution coming from changes in the relative number of incumbent, entering and exiting firms represents around 15% of productivity growth. The fact that both entering and exiting firms have lower productivity than incumbent firms and net entry is positive produces, in the period 1990–1997, a negative impact on total factor productivity growth. This effect generates a counter-cyclical movement in productivity: a positive net entry of firms, occurring in recovery periods, decreases productivity and a negative net entry, usually occurring in slumps, tends to improve productivity. Among the set of reallocation effects that have an impact on productivity growth, changes associated to variations in the relative number of incumbent firms that are induced by net entry (positive or negative) generate a counter-cyclical movement in aggregate productivity.

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Notes

[1] According to the ESEE information for the base year, the probabilities of being a small firm and a large firm are $\hat{p} = 0.973$ and $(1 - \hat{p}) = 0.027$, respectively. This information is not available for the rest of the years and we assume this remain constant over the period.

[2] Firms entering the market after 1990 and exiting before 1997 are excluded from the analysis.

[3] Notice that $Pr_{90}(G = X)$ and $Pr_{97}(G = E)$ are the complementary probabilities to $Pr_{90}(G = I)$ and $Pr_{97}(G = I)$, respectively and, therefore, differences between the former are implicitly taken into account when considering the evolution of the probability of being an incumbent.

[4] These four distribution functions have been estimated applying the methodology described in section 2.3 and, therefore, refers to the whole population of small and large firms. In the case of counterfactual distributions, the estimators are constructed from the (weighted) conditional distribution functions estimates corresponding to the groups of incumbents, entering and exiting firms. Additionally, the probabilities of being either an incumbent firm ($G = I$) or an exiting firm ($G = X$) have been estimated by the shares of both groups in year 1990 for manufacturing population that can be calculated from the data in the ESEE.

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