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Catching Up in Total Factor Productivity through the Business Cycle: Evidence from Spanish Manufacturing Surveys[*]

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Abstract

Spain has recently experienced more than a decade of price stability and economic growth however now is showing one of the most significant slowdowns in economic activity of the EU economies. There is a general consensus that this slowdown in economic activity is particularly important in Spain due to the low level and low rates of growth experienced by total factor productivity (TFP) during more than a decade. Among the key policy elements that could enhance TFP of manufacturing firms in Spain we find those related to human capital, foreign direct investment, and process innovations. We evaluate the effect of recessions on the productivity growth of firms with different level of productivity. We present evidence on the dynamic of firm's TFP through the business cycle allowing for a differentiated behavior for technological leaders and followers. We observe lower persistence and faster convergence in TFP during recessions and, higher persistence and non convergence in TFP during expansions. These empirical findings are consistent with the predictions obtained from the technological diffusion literature and from the fact that firm's innovation is pro-cyclical. These conclusions are obtained from a microeconometric analysis of surveys of Spanish manufacturing firms (ESEE) from 1991 to year 2005.

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1 Introduction

Spain has recently experienced more than a decade of price stability and economic growth. However, we are observing now one of the most significant slowdowns in economic activity of the EU countries. The recent internationally transmitted shocks on liquidity, on petroleum and agricultural prices and the high value of the exchange rate of the Euro relative to the dollar, are exacerbating the problems of Spanish unemployment, inflation, foreign trade deficit and credit constraints which are negatively affecting the manufacturing sector and especially the housing sector; one of key engines of economic growth in the last twenty years. There is a general consensus that this slowdown in economic activity is particularly important in Spain due to the low levels and low rates of growth experienced in total factor productivity (TFP) during more than a decade.

Since 1996 the Spanish[1] economy showed one of the most stable evolutions of the European Union in terms of per-capita income growth and employment creation. However, this success is in contrast with the poor performance in terms of productivity (See van Ark et al., 2007). Panel a in Figure 1 shows the decomposition of the gross domestic product (GDP) per capita in terms of its two main components; labor productivity (Y/L) and the labor force participation (L/Pop); Y indicates output or gross domestic product (GDP), L is employment and Pop indicates population. We observe that, from 1995 to 2005, the Spanish GDP per capita showed a growing trend with an annual average rate of growth of 2.68%. Since the labor productivity component was almost constant during that period it is clear that the per-capita income growth during the last ten years was dominated by the growing trend in the labor force participation. Notice that the evolution of total factor productivity (TFP) was almost constant until 2000 and slowly declining since then. This fact together with the recent worldwide slowdown in economic activity creates a particularly fragile economic situation in Spain due to the low rates of growth experienced by TFP during more than a decade and especially due to the negative rates of growth in TFP during the last five years (2001-2005).

Panel b of Figure 1 shows the previous GDP per-capita decomposition but relative to the average value of European Union (EU) countries and clearly shows a downward trend (divergence) in labor productivity and in TFP. However, due to the stable positive rate of growth in the labor force participation, relative to the EU countries, the Spanish per-capita income was converging fast to EU levels. In fact, Spanish per-capita income moved from an 84.17% of the GDP per capita of the European Union in 1995 to a 93.2% in year 2005.

[1] From 1991 to 1994 the Spanish economy experienced a recession period, with a decreasing evolution of labour productivity and a divergent behaviour in the Spanish per-capita income relative to the mean of other EU countries, see Panels a and b of Figure 1.

For those reasons, the study of the microeconomic determinants of the Spanish productivity (TFP) evolution deserves special attention at the firm level. A non exhaustive list of papers studying TFP of Spanish firms includes Delgado et al. (2002), Huergo and Jaumandreu (2004), Fariñas and Ruano (2005), Ornaghi (2006), and Lopez-García et al. (2007). In this paper we study the dynamic of firms' productivity and its evolution through the business cycle. In particular, we are interested in evaluating whether there is a differential behavior in firms' TFP convergence rate during recessions and expansions.

[FIGURE 1 ABOUT HERE]

In particular, we use firm level data obtained from the "Survey on Business Strategies" (Encuesta sobre Estrategias Empresariales, ESEE). These surveys provide representative samples of the Spanish manufacturing sector for the period 1991-2005. The main characteristic of the selected period is that it is sufficiently large to include recessions and expansions of the Spanish economy. The average annual growth rate of the Spanish GDP in the first half of the 1990s was less than one third of the growth rate of the second half and less than one half of growth rate of the early 2000s. In particular, during the last quarter of 1992 and during the first two quarters of 1993 we observed negative growth rates (recession period). Another nice feature of the ESEE survey is that firms provide annual answers to questions related to whether the markets where the firm operates are in recession or expansion. It is interesting to observe that these answers on the timing of the business cycle, based on firms' perceptions, are consistent with the timing of the business cycles defined in terms of growth rates of GDP. The consistency of the dating of recessions and expansions periods using information at different aggregation levels supports the use of the ESEE surveys to analyze the firms' productivity catching up through the business cycle.

The productivity literature has documented large and persistent heterogeneity in firms' productivity (see Baily et al. 1992 and Bartelsman and Drymes, 1998). In this paper, we also study the dynamics of firms' productivity and therefore our paper is related to Fariñas and Ruano (2005) and Lopez-García et al. (2007) who also studied the Spanish case. However, they study different issues. While the first paper focuses on the dynamics of entrants, continuing, and exiting firms the second one focuses on the dynamic effects of firms' productivity on aggregate productivity. We contribute to this literature by analyzing the persistence of firms' productivity through the business cycle.

Relative to the literature that studies the cyclical patterns of productivity (Basu, 1996, and Basu and Fernand, 2001) our contribution is based on the analysis of firms' productivity dynamics at different states of the business cycle and its relation to the convergence literature. There is a long list of studies focusing on countries, regions or industries but based in firm's level data the number of empirical studies is small and mainly focused on testing Gibrat's Law.[2] To the best of our knowledge, the exhaustive

[2] See Sutton (1997) and the references therein.

list of studies interested in convergence in productivity across firms is Oulton (1998), Fung (2005), Girma and Kneller (2005) and Nishimura, Nakajima and Kiyota (2005) and none of them analyzed the relationship between convergence and the business cycle. Cyclical convergence is consistent with technological diffusion and pro-cyclical innovation. The impact of innovation on Spanish manufacturing firms' productivity has been studied by Huergo and Jaumandreu (2004) and the diffusion effect of technology by Ornaghi (2006). However, these studies do not analyze the differential TFP effects or their catching up effect on firms' productivity through the business cycle.

In particular, we follow three complementary approaches to check the robustness of the catching up results through the business cycle. First, we split the sample in three periods of 5 years and we extend the convergence approach of Barro and Sala i Martin (1991, 1992) controlling for sample selection. When firms exit the market for reasons that are related to productivity (TFP), for example if those firms that exit the market are the least productive, we ought to control for sample selection when testing for convergence at the firm level. We check whether the conditional convergence rate of productivity of less productive firms is higher than the conditional convergence rate of more productive firms (conditional β- convergence) applying Heckman's (1979) procedure. Furthermore, we check whether differences in productivity growth rates were sufficiently large to imply a reduction in the unconditional dispersion of productivity across firms (σ - convergence).

Given that the period with a reduction in the dispersion of firms' productivity coincides with a recession in the Spanish economy and the period with an increase in the dispersion with the expansion period, in the second and third approaches we evaluate the differential convergence properties through the business cycle. In the second approach we evaluate the differential productivity growth effects and convergence rates through the business cycle of firms that are "technological" leaders and followers'.

In the third approach we evaluate the effect of recessions on the persistence of firms' productivity by estimating the conditional convergence rate at the industry level in each period and relate it with the percentage of firms in recessions. In particular, we evaluate whether those firms that tend to converge in productivity during recessions do not converge in expansions. These findings are consistent with the models of technological diffusion (see Jovanovic and MacDonald, 1994) and with the literature that found that innovation is pro-cyclical (see Barlevy, 2007). The intuition is clear; leaders innovate more during expansions. Imitation of followers takes time and makes technology to spread from leaders to followers, forcing technological convergence as the industry matures. These convergence impacts are larger during recessions since firm's innovation rates are reduced and therefore there is a faster catching up effect.

The rest of the paper is organized as follows: Section 2 describes the survey of manufacturing firms and discusses the evolution of firms' productivity from 1991 to 2005 for several productivity (TFP) measures. Section 3 presents the analysis of conditional β-convergence and σ-convergence in productivity by splitting the sample in three sub-periods, 1991-1995, 1996-2000 and 2001-2005. Section 4 evaluates the relationship between firm's TFP conditional β-convergence for technological leaders and followers through the business cycle. The differential effects of human capital and process innovation on the TFP growth "technological" leaders and followers over the business cycle are also considered. Finally, section 5 presents the main conclusions.

2 Data and Descriptive Statistics

We use firm level data from the "Survey on Business Strategies" (Encuesta sobre Estrategias Empresariales, ESEE) which is an annual survey based on representative samples of Spanish manufacturing firms conducted by the SEPI Foundation. In this survey, firms with more than 200 employees in the first year (1990) were asked to participate, the rate of participation reached approximately 70% of the population of firms within that size category. Firms that employed between 10 and 200 employees were sampled randomly by industry and size strata. The rate of participation was 5% of the number of firms in the population. Another important feature of the survey is that after 1990 the properties of the initial sample have been maintained. Newly created firms have been added annually with the same sampling criteria than in the base year. There are exits from the sample coming from shutdown and no reporting. Therefore, due to this entry and exit process, the data set is an unbalanced panel of firms. Even though when the first year of the survey is 1990, we decided to use the information from 1991 to 2005 because the data corresponding to 1990 is not perfectly comparable with that of subsequent years. After dropping outliers (see Appendix A), we end up having an unbalanced panel of 3,759 firms and 22,922 observations.

We compute firms' productivity (P_{it}) considering the most common Total Factor Productivity (TFP) measure based on Solow's residuals extended to control for the degree of capacity utilization. In particular, the log of firm *i*'s productivity (TFP) in period *t* (p_{it}) is defined as,

$$p_{it} = y_{it} - \alpha_l l_{it} - \alpha_m m_{it} - \alpha_k \left(k_{it} + \kappa_{it} \right), \tag{1}$$

where *y* is the log of output, *l*, *m*, and *k* are the log of labor, materials, and capital, κ is the log of the annual average capacity utilization rate reported by each firm,[3] and α_x

[3] Including this variable in our analysis is important because the utilization of the capacity fluctuates through the business cycle.

($x=\{l, m, k\}$) are input-output elasticities.[4] To measure those input-output elasticities, α_x, we use industries' average cost shares over the total sample period.[5]

Output is measured by the value of produced goods and services deflated with a firm's price index of output. Labor inputs are measured in hours, capital as firm's value of the capital stock deflated using the price index of investment in equipment goods, and materials as the value of intermediate consumption deflated by a firm's price index of materials. Further details on these variables can be found in Appendix A. Having firm level price indexes is an advantage over traditional TFP measures that deflate nominal variables with industry level price indexes. In this sense, our productivity measure is close to the "physical productivity" defined in Foster et al. (2008).

Table 1 highlights some interesting facts on TFP, labor productivity and their growth rates. First of all, there is large heterogeneity in the level of TFP (logs in Table 1). However, the heterogeneity in terms of rates of growth of TFP is much larger than the heterogeneity in levels; the coefficient of variation of the growth rates is larger than the coefficient of variation in the levels. Second, small firms have (in mean) the lowest productivity growth rates. Third, from 1995 on, there is a stable reduction in the productivity growth rate of all size groups but for the small firms that show an average growth rate in 2001-2005 larger than in 1996-2000.

[TABLE 1 ABOUT HERE]

These facts are also evident if we analyze the distribution function of firms' productivity and their corresponding cumulative distribution functions. To compare firms in different industries Delgado et al. (2002), following Caves et al. (1982), used a productivity index that measures the proportional difference of total factor productivity for firm *i* at time *t* relative to a given reference firm that varies across industries. For a given industry *j*, the firm of reference is defined as: (i) a firm such that its output is equal to the geometric mean of firm's output quantities in industry *j* over the entire period; (ii) its quantities of inputs are equal to the geometric means of firms input quantities in industry *j* over the entire period; and (iii) its cost shares of inputs are equal

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[4] This productivity measure rests on the assumption of constant returns to scale. We are confident on this assumption because several papers have tested this assumption for the same dataset (Alonso-Borrego and Sanchez-Mangas, 2001 and Jaumandreu and Doraszelski, 2007) and do not find evidence against it.

[5] Alternatively, the input-output elasticities can be obtained by estimating the production function (See Olley and Pakes, 1996; Levinsohn and Petrin, 2003; Ackerberg, Caves, and Frazer, 2005). These methods assume that firm produces at full capacity and that productivity follows an exogenous Markov process. However, those conditions are not convenient for our purpose because we are interested in: first, the dynamics of firm's productivity process through the business cycle, allowing for different degree of capacity utilization, and second in its economic determinants (innovation, human capital, FDI, etc.). Doraszelski and Jaumandreu (2007) extend the structural identification of productivity to the case of an endogenous Markov process but even in this case it is too restrictive since they only consider a single economic determinant of the Markov process. Other advantages of the Solow's residuals based on cost shares are that it is not necessary to assume perfect competition in the products market and it is not necessary to deal with the endogeneity of the inputs.

to the arithmetic mean of firms cost shares in industry j over the entire period. Therefore, when observations of different industries are pooled, productivity differences among industries are removed. If firm i belongs to the size group τ and the industry j, then its productivity index (in logs) at time t is given by

$$\begin{aligned}\omega_{it} = y_{it} - \bar{y}_{\tau j} - \frac{1}{2}\sum_{x=\{l,m,k\}} \left(\alpha^x_{it} + \bar{\alpha}^x_{\tau j}\right)\left(x_{it} - \bar{x}_{\tau j}\right) \\ + \bar{y}_{\tau j} - \bar{y}_j - \frac{1}{2}\sum_{x=\{l,m,k\}} \left(\bar{\alpha}^x_{\tau j} + \bar{\alpha}^x_j\right)\left(\bar{x}_{\tau j} - \bar{x}_j\right),\end{aligned} \qquad (2)$$

where $x= l, m, k$; j=1,2,…, 18; τ={small or medium size, large}; and for a generic variable z_{it} which can be y_{it}, α^x_{it} or x_{it}, $\bar{z}_{\tau j}$ is the average of variable z_{it} for the firms that in period t are in industry j and belong to the size category τ, and $\bar{z}_j$ is the average of variable z_{it} for the firms that in period t are in industry j.

Figure 2 shows the density (Panel a) and cumulative distribution functions (Panel b) of this productivity index for 1991, 1996, 2000 and 2005. The distribution of firms' productivity in 2005 is at the right of the distribution in 2000 both for the group of small and medium size firms and the group of large firms. Similarly, the distributions of productivity in 2000 are at the right of the distributions in 1996, and the distributions in 1996 to the right of the distributions in 1991. These shifts to right of the productivity distributions show the improvements observed in manufacturing firms' productivity (TFP) over the time. The reduction in the productivity growth rate after 1995 is evident in the sense that the shift in the distribution from 1991 to 1996 is larger than the shifts in following years. The second half of the 90s was particularly bad in terms of productivity growth with a productivity distribution in 2000 close to the distribution in 1996. Another interesting feature that emerges from Figure 2 is that from 1991 to 1996 there is an asymmetric movement in the productivity distribution. The largest movement is in the left tail of the productivity distribution meaning that the productivity growth rate of firms with productivity levels below the average of each industry was higher than the productivity growth rate of firms with productivity above the industry average. This is even more evident for large firms.

[FIGURE 2 ABOUT HERE]

A common finding in the literature is that productivity differences across firms are persistent over time (See Bartelsman and Doms, 2000). Table 2 shows the transition matrix of productivity (TFP) and the transition matrix of productivity (TFP) weighted by firm's market share. The weighted productivity measure the relative contribution of each firm to the productivity of the industry. To construct these transitions matrices in each year, firms belonging to the same industry were ranked by their productivity (or weighted productivity) and then placed in the corresponding quintile. The transition matrix gives the fraction of firms that moves across different quintiles and, therefore, is an indicator of the mobility of firms within the productivity (or weighted productivity) distribution.

[TABLE 2 ABOUT HERE]

Table 2 shows five interesting features related to the dynamics of firms' productivity. First, after 1995 there is an increase in the persistence (reduction in firm's mobility among productivity quintiles) of firms' productivity suggesting that the upward mobility among productivity quintiles within the productivity distribution was higher in the early 90s (convergence in productivity). This is consistent with the largest shift to the right observed in Figure 2 in the lower tail of the productivity distribution from 1990 to 1996. Second, the persistence of weighted productivity is higher and more stable through sub-periods than the persistence of productivity. This is due to the high persistence observed in firms' size. Third, the persistence in firms' productivity is stronger for the right tail of the productivity distribution of the firms. Once the firms become more productive than the mean productivity of the firms, it becomes more difficult to enhance inter quintile mobility in productivity. Fourth, exiting firms were located mainly at the bottom quintile of the productivity distribution in the year before exiting the market and firm's exit is higher during recessions than during expansions. Fifth, in the entry year, entrants were located at the bottom quintile of the productivity distribution and the entry rate is higher during the last year of the recession and the beginning of the expansions. The last two findings are consistent with Fariñas and Ruano's (2005) findings who study the dynamic of productivity of entrant, continuing and exiting firms during the 1990s.

As we mentioned before, Figure 2 and Table 2 suggest also that in the early 1990s Spanish manufacturing firms displayed an upward mobility of the least productive firms indicating the existence of convergence in productivity during this recession period. The empirical analysis of this hypothesis is the main purpose of the following section.

3 Testing for convergence in firms' productivity

The classical convergence literature (Barro and Sala i Martin, 1991, 1992; and Sala i Martin, 1996) provides us with the tools for testing convergence in firms' productivity. According to this literature, there is β-convergence if the productivity of less productive firms tends to grow faster than the productivity of more productive firms. The β-convergence hypothesis is tested through the following regression model

$$g_i = a_g + bp_{i,0} + \alpha' \mathbf{x}_{i,0} + u_i, \tag{3}$$

with $g_i = T^{-1}(p_{i,T} - p_{i,0})$ being the productivity growth rate of the firm i from the initial year 0 to T. There is β-convergence if b<0.[6] Since equation (3) includes a vector of

[6] This coefficient is equal to $-(1-e^{\beta T})T$ where β is the convergence rate. We will consider periods with the same number of years (T) and therefore convergence rate comparisons can be done directly through *b*. In general, the productivity coefficient *b* is negative; the larger its absolute value is, the higher

control variables, $\mathbf{x}_{i,0}$, we are testing for convergence conditional on these control variables. In the growth literature this is known as "*conditional β-convergence*" however for simplicity in the rest of the paper we call it β-convergence. The estimation of the standard errors of the parameters of equation (3) must take into account the heteroskedasticity present in the error term, see appendix C.

Table 3 reports the results of the β-convergence tests for the whole period (1991-2005) and for each sub-period (1991-1995, 1996-2000, and 2001-2005). The null hypothesis of no β-convergence, H_0: *b*=0, is tested against the alternative of β-convergence (mean reversion). Regression Model 1 includes productivity, size dummies, age (in logs), age squared, a dummy variable that takes value one if the firm is an incorporated company, the proportion of foreign capital, human capital (the proportion of employees with university level education), a dummy variable that takes value one if the firm introduced a process innovation, and merger, scission and entry dummies. All these variables are evaluated at the initial period zero.

The main drawback of these type of parameter constant β-convergence test is that it assumes symmetric mean reversion; firms with productivity above the average level of productivity regress towards the mean at the same speed than those firms with productivity levels below the average. To overcome this problem, we follow Oulton (1998) and estimate different models. Model 2 is equal to model 1 but it also includes an interaction between the initial level of productivity and a dummy variable that takes value one if in the initial period the i^{th} firm had a productivity level above the average productivity level of the corresponding industry. This interaction term allow us to capture asymmetric mean reversion. That is, we are interested in evaluating whether the persistence (lower speed of β-convergence in this case) of firms with productivity above average is higher. A positive (negative) and significant value of this interaction term means that firms with productivity levels above the average industry level will have lower speed of productivity convergence and therefore more persistence in their productivity level.

[TABLE 3 ABOUT HERE]

Table 3 shows that the null hypothesis of no β-convergence is rejected in all the cases in favor of convergence. The productivity catching up of less productive firms is on average faster (b=-0.17) than the productivity catching up of more productive firms (*b*=-0.165), at 1% significance level, but only during the recession period (1991-1995).[7] The implied speed of convergence in the period 1991-1995 is higher than the speed of

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the convergence rate in productivity will be (mean reversion). When there is no convergence β=0 and the coefficient *b*=0, indicating that there is no mean reversion in productivity.

[7] Note that we are keeping fixed the variable "TFP above the mean"; therefore, the interpretation of the coefficient is valid only for marginal changes in productivity that do not imply a change in the condition of been above the average value of the productivity of the industry at which the firm belongs to.

convergence in the period 1996-2000, and also higher than the speed of convergence during the period 2001-2005. These findings confirm the intuition of Figure 2 and Table 2.

The macroeconomic convergence literature among countries, regions or industries, do not need to control for sample selection. However, when working with survey data we have to be aware of the reasons why firms exit the markets. When exiting firms are less productive than the survivals the estimates of equation (3) in Table 3 are biased due to an endogenous selection problem. To control for this sample selection bias we use Heckman's (1979) procedure. This procedure involves estimating a system of equations formed by equation (3) and a selection equation that captures the survival probability.

Let $\mathbf{1}[\cdot]$ be an indicator function and χ_i a dummy variable that takes value one when firm *i* survives in the market between period 0 and *T*, then the selection equation is given by

$$\chi_i = \mathbf{1}[a_s + b_s p_{i0} + \alpha_{xs}'\mathbf{x}_{i0} + \alpha_e \mathbf{y}_{i0} + v_i > 0]. \qquad (4)$$

The survival probability is function of the same variables included as regressors in equation (3), i.e. p_{i0} and $\mathbf{x}_{i0}$, plus a vector of variables , $\mathbf{y}_{i0}$, not included in equation (3) that allows us to identify the parameters in the system. This vector includes the log of the firm's capital stock (*k*), the value of the firm's debt (in logs), and a dummy variable that takes value one if the firm is an exporter. We exclude the dummy variable of being exporter from equation (3) because it resulted statistically not significant when we included it. This result is in line with Delgado et al. (2002) who find that, in the Spanish manufacturing sector, more productive firms export but exporters do not increase their productivity at higher rates than non exporters. With respect to the capital stock and the value of the firm's debt, we can exclude them from equation (3) because most models of productivity growth do not include these variables among the main determinants. Assuming that the errors u_i and v_i are normally distributed we can estimate the parameters of equations (3) and (4) by maximum likelihood. Table 4 shows these estimates. The last row of this table presents the results of the p-values for testing the null hypothesis that there is no correlation between u_i and v_i (no selection bias). The no selection hypothesis is strongly rejected for the whole period (1991-2005) and for the last sub period 2001-2005. From 1991 to 1995 (recession period) and from 1996-2000 the selection hypothesis is not rejected at the traditional significant values. Notice that at least one of the excluded variables is always significant in each of the periods considered and therefore the parameters are identified and not only because of the different functional form. The previous conclusions regarding the productivity catching up rates in each sub period are robust even after controlling for the selection bias. That is, there is strong empirical evidence of faster β-convergence in productivity during the recession period in the early 1990s.

[TABLE 4 ABOUT HERE]

As Quah (1993a, 1993b) pointed out, β-convergence does not necessarily implies convergence. He claims that the relevant concept of convergence is the Barro and Sala i Martin's σ-convergence concept which is stronger than β-convergence. That is, β-convergence is a necessary but not a sufficient condition for σ-convergence.

According with this convergence concept, there is σ-convergence in productivity if the variance (standard deviation) in firm's productivity is decreasing over time and therefore the productivity distribution becomes more concentrated around the average productivity. Figure 3 shows the evolution of the standard deviation of three productivity measures. To evaluate the evolution of each standard deviation we normalize them to take value one in 1991.[8] The black solid line is the standard deviation of firms' productivity of equation (1). The grey continue line shows the evolution of the standard deviation of firms' productivity in deviation from their corresponding industry average, i.e., if firm *i* belongs to industry *j* we consider $\tilde{p}_{it} = p_{it} - \frac{1}{N_{jt}} \sum_{i \in j} p_{ijt}$, *j*=1,…,18. Because of this reason we call it "*within industry*" standard deviation. Finally, the grey dashed line shows the standard deviation of the TFP index, ω, defined in equation (2). As we mentioned before, this variable is measured as a difference with respect to a reference firm that varies across industries and size groups and therefore its standard deviation also measures within industry dispersion.

[FIGURE 3 ABOUT HERE]

To test for a reduction in the variance of the distribution we apply the tests developed by Caree and Klomp (1997). The null hypothesis of no convergence states that the variance of productivity in period *T* is equal to the variance of productivity in period 0, $H_0 : \text{var}(p_T) = \text{var}(p_0)$, and is tested against the alternative of convergence, $H_1 : \text{var}(p_T) < \text{var}(p_0)$. To compare the variance of productivity in period *T* with the variance of productivity in period 0 it is possible to evaluate the ratio of these variances. However, because productivity in period *T* depends on productivity in period 0, and therefore variance in *T* depends on variance in 0, the ratio of variances does not converge to an F-distribution and therefore we can not apply the standard test to compare variances. Caree and Klomp (1997) propose two statistics T_2 and T_3, to control for these dependence:

$$T_2 = (N - 2.5) \log \left(1 + 0.25 \frac{(\hat{\sigma}_0^2 - \hat{\sigma}_T^2)^2}{\hat{\sigma}_0^2 \hat{\sigma}_T^2 - \hat{\sigma}_{0T}^2} \right) \qquad (5)$$

and

[8] We show a normalized version because we are interested in the evolution of dispersion not in comparing the dispersion of different productivity measures.

$$T_3 = \frac{\sqrt{N}(\hat{\sigma}_0^2 / \hat{\sigma}_T^2 - 1)}{2\sqrt{1-\hat{\pi}^2}}, \quad (6)$$

with $\hat{\sigma}_0^2$, $\hat{\sigma}_T^2$ and $\hat{\sigma}_{0T}$ being the sample variance of p_0 and p_T and the sample covariance between p_0 and p_T, respectively. Finally, $\hat{\pi}$ is the estimate of the autoregressive coefficient of p_{iT} on p_{i0}. The assumption behind these statistics is that firms' productivity follows a first order autoregressive process.[9] Under the null hypothesis of no convergence, $T_2 \xrightarrow{d} \chi^2(1)$ and $T_3 \xrightarrow{d} N(0,1)$.

We can also test for a reduction in the variance following a similar procedure to the one discussed in Granger and Newbold (1986), Chapter 7. Let p be the variable of interest (log of productivity in our case). Defining $p_+ = p_T + p_0$ and and $p_- = p_T - p_0$, the procedure to test for a reduction in the variance of firms' productivity consists in regressing p_- on p_+. Let α_D be the coefficient of this regression, then $\alpha_D = cov(p_-, p_+) / \mathrm{var}(p_+)$. Since the variance $\mathrm{var}(p_+)$ is always positive, the sign of α_D depends on the covariance between p_+ and p_- which is equal to $\mathrm{var}(p_T) - \mathrm{var}(p_0)$. If α_D is negative (positive) there is σ-convergence (σ-divergence). Therefore, the no σ-convergence null hypothesis, $H_0 : \alpha_D = 0$, or $H_0 : \sigma_T^2 - \sigma_0^2 = 0$, is tested against the alternative hypothesis of σ-convergence, $H_1 : \alpha_D < 0$, or $H_1 : \sigma_T^2 - \sigma_0^2 < 0$. The advantage of this testing procedure is in its simplicity since it rest on testing the equality of the variances of firm's productivity during the two periods by testing the significance of the regression coefficient (α_D).

Table 5 shows the results of testing convergence for the whole period and for the same three sub-periods that we tested β-convergence. We test for convergence in productivity using the same productivity definitions plotted in Figure 3.[10]

The first row of Table 5 shows the ratio of the sample variance in period 0 and the sample variance in period T, $\hat{\sigma}_0^2 / \hat{\sigma}_T^2$.[11] Between 1991 and 2005 the variance of productivity (p_{it}) was almost constant with a ratio close to 1. However, in 2005 relative to 1991 the variance of productivity in deviations from the industry mean, $\tilde{p}_{it}$, and the

[9] This assumption is standard in the production function literature. See Ackerberg, Caves, and Frazer (2005) and the references therein.

[10] We follow this approach instead of considering each industry separately because the number of observations en each industry is not sufficiently large.

[11] When $\hat{\sigma}_0^2 / \hat{\sigma}_T^2 < 1$, we test for σ-divergence. The alternative hypothesis in this case is $H_1 : \mathrm{var}(p_T) > \mathrm{var}(p_0)$.

variance of the TFP index, ω, were significatively lower. Table 5 shows the T_2 and T_3 test statistics and the coefficient α_D. All these test statistics reject the no convergence hypothesis within industries but not for the whole manufacturing sector. The reduction in the dispersion of firms' productivity between 1991 and 2005 within each industry was quantitatively and statistically significant. However, a more detailed analysis of σ-convergence through the business cycle shows that the reduction in the productivity variance of firms was only due to the variance reduction during the recession period of 1991-1995. In fact, during the period 2001-2005 the dispersion observed in firms' productivity within each industry increased creating a period of firm's productivity divergence while during 1996 to 2000 there was simply no convergence.

[TABLE 5 ABOUT HERE]

In general, the σ-convergence finding is considered to be stronger than β-convergence because it means that within each industry firms converge in productivity even without conditioning on other variables. However, in this case, given that the σ-convergence tests do not control for sample selection, the results have to be interpreted with some caution. When the no σ-convergence hypothesis is rejected, then the reduction in the variance could be the result of less productive firms leaving the market. That is, if less productive firms leave the market and the group of continuing firms is more homogeneous in terms of productivity, we should observe a reduction in the variance of firms' productivity. However, when testing β-convergence we find that the convergence rate controlling for selection does not differ from the convergence rate without controlling for selection. Therefore, we can conclude that the reduction in the variance is not only the result of less productive firms leaving the market. From 2001 to 2005, the no selection hypothesis (when testing β-convergence) is strongly rejected and the σ-convergence tests finds evidence on divergence. In this case, if the selection hypothesis had not been rejected the increase of the variance would be even larger.

4 Convergence and the Business Cycle

These results on σ-convergence are consistent with our previous results showing that only during the first half of the 1990s (recession period) the β-convergent coefficient (-0.17 of Table 3 Model 2) was significant with a first order autoregressive coefficient equal to 0.83, is far from the unit root value. However, during the period 1996-2000 and 2001-2005 the corresponding autoregressive coefficients were much closer to the unit root values; 0.88 and 0.91 respectively.

Going deeper in the study of the relationship between β-convergence in firms' productivity and the business cycle involves using the panel data structure of the dataset. Therefore, we first want to make sure that there is no unit root or to check that firms' productivity is stationary. The convergence study in section 3 suggests that this is the case but to be sure we formally test for the presence of a unit root in firms' productivity. For that we use the recent panel unit root tests developed by Levin et al.

(2002), Im et al. (2003), Maddala and Wu (1999), and Pesaran (2007). Table 6 shows the equation used in each of these tests together with the hypothesis we are testing. The interpretation of these results needs some care because the null hypothesis and the controlled variables used are not the same in each test. The Levin, Lin and Chu test is the most restrictive; the null hypothesis states that all the firms have a unit root in productivity and the alternative states that productivity in all the firms is a stationary variable with an equal autoregressive coefficient. The other tests relax the alternative hypothesis allowing for a group of firms in which productivity is stationary (with different autoregressive coefficients) and a group of firms with nonstationary (unit roots) productivity. Regarding the structure of the dataset, the tests of Levin, Lin, and Chu, Im Pesaran and Shin, and Pesaran require a balanced panel; therefore in this case we used the firms that were in the manufacturing sector during the 15 years. There is also a difference in terms of the assumptions needed regarding the dependence among the cross section units; the only one that allows for dependence across firms is the test (CADF) of Pesaran. The last columns of Table 6 show the results. In all the cases, the null hypothesis of all firms having a unit root is clearly rejected with p-values equal to 0 in all the cases.

[TABLE 6 ABOUT HERE]

After rejecting the null hypothesis of a unit root in firms' productivity we can use the standard econometric techniques to evaluate the relationship between β-convergence and the business cycle.

An important feature of our dataset is that each firm reports important information about the dynamism of the market in which it operates,[12] i.e. recessive, stable, or expansive. Remember that the period showing convergence in firms' productivity (1991-1995) coincides with the recession period of the Spanish economy and the period showing productivity divergence (2001-2005) with an expansion period. With this survey information we can construct firm level perceptions of business cycle for each industry to check the robustness of the results to alternative measure of the business cycle.

In particular, define R_{jt} and E_{jt} as the proportion of firms in industry *j* and period *t* that report that their markets are in recession and expansion, respectively. As Figure 4 shows, the evolution of the ratio of firms reporting that their markets are in expansion over the firms reporting that their markets are in recession (E_t / R_t) is similar to the evolution of the growth rate of the Spanish economy and therefore is a good industry level indicator of the business cycle. This fact, allows us to go deeper into the empirical evaluation the relationship between firm's productivity convergence and the business cycle. An advantage of using the proportions of firms in recession and expansions is that they provide variability across time and industries and therefore they also give

[12] Given that each firm can attend more than one market, the ESEE dataset provides a weighted index of the dynamism of the markets as reported by the firm for the markets in which it operates.

important cross-section information to identify other types of firm's heterogeneity through the business cycle.

We follow two additional approaches to evaluate the relationship between the business cycle and β-convergence in firms' productivity. First, we compare the effect of downturns and expansions on the productivity growth rate of what we call "technological" leaders and followers. We also evaluate the effects of downturns and expansions on the quintiles of the productivity distribution. Second, we estimate the convergence rate by industry and evaluate its behavior in downturns.

[FIGURE 4 ABOUT HERE]

Let Qs_{jt} (s=1, 2,…, 5) be the quintile s of the productivity distribution of firms in industry j in period t. We define two dummy variables, L_{it} and F_{it}, that take value 1 when firm i in period t is a technological leader or a technological follower, respectively.[13] We classify as followers those firms in quintiles 1, 2, 3 and 4 of the productivity distribution of their industry and as leaders those firms in the fifth quintile. That is, if firm i belongs to industry j then it will be a follower or a leader in period t according with the following definitions:

$$\begin{aligned} F_{it} &= \mathbf{1}[\text{In period } t \text{ firm } i \text{ is in } Q1_{jt}, Q2_{jt}, Q3_{jt}, \text{ or } Q4_{jt}] \\ L_{it} &= \mathbf{1}[\text{In period } t \text{ firm } i \text{ is in } Q5_{jt}] \end{aligned} \quad (7)$$

where $\mathbf{1}[\cdot]$ is an indicator function.

The relationship between convergence and the business cycle can be analyzed by evaluating the differential effect of recessions and expansions on the productivity growth rate of followers and leaders through the following regression model

$$\begin{aligned} \Delta p_{it} = c &+ \alpha_{LR} R_{jt} + (\alpha_{FR} - \alpha_{LR}) F_{i,t-1} \times R_{jt} \\ &+ \alpha_{LE} E_{jt} + (\alpha_{FE} - \alpha_{LE}) F_{i,t-1} \times E_{jt} \\ &+ \alpha_x \mathbf{x}_{it-1} + \alpha_z \mathbf{z}_{it} + \rho p_{i,t-1} + u_{it}, \end{aligned} \quad (9)$$

where Δp_{it} is the growth rate of productivity, and $\mathbf{x}_{i,t-1}$ is a vector that includes the same control variables used in the convergence analysis of section 3, i.e., a dummy variable for incorporated companies, the proportion of foreign capital, human capital (the proportion of engineers and workers with a college degree), and a dummy variable for process innovation. Using lagged variables helps to avoid inconsistency problems caused by possible endogenous variables. Vector $\mathbf{z}_{it}$ includes a set of exogenous

[13] We acknowledge that calling "technological" leaders and followers to firms in quintile 5 and 1 to 4 of the productivity (TFP) distribution, respectively, is a simplification. We make this distinction in order to identify differential effects of the most productive firms. However, we are aware of the existence of other economic factors beside technology determining firms' TFP.

variables like size, year and industry dummies, the log of age and its square. It also includes dummies for firms involved in a merger or scission process and for entrants and exiting firms. The lag of productivity, $p_{i,t-1}$, captures a constant β-convergence rate during the whole period. Later we will also allow this coefficient to vary through the business cycle.

The differential effects of recessions and expansions on firms that are "technological" followers and leaders are measured by $\alpha_{LR} + (\alpha_{FR} - \alpha_{LR}) F_{i,t-1}$ and $\alpha_{LE} + (\alpha_{FE} - \alpha_{LE}) F_{i,t-1}$, respectively. Then, α_{FR} and α_{LR} measure the effect of recessions on the rate of growth of productivity of followers and leaders, respectively, and α_{FE} and α_{LE} the corresponding effects of expansions. The differential effects of recessions and expansions on the productivity growth rate of leaders and followers can be analyzed directly by the sign of $(\alpha_{FR} - \alpha_{LR})$ and $(\alpha_{FE} - \alpha_{LE})$. The literature has documented that productivity is pro-cyclical (see, for example, Basu, 1996; Basu and Fernand, 2001) and therefore we expect $\alpha_{LR} < 0$ and $\alpha_{LE} > 0$. Then, if $(\alpha_{FR} - \alpha_{LR}) > 0$, the negative effect of recessions on followers' productivity growth is lower than the effect on leaders' productivity growth. On the other hand, if $(\alpha_{FE} - \alpha_{LE}) < 0$, the effect of expansions on productivity growth is higher for leaders. Table 7 presents the results of estimating equation (9). Columns [1] and [1'] present the results imposing the same β-convergence rate for the whole period and Column [2] and [2'] allow for different convergence rates in each of the sub-period considered in the convergence analysis of section 3. The difference between columns [.] and [.'] is that columns [.'] also include the lag of the productivity growth rate (lagged dependent variable) as an additional regressor to control for autocorrelation. As will become clear later, the error term in columns [.] has first order autocorrelation which in a dynamic model affects all the estimated coefficients. However, in this case it is mainly creating important biases in the estimated coefficient of the first lag of productivity because this is the explanatory with the highest correlation with the error term.

As Table 7 shows, the coefficient of the proportion of firms in downturn is negative indicating that as the proportion of firms in recession in each industry increases there is a reduction the expected rate of growth in productivity, keeping the rest of the variable constant. On the other hand, the partial effect of the proportion of firms in expansions in productivity is positive showing that productivity is pro-cyclical. As we mentioned above, this is consistent with the productivity literature and confirms that the productivity of Spanish manufacturing firms is also pro-cyclical. Columns [1] and [1'] show that the coefficient of the interaction term between being a follower and the proportion of firms in downturn is also positive. These finding shows that the negative impact of recessions on "technological" followers is lower than the impact on leaders' productivity and therefore the followers tend to catch up with leaders productivity during recessions. However, the effect is only significant when we do not control for the autocorrelation in the error term[14], see model [1] of Table 7. On the other hand, the coefficient of the interaction terms between followers' firms and the proportion of firms in expansion is negative showing that there is a significant productivity divergence during expansions since the effect of expansions on productivity growth is higher for leaders.

The corresponding first order autoregressive coefficient of productivity is 0.65 and 0.74 in models [1] and [1´] respectively, again far from the unit root values. To allow for different β-convergence rate in each sub-period we also include interactions terms between the lag of firms' productivity and dummy variables for each of the three sub-periods (1991-1995, 1996-200 and 2000-2005); see columns [2] and [2']. The corresponding autoregressive coefficient is now lower during the recession period of 1991-1995 implying lower persistence in firms' productivity. In this case, the negative effect of recessions on followers' productivity growth rate is still lower than the effect on leaders' productivity growth (the coefficient is positive) but it is not significant after controlling for different speed of convergence through the business cycle.

[TABLE 7 ABOUT HERE]

Columns [3] and [4] in Table 7 show analogous results to columns [1] and [2] but instead of evaluating the impact of recessions and expansions of followers and leaders' productivity growth rates, we evaluate the differential effect of the business cycle on each quintile of the productivity distribution of the previous year. We do this by including interaction terms between the variables reflecting the percentage of firms in recessions (R_{jt}) and expansions (E_{jt}) and a set of dummy variables indicating the corresponding quintile of the productivity distribution of the previous year, $Qs_{i,t-1}$ with s = 1, 2, … , 5. Columns [3] and [3'] of Table 7, show negative coefficients in all the interaction terms between the proportion of firms in recession and the lagged productivity quintiles. However, firms in quintiles 1, 2, 3, and 4 show lower negative impacts of recessions than firms in quintile 5 reflecting that there is convergence in productivity during recessions since the most productive firms grow at a lower rate than the rest of the firms. In expansions, firms in quintiles 5 of the previous period, show a higher and significant productivity growth rate indicating that there is a productivity divergence during expansions. Columns [4] and [4'] shows similar results after controlling for different speed of convergence through the business cycle. In recessions, the firms with the lowest reduction in the productivity growth rate are those in quintile 4 of the productivity distribution.

Panel (a) in Figure 5 shows the average productivity growth of "technological" leaders and followers obtained from columns [1] and [1'] of Table 7. Panel (b) of Figure 5

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[14] Controlling for autocorrelation in this case requires losing information on the first two years the firm appears in our sample. Given that the first year in our dataset is 1991, we lose information on 1991 and 1992 and given that 1992 is a very important year in terms of the proportion of firms in recession this affect the estimates of the standard errors of the recession variables.

shows the difference between the productivity growth rate of leaders and followers. We observe that the productivity growth rate of followers was higher than the productivity growth rate of leaders only during the first years of the 90´s describing the firm's productivity convergence observed in recessions.

[FIGURE 5 ABOUT HERE]

To check the robustness of the previous results to sample selection issues, we estimate models in columns [1] to [4] controlling for sample selection due to fact that firms exit the market for endogenous reasons. Let $\mathbf{1}[\cdot]$ be an indicator function and χ_i a dummy variable that takes value one when firm *i* survives in the market between period t-1 and t, then the selection equation is given by

$$\chi_{it} = \mathbf{1}[a_s + \alpha_{s,LR}R_{jt} + (\alpha_{s,FR} - \alpha_{s,LR})F_{i,t-1} \times R_{jt} + \alpha_{s,LE}E_{jt} + (\alpha_{s,FE} - \alpha_{s,LE})F_{i,t-1} \times E_{jt} + \\ + b_s p_{it-1} + \alpha_{xs}'\mathbf{x}_{it-1} + \alpha_{zs}'z_{it} + \alpha_e \mathbf{y}_{it-1} + v_{it} > 0]. \quad (10)$$

The survival probability is a function of the same variables included as explanatory variables in equation (9) plus a vector of variables, $\mathbf{y}_{it-1}$, not included in (9) that allows to identify the parameters in the system. As in selection equation (4), this vector of variables includes the log of the capital stock (*k*), the value of the debt (in logs), and a dummy variable that takes value one if the firm is an exporter.

Table 8a and Tables 8b show the maximum likelihood estimates of equation (9) and the survival equation (10). As in Table 7, columns [.'] in Tables 8a and 8b include also the lag of the rate of growth of productivity to control for the first order autocorrelation detected in equation (9). Table 8a shows that the main results in Table 7 are robust to sample selection. The estimates of the survival equation show that the log of capital is significant in all the models and the exporter dummy in the first two. This means that these variables are good indicators of the survival probability. However, the selection hypothesis is rejected in all the models.

[TABLES 8a and 8b ABOUT HERE]

The hypothesis of productivity divergence in expansions finds strong support in Table 7 and Tables 8a and 8b. However, the evidence of convergence in recessions is weak in the most dynamic model; the coefficient $\alpha_{FR} - \alpha_{LR}$ is positive but statistically not significant. Therefore, in order to add to the effects of recessions on productivity convergence we perform an alternative exercise. We estimate the coefficient that provides the speed of convergence, *b*, in each year by estimating recursively the following equation,

$$\Delta p_{it} = c_t + b_t p_{i,t-1} + \alpha_{xt}'\mathbf{x}_{it-1} + \alpha_{zt}'\mathbf{z}_{it} + u_{it}, \quad (11)$$

with *t* = 1992, 1993, …, 2005 and $\mathbf{x}_{it-1}$ and $\mathbf{z}_{it}$ including the same control variables used in the β-convergence analysis of section 3. The evolution of estimated coefficients b_t is shown in Panel (a) of Figure 6. Remember that the closer the value of b to zero is the lower the convergence rate will be. We also show the evolution of b_t obtained replacing the usual TFP measure by the TFP index ω defined in equation (2). In both cases, the evolution is similar. The estimated coefficient b_t increases over time from -0.45 in 1992 to -0.20 in 2005. This finding is consistent with section 3 in the sense that from 1991 to 1995 the convergence rate was sufficiently large to imply a reduction in the dispersion of firms' productivity and after 1996 the speed of convergence was not high enough to imply a reduction in productivity dispersion and, in fact, after 2001 there was an increase of the productivity dispersion.

[FIGURE 6 ABOUT HERE]

A possible concern is that the evolution of b_t, according with Figure 5, could be explained by a trend in the dynamic of firms' productivity and not necessarily by the business cycle. Addressing this issue is important because the interpretation of the results in each case is different. To evaluate whether the increase in the absolute values of the coefficient b (increase in the speed of convergence) is related to the business cycle we estimate equation (12) for each industry obtaining a coefficient b_{jt} for t = 1992, … , 2005 and j = 1, …, 18. Panel (b) in Figure 6 shows the relationship between these coefficients and the proportion of firms in recessions in each industry. Clearly, there is a negative relationship between the proportion of firms in recession and the coefficient b, i.e., a positive relationship between the speed of productivity convergence and the proportion of firms in recessions. To evaluate this relationship we estimate the following regression model:

$$b_{jt} = \alpha_b + \alpha_R R_{jt} + \alpha_{93} yr1993 + \alpha_{94} yr1994 + \cdots + \alpha_{05} yr2005 + \varepsilon_{it}, \qquad (12)$$

where R_{jt} was defined before as the percentage of firms in industry j reporting that their markets are in recession, and $yr1993$, $yr1994$, …, $yr2005$ are year dummies. By including these time dummies we isolate the recessions effects from the possible trend effect in b_{jt} shown in panel (a) of Figure 6. A limitation of this approach is that it rests on the estimation of a coefficient for each industry and each year and the number of observations to estimate b_{jt} of some industries is low. Therefore, in what follows we concentrate only in the coefficients b_{jt} that are statistically significant. Column [1] in Table 9 shows the estimates of this equation. The coefficients $\alpha_{93}, \alpha_{94}, \ldots, \alpha_{05}$ are increasing and therefore there is an increasing trend, however, none of them is significant. On the other hand, the coefficient α_R of the percentage of firms in recessions is negative and significant. This means that the evolution in the speed of productivity convergence is explained by the business cycle. Panel (b) in Figure 6 shows some industries with a positive coefficient b, indicating divergence in firms' productivity. By including industry dummies in the estimation of equation (12), i.e., controlling for industry fixed effects, we can evaluate which are the industries in which it is more likely to find divergence. Column [2] in Table 9 shows that these industries are Meat and Meat Products, Beverages, Textiles and Apparels, Leather products and Shoes, and Paper, Paper Products and Printing Products. We observe that after controlling for industry dummies, the effect of recessions on the speed of convergence is even faster.

Columns [1´] and [2´] of Table 9 show the same estimates of models [1] and [2] but instead of including a dummy variable for each year we include a dummy variable for each main period; 1992-1995 (recession period) and 1996-2001 (expansion periods). We show that the previous results are robust; the dummy variable for the sub-periods is not significant and the α_R coefficient of the percentage of firms in recession in each industry is negative and statistically significant (the magnitude of the coefficient is slightly lower in absolute terms and the significance is higher). Column [2´] shows that the industries showing higher speed of convergence are the same as those of column [2].

[TABLE 9 ABOUT HERE]

4.1 Economic explanation of the relationship between convergence and the business cycle

An explanation of why less productive firms catch up with more productive ones can be found in Jovanovic and MacDonald (1994). They propose a technological diffusion model in which leaders innovate and imitation causes technology to spread from leaders to followers as the industry matures. The empirical evidence presented in this paper suggests that this is actually taking place in the Spanish manufacturing sector. However, the evidence shows that the speed of convergence is not constant but higher in recessions and that there is productivity divergence in expansions.

The innovation literature has documented that innovation is pro-cyclical (see, for example, Geroski and Walters, 1995; Barlevy, 2007)[15] and therefore it provides an explanation for the difference in the speed of convergence. More productive firms innovate more in expansions and therefore less productive firms can not catch up with them. On the other hand, in recessions, when more productive firms do not innovate as much as in expansions less productive firms catch up with them because they learn by imitation. In our sample, the percentage of firms that report process innovations in downturns and expansions is 31.6% and 45.09%, respectively.[16] Therefore, it is very

[15] Geroski and Walters (1995) not only find that innovation is pro-cyclical. They find that the causal relation runs from variations in demand to variations in innovative activity but not from innovations to changes in demand. This is important because it means that during a recession there is less incentive to innovate and not that there is a recession because firms do not innovate.

[16] Huergo and Jaumandreu (2004) analyzed the relationship between process innovations and productivity growth and Ornaghi (2006) the diffusion of technology in Spanish manufacturing firms during the 1990s. The innovation variable provided in ESEE takes value one if the firm says that it has introduced a process innovation. Actually, the introduction of a process innovation may be the result of imitation and therefore we can not distinguish between innovation and imitation.

likely that a cyclical innovation-imitation process is taking place. The estimates in Table 7 provide support to this hypothesis. The divergence in expansions is explained by the productivity growth increase in the most productive firms' and these firms are the ones that innovate more. In recessions, the firms with the lowest reduction in the productivity growth rate are those in quintile 4 of the productivity distribution. These firms are close to the technological frontier and therefore are the ones who can imitate easier.

During recessions periods there is another economic force driving convergence. After a reduction in the demand, the competition for the market is stronger and firms have more incentives to reduce costs. Firms have incentives to reduce the cost of production *at any moment of time; h*owever, less productive firms might have more incentives to reduce costs of production in recessions since they are the main candidates to exit the market.[17] The literature studying the effect of competition on firms' productivity is large, however, for the purpose of this paper the most important references might be Oulton (1998) and Syverson (2004). They found an inverse relationship between industry competition and the dispersion in firms' productivity. This explanation for observing higher speed of convergence in downturns has less support in our case. If the least productive firms are those who try to avoid exiting the market by increasing their productivity, we should observe firms in lowest quintiles being the least affected by recessions. Certainly, they are less affected by downturns than firms in quintile 5, however, as we mention before, the firms that are the least affected by recessions are those in quintile 4; the ones who are near the productivity frontier.

4.2 The effect of human capital and innovation

With respect to the economic variables used as control variables in all the estimated convergence models we obtained similar results, both in terms of the magnitude or the significance of the coefficients. The main expected partial effects, keeping the rest of the variables constant, can be summarized as follows: (i) Incorporated companies and large firms showed higher productivity growth; (ii) the larger the proportion of workers with a university degree (higher human capital) and the larger the proportion of foreign capital in the firm, the higher the productivity growth; (iii) firms that introduced a process innovation in the previous year also showed higher productivity growth rates; finally (iv) the firms that exit the market showed lower productivity growth.

This analysis can be extended to evaluate whether human capital and innovation have a differential effect of "technological" followers and leaders in productivity growth through the business cycle. In order to do this, we use equation (9) but including also interaction terms between human capital and process innovation with the "technological" follower dummy variable as defined in (7). Additionally, we are interested in evaluating whether the effects are different in recessions than in expansions and therefore we include also in the interaction terms the proportion of firms in

[17] Schimtz Jr. (2005) finds that after an increase in external competition, U.S. iron ore producers more than double their level of productivity.

recession. Column [1] in Table 10 shows the result of including this set of interactions in the human capital variable. We choose the model specification that allows us to have different speed of convergence through the business cycle. The estimated coefficient of the interaction between human capital and the follower dummy is equal to the coefficient of human capital but with negative sign. This implies that human capital does not have an additional effect on followers' productivity growth. However, the interaction between human capital, the follower dummy and the proportion of firms in recession shows a positive coefficient indicating that the effect of human capital on followers' productivity growth is larger when there are a large proportion of firms in recession, i.e. when the recession is more severe. On the other hand, column [2] shows that innovation does not have a differentiated effect on followers' productivity growth through the business cycle. These results are robust if we include the interactions of human capital and innovation at the same time (column [3]) and if we use the quintiles instead of follower dummy as indicated in Table 7 columns [4], [5], and [6].

[TABLE 10 ABOUT HERE]

5 Conclusions

This paper studies the dynamic evolution of firms' productivity through the business cycle for firms that are considered "technological" leaders and followers. The data comes from annual surveys of Spanish manufacturing firms done over the period 1991 to 2005. This period of time is sufficiently large to cover recessions and expansions of the Spanish manufacturing sector.

We find firm's productivity (TFP) convergence during recessions but not during expansions. The reason for this productivity convergence is because in recessions, firms with productivity levels below the average productivity of the industry catch up with the firm's productivity above average (asymmetric mean reverting behavior). These results are robust to several measures of productivity (TFP and a TFP index) and to several productivity convergence approaches; testing conditional β-convergence, testing σ-convergence and evaluating the persistence observed in transition productivity matrices through the business cycle.

These empirical regularities are consistent with models of technological diffusion (see Jovanovic and MacDonald, 1994) and with the fact that innovation is pro-cyclical (see Barlevy, 2007). Leaders innovate and imitation causes technology to spread from leaders to followers forcing the productivity (TFP) convergence as the industry matures. The diffusion of technology is not instantaneous because followers need time to imitate or adapt certain innovations. Since the innovation rate of the most productive firms is higher in expansions we observe less productivity convergence during expansions. Summarizing, the imitation lag plus the fact that innovation is pro-cyclical lead us to observe firm's productivity convergence in recessions but not in expansions.

We find consistent and robust empirical results from six different methodologies. First, we split the sample in periods of five years and extend several convergence tests (conditional β-convergence and σ-convergence) through the business cycle and for differential effects of "technological" leaders and followers. Second, we compare recessions and expansions effects on the productivity growth rates of leaders and followers. Third, we compare the effects of recessions and expansions on the productivity growth rates of firms at different quintiles of the productivity distribution. Fourth, we study productivity β-convergence and productivity growth based of the business cycles effects provided by the firm's perceptions on the proportion of firms in recessions and expansions in each industry. Fifth, we check whether the negative effect of recessions on productivity growth is lower for "technological" followers than for leaders, enhancing even more firm's convergence during recessions. On the other hand, in expansions we check whether leaders increase their productivity growth faster than followers and firms tend to diverge in productivity. These findings are also consistent with a process of technological diffusion and the fact that innovation is pro-cyclical. Sixth, given that we observe a decreasing path in the coefficient of β-convergence on the percentage of firms in recession, we tested whether this evolution follows a trend or is related to the business cycle. Once again, we find that the speed of β-convergence is related to the proportion of firms in recession in each industry.

Controlling for industry fixed effects in the previous time varying β-convergence case; we find that four out of the eighteen industries have a significantly lower speed of β-convergence. These industries are: (i) Meat and Meat Products, (ii) Beverages, (iii) Textiles and Apparels, Leather products and Shoes, and (iv) Paper, Paper Products and Printing Products.

Among the economic variables used as control variable in the previous β-convergence approaches we find that: (i) Incorporated companies and large firms showed higher productivity growth; (ii) the larger the proportion of workers with a university degree (higher human capital) and the larger the proportion of foreign capital in the firm, the higher the productivity growth; (iii) firms that introduced a process innovation in the previous year also showed higher productivity growth rates; finally (iv) the firms that exit the market showed lower productivity growth.

We have seen that there is a slowdown in labor productivity and in total factor productivity (TFP) during more than a decade. This is particularly problematic since during this period the per capita income was growing and we have experienced an important per capita income convergence to European income levels. The main factors were related to the evolution of the labor force participation in that period. The actual international slowdown in economic activity will force the labor force participation to be reduced creating serious problems of unemployment.

Under this recent macroeconomic scenario, the fact that TFP is not growing in Spain is creating a very fragile and unstable economic situation. The economic policy implications derived from the results of this paper are clear. We find that human capital effects on followers' productivity growth are larger when the proportion of firms in recession is high (more severe recessions) therefore; investments done by firms in human capital would help preventing a reduction in productivity (TFP) during downturns. This is important because these less productive firms are the main candidates to leave the market; a major source of unemployment. On the other hand, we observe that investment in process innovation also enhances firms' productivity. Therefore policies enhancing firm's innovation would help relaxing the main constraints of the Spanish economy. However, they do not have a differential effect on followers' productivity through the business cycle.

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7 Appendix A: Data and Variable Definitions

7.1 Rules for excluding firms and observations from the sample

We drop few firms and observations from the sample following five rules. First, we exclude those firms that move from one industry to another since otherwise firm's productivities at different years are not comparable. Second, we exclude observations with negative values of value added or negative intermediate consumption. Third, we exclude observations with ratios of labor cost to sales or material cost to sales larger than one. Fourth, we exclude the observation if the firm reports an incomplete exercise in a year different than the one in which it leaves the market. Finally, we exclude the observations of those firms that does not report all the information needed to compute productivity (TFP) or if the firm only provides information for one year (3043 and 920 observations, respectively, see Table 11). Table 12 shows the number of observations by industry and size and Table 13 the number of observations by industry and year.

[TABLES 11, 12, AND 13 ABOUT HERE]

7.2 Variable Definitions

- *Output*: Value of produced goods and services computed as sales plus the variation of inventories deflated by the firm's price index of output.
- *Labor*: Effective total hours worked. Computed as the number of workers times the average hours per worker. The average hours per worker is computed as the normal hours plus average overtime minus average working time lost at the workplace.
- *Intermediate materials*: Value of intermediate firm's consumption deflated by the firm's price index of materials.
- *Capital*: See Appendix B.
- *Investment*: Value of current investment in equipment goods.
- *Wages*: Firm's hourly wage rate (total labor cost divided by effective total hours of work) deflated by the firm's price index of output.
- *User cost of capital*: Is the sum of the weighted long term interest rates of banks and other long term debts plus the industry-specific depreciation rate minus the investment inflation rate.
- *Age*: The age of the firm is the difference between the current year and the year of birth declared by the firm.

- *Size*: Three categories are considered. Firms with more than 200 employees (Large firms) and firms with less than 200 but more that 50 employees (Medium- sized firms) and firms with less than 50 employees (Small firms).

- *Industry*: Firms are classified in 18 industries. See Table 12.

- *Recession and Expansion*: Firms report whether they operate in expansive, stable, or recessive market. Recession (Expansion) is the reported proportion of firms that produce in a market in recession (expansion) at the industry level.

- *Human capital*: Proportion of engineers and workers with a college degree.

- *Foreign capital*: Proportion of foreign capital.

- *Process innovation*: Dummy variable that takes value one when the firm reports that has introduced a process innovation.

- *Incorporated company*: Dummy variable that takes value one when the firm is an incorporated company.

- *Merger*: Dummy variable that takes value one when the firm has been involved in a merger process.

- *Scission*: Dummy variable that takes value one when the firm has been involved in a scission process.

- *Entry*: Dummy variable that takes value one if the firm have entered in the market after 1990.

- *Exit*: Dummy variable that takes value one if the firm exit the market during the period 1991-2005.

- *Exporter*: Dummy variable that takes value one if the firm exports part of its production.

- *Debt*: Value of the loans and financial obligations lasting over one year.

- *TFP*: Total factor productivity. Described in section 2, see equation (1).

- *TFP above the mean*: Dummy variable that takes value 1 if the firm has a TFP level greater than the level of the average TFP of the industry at which it belongs to.

Appendix B: Capital Stock

The ESEE surveys provide firms' real capital stock data from 1991 to 1999 (variable KNRBE). The capital stock evaluated at the current replacement value (K_t) is computed recursively from an initial estimate (K_0) and the data on current investment (I_t) applying the perpetual inventory formula,

$$K_t = (1-d)K_{t-1}\frac{P_{It}}{P_{I,t-1}} + I_t, \tag{B.1}$$

where d is the depreciation rate (which is product-specific) and P_{It} is the investment price index. The initial stock of capital is given by

$$K_0 = (1-d)^{al}\,GHK_0\frac{P_{It}}{P_{I,t-al}}, \tag{B.2}$$

where *al* is the average life of fixed assets and *GHK* is the book value of equipment goods (at their purchase price); see Martin-Marcos and Suarez (1997) for more details on the construction of the initial capital stock .

Following the same procedure we re-estimate the stock of capital for the period 1991-1999 and extend it to the year 2005. We are not able to recover exactly the same values before 2000 because it is not possible to recover the information at the product level, and therefore, instead of using product-specific depreciation rates we use industry-specific depreciation rates. To obtain the value of the depreciation rate we average the values at the product level in Martin-Marcos and Suarez (1997) to obtain the values at the industry. Figure 7 shows the obtained depreciation rates by industry.

[FIGURE 7 ABOUT HERE]

Another reason why our capital stock variable does not match perfectly with the previous available measure (KNRBE) is because of the variable used to measure the average life of fixed assets (*al*). If the firm reports that has not updated the value of the fixed assets, KNRBE is constructed using the average oldness of the fixed assets (RIMAME). If the firm reports that has updated the value of its fixed assets, KNRBE is constructed using date in which the firm updated the value of its fixed assets. The information on the whether the firm has updated the value of its fixed assets is not available and therefore we always use the average oldness of the fixed assets (RIMAME) to measure the average life of the fixed assets (*al*).

Given that the older the firm the more likely that the firm has updated the value of its fixed assets, we adjust the initial measure of the capital stock in the following way. First, we estimate the following regression:

$$\log KNRBE_{i0} = \beta_0 + \beta_1 \log K_{i0} + \beta_2 ENTRY_i + \beta_3 SCISS_i + \beta_4 \log AGE_{i0} + \beta_5 (\log AGE_{i0})^2 + u_i. \quad \text{(B.3)}$$

The initial value of capital is obtained from the fitted values of (B.3),

$$K^*_{i0} = \hat{\alpha}\hat{m}_i, \quad \text{(B.4)}$$

where $\hat{m}_i = \exp\left(\widehat{\log} KNRBE_{i0}\right)$ and $\hat{\alpha}$ is bias correction obtained from the coefficient of the regression of KNRBE on $\hat{m}_i$ (without a constant). Table 14 shows the estimate of equations (B.3) and (B.4).

[TABLE 14 ABOUT HERE]

Table 15 shows the descriptive statistics of the capital stock we construct (K) and the capital stock in ESEE (KNRBE) for the period in which we have both variables (1991-1999). This table shows the descriptive statistics, before and after the correction in the initial capital stock. Finally, Table 16 shows the correlation between these two variables, both in levels and in growth rates, and show that in both cases the correlations are at least equal to 80%, after the bias correction in the initial capital stock. The similarity in the results gives us confidence on our new capital measure.

[TABLES 15 AND 16 ABOUT HERE]

Appendix C: The Growth Equation

Consider the following model for firms' productivity where $p_{iT} = \log P_{iT}$,

$$p_{i,T} = \beta' x_{i,T} + w_{i,T} \quad \text{(C.1a)}$$

with

$$w_{i,T} = \rho w_{i,T-1} + \varepsilon_{i,T}. \quad \text{(C.1b)}$$

Assuming that the errors $\varepsilon_{i,T}$ are i.i.d.(0, σ^2_{it}) with $E\left(\varepsilon_{iT} \middle| x_{iT}, w_{i,T-1}\right) = 0$, this model specification, (C.1a) and (C.1b), indicates that productivity is determined by the exogenous and predetermined variables x_{iT} and by an autoregressive AR(1) structure in the productivity shocks ($w_{i,T}$) that introduces persistence in productivity (ρ <1).

According to this specification we have;

$$p_{i,T} - \beta' x_{i,T} = \rho w_{i,T-1} + \varepsilon_{i,T}. \quad \text{(C.2)}$$

Since w_{iT} follows a AR(1) process, $w_{i,T-1}$ can be expressed as

$$w_{i,t-1} = \rho^{T-1} w_{i,0} + \sum_{j=0}^{T-2} \rho^{j} \varepsilon_{i,T-1-j} . \tag{C.3}$$

Substituting equation (C.3) into equation (C.2) we obtain

$$p_{i,T} - \beta' x_{i,T} = \rho \left(\rho^{T-1} w_{i,0} + \sum_{j=0}^{T-2} \rho^{j} \varepsilon_{i,T-1-j} \right) + \varepsilon_{i,T} ,$$

which can be rewritten as

$$p_{i,T} - \beta' x_{i,T} = \rho^{T} \left(p_{i,0} - \beta' x_{i,0} \right) + \sum_{j=0}^{T-2} \rho^{j+1} \varepsilon_{i,T-1-j} + \varepsilon_{i,T} .$$

Subtracting the initial productivity conditions p_{i0} from both sides and dividing by T,

$$T^{-1}(p_{i,T} - p_{i,0}) = \frac{(\rho^{T} - 1)}{T} p_{i,0} - \frac{\rho^{T} \beta'}{T} x_{i,0} + \frac{\beta'}{T} x_{i,T} + \frac{1}{T} \left(\sum_{j=0}^{T-2} \rho^{j+1} \varepsilon_{i,T-1-j} + \varepsilon_{i,T} \right) .$$

Defining $b = \frac{(\rho^{T} - 1)}{T}$, $\alpha' = \frac{\rho^{T} \beta'}{T}$, and $g_i = T^{-1}(p_{iT} - p_{i0})$ assuming that equation (C.1a) includes a constant and defining $u_i = \frac{\beta'}{T} x_{i,T} + \frac{1}{T} \left(\sum_{j=0}^{T-2} \rho^{j+1} \varepsilon_{i,T-1-j} + \varepsilon_{i,T} \right)$ then the previous equation can be reduced to equation (3) of section 3,

$$g_i = a + b p_{i,0} + \alpha' x_{i,0} + u_i . \tag{C.4}$$

Notice that in (C.4) and in equation (3) we have added a constant term to allow for the presence of a constant term in (C.1a). The parameters of equations (C.4) can be consistently estimated by OLS and hypothesis testing can be done based on heteroskedasticity robust standard errors, under standard regularity conditions on the regressors and the error term u_i.

Appendix D: Tables

Table 1: Descriptive statistics of firm's productivity level and rates of growth, by size of the firm through the business cycle

	1991-1995 (Recession)			**1996-2000 (expansion)**			**2001-2005 (expansion)**		
	Mean	**S.D.**	**C.V.**	**Mean**	**S.D.**	**C.V.**	**Mean**	**S.D.**	**C.V.**
Small (Less than 50 employees but more than 10)									
TFP (in logs)	3.54	0.56	0.16	3.62	0.57	0.16	3.69	0.55	0.15
TFP (Annual Growth Rate, in percentage)	1.86	22.20	11.90	1.45	16.79	11.56	1.56	17.25	11.03
Labor Productivity (in logs)	10.33	0.72	0.07	10.53	0.72	0.07	10.66	0.71	0.07
Labor Productivity (Annual Growth Rate, in percentage)	2.95	28.33	9.60	2.95	22.65	7.68	1.35	22.37	16.62
Medium (Less than 200 employees but more than 50)									
TFP (in logs)	3.65	0.53	0.14	3.69	0.53	0.14	3.73	0.51	0.14
TFP (Annual Growth Rate, in percentage)	2.99	16.52	5.53	1.57	13.13	8.35	1.43	12.41	8.66
Labor Productivity (in logs)	10.75	0.69	0.06	11.02	0.70	0.06	11.13	0.67	0.06
Labor Productivity (Annual Growth Rate, in percentage)	7.01	25.48	3.63	2.84	18.65	6.57	1.14	20.52	17.95
Large (More than 200 employees)									
TFP (in logs)	3.55	0.55	0.16	3.67	0.54	0.15	3.69	0.53	0.14
TFP (Annual Growth Rate, in percentage)	2.34	14.73	6.29	1.45	8.94	6.15	1.16	11.04	9.54
Labor Productivity (in logs)	10.98	0.61	0.06	11.32	0.63	0.06	11.50	0.64	0.06
Labor Productivity (Annual Growth Rate, in percentage)	6.58	20.66	3.14	4.57	15.49	3.39	2.33	15.40	6.60

Notes: Firms for which it is possible to compute TFP at least during two years. S.D.= standard deviation and C.V.= coefficient of variation=(S.D./mean).

Table 2: Firm entry and exit rates and transition matrix of firms' productivity through the business cycle

		Total Factor Productivity						Weighted Total Factor Productivity					
		Quintile t+1						Quintile t+1					
	Quintile t	1	2	3	4	5	Exit	1	2	3	4	5	Exit
Average 1991-1995 (recession)	1	0.454	0.214	0.076	0.044	0.044	0.167	0.654	0.118	0.009	0.000	0.000	0.220
	2	0.200	0.301	0.199	0.115	0.069	0.117	0.137	0.593	0.156	0.000	0.003	0.112
	3	0.067	0.243	0.303	0.207	0.063	0.116	0.005	0.124	0.592	0.151	0.005	0.122
	4	0.044	0.065	0.232	0.353	0.196	0.109	0.000	0.005	0.118	0.639	0.123	0.115
	5	0.027	0.065	0.080	0.165	0.497	0.165	0.000	0.000	0.008	0.077	0.800	0.115
	Entry	0.184	0.118	0.115	0.102	0.158		0.195	0.166	0.123	0.123	0.076	
Average 1996-2000 (expansion)	1	0.501	0.235	0.092	0.039	0.037	0.096	0.784	0.096	0.003	0.000	0.000	0.117
	2	0.196	0.367	0.201	0.093	0.040	0.102	0.134	0.641	0.143	0.002	0.000	0.081
	3	0.076	0.219	0.364	0.191	0.062	0.088	0.003	0.167	0.587	0.129	0.003	0.110
	4	0.037	0.085	0.180	0.420	0.197	0.080	0.002	0.008	0.187	0.628	0.093	0.082
	5	0.030	0.025	0.082	0.174	0.589	0.099	0.000	0.002	0.011	0.148	0.762	0.078
	Entry	0.222	0.172	0.171	0.166	0.178		0.168	0.182	0.154	0.175	0.226	
Average 2001-2005 (expansion)	1	0.537	0.190	0.091	0.031	0.025	0.126	0.773	0.090	0.003	0.000	0.000	0.134
	2	0.206	0.366	0.203	0.069	0.045	0.112	0.122	0.690	0.111	0.001	0.000	0.076
	3	0.085	0.213	0.350	0.210	0.058	0.085	0.007	0.146	0.635	0.104	0.000	0.108
	4	0.041	0.084	0.215	0.383	0.196	0.081	0.001	0.003	0.144	0.701	0.062	0.090
	5	0.016	0.044	0.052	0.194	0.589	0.106	0.000	0.000	0.000	0.069	0.829	0.102
	Entry	0.100	0.117	0.103	0.113	0.110		0.097	0.092	0.116	0.120	0.117	

Notes: (i) Total Factor Productivity is defined in equation (1). Weighted Total Factor Productivity is Total Factor Productivity defined in equation (1) weighted by the firm's market share. (ii) Each transition matrix is the average of the transition matrix of each year weighted by the quantity of firms in each year. (iii) The fraction of exiting firms is with respect to the number of firms in t -1 and the fraction of entering firms is with respect to the number of firms in period t. (iv) The firms we consider to compute the transition matrix are the following: (a) those firms belonging to the balanced panel; (b) those firms exiting the market because of permanent shutdown or non reporting (firms that do not collaborate); and (c) those firms that have entered in the market during the 1990s. We do not consider firms that exit from our sample because in some year does not report some of the variables needed to compute productivity. We follow this approach because we want to evaluate the effect of exiting by death and no reporting. When we consider all the firms we observe an equal proportion of exits from each quintile indicating the non response in some of the variables is not related to productivity.

Table 3: Firm's TFP conditional β-convergence tests through the business cycle; equation (3)

	1991-2005		1991-1995 (Rec.)		1996-2000 (Expans.)		2001-2005 (Expans.)	
	Model 1	**Model 2**	**Model 1**	**Model 2**	**Model 1**	**Model 2**	**Model 1**	**Model 2**
TFP_0 (in logs)	-0.060***	-0.060***	-0.143***	-0.170***	-0.104***	-0.116***	-0.083***	-0.092***
Medium Size Firms	-0.001	-0.001	0.005	0.004	0.000	-0.001	-0.002	-0.001
Large (more than 200 employees)	-0.001	-0.001	0.003	0.002	0.003	0.002	0.002	0.002
Age (in logs)	-0.005	-0.005	-0.007	-0.007	0.002	0.002	0.001	0.001
Age Squared (Square of logs)	0.001*	0.001*	0.002	0.001	0.000	0.000	0.000	0.000
Incorporated Company	0.007***	0.007***	0.006	0.005	0.008***	0.008***	0.007**	0.006**
Foreign Capital	0.002	0.002	0.011**	0.012***	0.009**	0.009**	0.000	0.000
Human Capital	0.045**	0.045**	0.095**	0.103**	0.014	0.014	0.036*	0.037*
Process innovation	-0.001	-0.001	0.002	0.002	-0.002	-0.002	0.001	0.001
Merger	0.003	0.003	0.006	0.006	0.004	0.004	0.000	0.000
Scission	-0.002	-0.002	0.000	0.000	0.001	0.001	-0.006*	-0.006
Entry	-	-	-	-	0.004	0.004	-0.001	-0.001
TFP_0 (in logs) X TFP_0 above the mean	-	0.000	-	0.005***	-	0.002	-	0.001
Constant	0.243***	0.243***	0.576***	0.672***	0.415***	0.458***	0.327***	0.362***
Observations	389	389	459	459	645	645	838	838
R^2	0.623	0.623	0.548	0.561	0.316	0.319	0.184	0.185

Notes: (i) Heteroskedasticity robust standard errors. (ii) All the regressors are evaluated at the initial year (0) of each sub period. (iii) All regressions include industry dummies. (iv) Rec.= recession and Expans.=expansion. (v) Significance levels: *= 10%; **= 5%; ***= 1%.

Table 4: Firm's TFP β-convergence tests through the business cycle controlling for sample selection: System of equations (3)-(4)

	1991-2005		1991-1995 (Recession)		1996-2000 (Expansion)		2001-2005 (Expansion)	
	Model 1	**Model 2**	**Model 1**	**Model 2**	**Model 1**	**Model 2**	**Model 1**	**Model 2**
Growth Equation (Equation (3))								
TFP_0 (in logs)	-0.061***	-0.060***	-0.144***	-0.170***	-0.104***	-0.115***	-0.086***	-0.095***
Medium-sized Firms	-0.001	-0.001	0.004	0.004	0.000	-0.001	-0.001	-0.001
Large (more than 200 employees)	-0.002	-0.002	0.002	0.002	0.002	0.002	0.006	0.006
Age (in logs)	-0.006*	-0.006*	-0.009	-0.008	0.001	0.001	0.001	0.001
Age Squared (Square of logs)	0.001**	0.001**	0.002	0.002	0.000	0.000	0.000	0.000
Incorporated Company	0.008***	0.008***	0.006	0.005	0.010***	0.010**	0.004	0.004
Foreign Capital	0.002	0.002	0.011***	0.012***	0.012***	0.011**	-0.003	-0.004
Human Capital	0.039**	0.039**	0.091**	0.100**	0.017	0.016	0.033*	0.033*
Process innovation	-0.001	-0.001	0.002	0.002	-0.003	-0.003	0.002	0.002
Merger	0.003	0.003	0.007*	0.007**	0.002	0.002	-0.001	-0.001
Scission	-0.003*	-0.003*	0.003	0.003	0.002	0.002	-0.002	-0.001
Entry	-	-	-	-	0.007	0.007	-0.016***	-0.015***
TFP (in logs) X TFP above the mean	-	0.000	-	0.005***	-	0.002	-	0.001
Selection Equation (Equation (4))								
TFP_0 (in logs)	0.328	0.329	0.1	0.096	0.154	0.147	0.257	0.233
Medium-sized Firms	-0.265	-0.266	-0.056	-0.054	-0.487**	-0.484**	0.068	0.061
Large (more than 200 employees)	-0.324	-0.325	-0.337	-0.334	-0.284	-0.277	0.308*	0.289*
Age (in logs)	0.231	0.231	0.850***	0.849***	0.11	0.119	-0.262	-0.25
Age Squared (Square of logs)	-0.042	-0.042	-0.155***	-0.154***	0.003	0.002	0.042	0.041
Incorporated Company	-0.274**	-0.274**	-0.175	-0.174	-0.610***	-0.599***	-0.061	-0.066
Foreign Capital	-0.316	-0.316	-0.269	-0.268	-0.676***	-0.674***	-0.367***	-0.365***
Human Capital	-0.304	-0.304	0.29	0.28	-1.085	-1.049	-0.112	-0.102
Process innovation	0.083	0.083	0.159	0.16	0.289**	0.290**	0.107	0.108
Merger	0.102	0.102	0.142	0.142	0.217	0.218	-0.039	-0.04
Scission	-0.138	-0.138	-0.29	-0.288	0.111	0.111	0.036	0.034
Entry	-	-	-	-	-0.759***	-0.755***	-0.912***	-0.914***
Exporter (dummy)	0.237*	0.236*	0.082	0.084	0.114	0.112	-0.111	-0.109
Capital (in logs)	0.146***	0.146***	0.108**	0.106**	0.168***	0.165***	-0.031	-0.026
Debt (in logs)	0.001	0.001	0.019*	0.018*	0.008	0.008	-0.010*	-0.010*
Statistics								
Number of Observations	626	626	626	626	765	765	1114	1114
Number of Censored Observations	242	242	172	172	128	128	278	278
chi2 [p-value]	554.52 [0.000]	557.19 [0.000]	318.71 [0.000]	363.15 [0.000]	149.62 [0.000]	151.82 [0.000]	147.74 [0.000]	163.43 [0.000]
Wald test of Ind. Eqns. (rho=0), p-value	0.027	0.026	0.135	0.146	0.361	0.525	0.000	0.000

Notes: (i) Heteroskedasticity robust standard errors. (ii) All the regressors are evaluated at the initial year (0) of each sub period. (iii) All regressions include a constant and industry dummies. (iv) Significance levels: *= 10%; **= 5%; ***= 1%.

Table 5: σ-Convergence tests in firm's productivity through the business cycle

TFP Measures	1991-2005	1991-1995 (Recession)	1996-2000 (Expansion)	2001-2005 (Expansion)
Manufacturing Sector				
$\hat{\sigma}_0^2 / \hat{\sigma}_T^2$	1.06	1.06	1.02	0.95 [(a)]
T_2 of equation (5)	1.18	3.57 **	0.50	3.94 **
T_3 of equation (6)	1.02	1.72 **	0.67	-2.39 ***
α_D (Granger and Newbold test)[(b)]	-0.21	-0.28 *	-0.14	0.36 *
Within industries TFP [(c)]				
$\hat{\sigma}_0^2 / \hat{\sigma}_T^2$	1.52	1.67	0.94 [(a)]	0.77 [(a)]
T_2 of equation (5)	18.22 ***	70.00 ***	1.08	20.12 ***
T_3 of equation (6)	5.23 ***	10.32 ***	-1.01	-4.18 ***
α_D (Granger and Newbold test) [(b)]	-0.25 ***	-0.42 ***	0.07	0.28 **
TFP Index [(d)]				
$\hat{\sigma}_0^2 / \hat{\sigma}_T^2$	1.31	1.73	1.04	0.73 [(a)]
T_2 of equation (5)	6.86 ***	80.16 ***	0.40	27.90 ***
T_3 of equation (6)	2.97 ***	11.11 ***	0.62	-4.78 ***
α_D (Granger and Newbold test)[(b)]	-0.16 ***	-0.45 ***	-0.04	0.34 ***

Notes: (a) When $\hat{\sigma}_0^2 / \hat{\sigma}_T^2 < 1$ we test the non σ-convergence hypothesis, $H_0 : \sigma_0^2 = \sigma_T^2$, against the alternative hypothesis of σ-divergence, $H_1 : \sigma_0^2 < \sigma_T^2$.
However, when $\hat{\sigma}_0^2 / \hat{\sigma}_T^2 > 1$ we test H_0 against the alternative hypothesis of σ-convergence, $H_1 : \sigma_0^2 > \sigma_T^2$.

(b) The sign of the regression coefficient α_D depends on the sign of $\sigma_T^2 - \sigma_0^2$, see section 3 and Granger and Newbold (1986), chapter 7.

(c) If firm *i* belongs to industry *j* then $\tilde{p}_{it} = p_{it} - \frac{1}{N_{jt}} \sum_{i \in j} p_{ijt}$.

(d) TFP Index is the productivity index ω defined in equation (2). Significance levels: *= 10%; **=5%; ***= 1%

Table 6: Panel data unit root tests applied to firms's total factor productivity, p_{it}

Unit root test	Regression equations	H$_0$	H$_1$	Deterministic Components	Test statistics	p-values
Levin, Lin, Chu (2002)	$\Delta p_{it} = \rho p_{i,t-1} + \theta_{1i}\Delta p_{i,t-1} + \alpha_{mi} d_{mt} + \varepsilon_{it}$ $m = 1,2$	$\rho = 0$	$\rho < 0$	$d_{1t} = \{1\}$ (a)	-38.33	0.000
				$d_{2t} = \{1,t\}$ (b)	-37.16	0.000
Im, Pesaran, Shin (2003)	$\Delta p_{it} = \rho_i p_{i,t-1} + \theta_{1i}\Delta p_{i,t-1} + \alpha_{mi} d_{mt} + \varepsilon_{it}$ $m = 1,2$	$\rho_i = 0 \quad \forall i$	$\rho_i < 0$ for $i = 1,2,\ldots,N_1$	$d_{1t} = \{1\}$ (a)	-8.93	0.000
			$\rho_i = 0$ for $i = N_1+1,\ldots,N$	$d_{2t} = \{1,t\}$ (b)	-8.41	0.000
Maddala and Wu (1999)	$\Delta p_{it} = \rho_i p_{i,t-1} + \theta_{1i}\Delta p_{i,t-1} + \alpha_{mi} d_{mt} + \varepsilon_{it}$ $m = 1,2$	$\rho_i = 0 \quad \forall i$	$\rho_i < 0$ for $i = 1,2,\ldots,N_1$	$d_{1t} = \{1\}$ (a)	8061.89	0.000
			$\rho_i = 0$ for $i = N_1+1,\ldots,N$	$d_{2t} = \{1,t\}$ (b)	6746.21	0.000
Pesaran CADF (2007)	$\Delta p_{it} = \alpha_i + \rho_i^* p_{i,t-1} + d_0 \bar{p}_{t-1} + \phi_1 \Delta \bar{p}_{t-1}$ $+ \theta_1 \Delta p_{i,t-1} + \alpha_{mi} d_{mt} + \varepsilon_{it},$ $m = 1,2$	$\rho_i^* = 0 \quad \forall i$	$\rho_i^* < 0$ for $i = 1,2,\ldots,N_1$	$d_{1t} = \{1\}$ (a)	-9.34	0.000
			$\rho_i^* = 0$ for $i = N_1+1,\ldots,N$	$d_{2t} = \{1,t\}$ (b)	-5.08	0.000

Notes: (a) Constant term included in the regression equations; (b) Constant and trend included in the regression equations.

Table 7: Firm's productivity β-Convergence: Differential effects in recessions and expansions of "technological" followers and leaders' productivity growth rate

	[1]	[1']	[2]	[2']	[3]	[3']	[4]	[4']
$P_{i,\ t-1}$ (in logs)	-0.353***	-0.255***	-	-	-0.379***	-0.272***	-	-
$P_{i,\ t-1}$ (in logs) x d9195	-	-	-0.368***	-0.272***	-	-	-0.396***	-0.290***
$P_{i,\ t-1}$ (in logs) x d9600	-	-	-0.347***	-0.254***	-	-	-0.375***	-0.272***
$P_{i,\ t-1}$ (in logs) x d0105	-	-	-0.343***	-0.249***	-	-	-0.371***	-0.267***
$P_{i,\ t-1}$ growth rate	-	-0.226***	-	-0.225***	-	-0.225***	-	-0.224***
Recession	-0.112***	-0.089**	-0.091***	-0.079**	-	-	-	-
Follower in t-1 x Recession	0.042*	0.024	0.032	0.018	-	-	-	-
Q1 in t-1 x Recession	-	-	-	-	-0.081**	-0.066*	-0.077**	-0.069*
Q2 in t-1 x Recession	-	-	-	-	-0.076***	-0.067**	-0.067**	-0.065**
Q3 in t-1 x Recession	-	-	-	-	-0.088***	-0.078***	-0.076***	-0.074***
Q4 in t-1 x Recession	-	-	-	-	-0.060**	-0.061**	-0.046*	-0.055*
Q5 in t-1 x Recession	-	-	-	-	-0.098***	-0.079**	-0.077**	-0.069*
Expansion	0.067***	0.043*	0.066***	0.045*	-	-	-	-
Follower in t-1 X Expansion	-0.093***	-0.061***	-0.087***	-0.059***	-	-	-	-
Q1 in t-1 x Expansion	-	-	-	-	-0.051*	-0.034	-0.044	-0.03
Q2 in t-1 x Expansion	-	-	-	-	-0.046**	-0.027	-0.040*	-0.023
Q3 in t-1 x Expansion	-	-	-	-	-0.025	-0.024	-0.02	-0.02
Q4 in t-1 x Expansion	-	-	-	-	0.004	0.006	0.007	0.009
Q5 in t-1 x Expansion	-	-	-	-	0.083***	0.053*	0.083***	0.056*
Incorporated company in t-1 (dummy)	0.015***	0.012***	0.015***	0.012***	0.014***	0.012***	0.014***	0.012***
Foreign Capital in t-1 (fraction)	0.018***	0.014***	0.018***	0.014***	0.017***	0.013***	0.017***	0.013***
Human Capital in t-1 (fraction)	0.144***	0.106***	0.144***	0.107***	0.143***	0.106***	0.144***	0.106***
Process Innovation in t-1 (dummy)	0.007***	0.006**	0.007***	0.006***	0.006***	0.006**	0.006***	0.006**
Age (in logs)	-0.018*	-0.018	-0.018**	-0.019	-0.018**	-0.019	-0.019**	-0.020*
Age Squared (square of logs)	0.004**	0.003*	0.004**	0.004*	0.004**	0.004*	0.004**	0.004*
Medium Size Firms	0.006	0.002	0.006	0.002	0.005	0.002	0.006	0.002
Large Firms	0.007*	0.004	0.007**	0.004	0.007*	0.004	0.007*	0.004
Observations	15837	13154	15837	13154	15837	13154	15837	13154
R^2	0.184	0.207	0.186	0.208	0.186	0.208	0.187	0.209
p-value of the F-test for autocorrelation	0.000	0.685	0.000	0.817	0.000	0.831	0.000	0.925

Notes: (i) Dependent variable is $\Delta p_{it} = \log P_{it} - \log P_{it-1}$. (ii) In this Table the explanatory variables Recessions (Expansions) measure the percentage of firms in the industry reporting that their markets are in recession (Expansion). (iii) Followers are those firms in quintiles 1,2,3, and 4 of the productivity distribution; see equation (7). (iv) d9195, d9600, and d0105 are dummy variables that take value one in the period 1991-1995, 1996-2000, and 2001-2005, respectively. (v) All regressions include a constant, entry rates, mergers, scissions and year and industry dummies. (vi) Columns [i′] for i=1, 2, 3 and 4 are the same regression models as [i] but controlling for autocorrelation by including a lag of the dependent variable as additional regressor. (vii) Heteroskedasticity robust standard errors. (viii) Significance levels: *= 10%; **= 5%; ***= 1%

Table 8a: Firm's productivity β-Convergence: Differential effects in recessions and expansions of "technological" followers and leaders' productivity growth rate controlling for sample selection; growth equation (9)

	[1]	[1']	[2]	[2']	[3']	[3']	[4]	[4']
$P_{i,\ t-1}$ (in logs)	-0.347***	-0.251***	-	-	-0.374***	-0.267***	-	
$P_{i,\ t-1}$ (in logs) x d9195	-	-	-0.363***	-0.268***	-	-	-0.391***	-0.286***
$P_{i,\ t-1}$ (in logs) x d9600	-	-	-0.341***	-0.249***	-	-	-0.370***	-0.267***
$P_{i,\ t-1}$ (in logs) x d0105	-	-	-0.338***	-0.245***	-	-	-0.366***	-0.263***
$P_{i,\ t-1}$ growth rate	-	-0.226***	-	-0.225***	-	-0.226***	-	-0.225***
Recession	-0.105***	-0.086**	-0.083***	-0.075**	-	-	-	-
Followers in t-1 x Recession	0.039*	0.024	0.029	0.017	-	-	-	-
Q1 in t-1 x Recession	-	-	-	-	-0.081**	-0.064*	-0.076**	-0.066*
Q2 in t-1 x Recession	-	-	-	-	-0.074***	-0.066**	-0.064**	-0.063**
Q3 in t-1 x Recession	-	-	-	-	-0.078***	-0.073***	-0.065**	-0.067**
Q4 in t-1 x Recession	-	-	-	-	-0.058**	-0.060**	-0.043	-0.053*
Q5 in t-1 x Recession	-	-	-	-	-0.091***	-0.077**	-0.069**	-0.065*
Expansion	0.065**	0.041	0.064**	0.043*	-	-	-	-
Followers in t-1 x Expansion	-0.086***	-0.057***	-0.080***	-0.055***	-	-	-	-
Q1 in t-1 x Expansion	-	-	-	-	-0.045	-0.033	-0.038	-0.029
Q2 in t-1 x Expansion	-	-	-	-	-0.040*	-0.024	-0.034	-0.019
Q3 in t-1 x Expansion	-	-	-	-	-0.022	-0.022	-0.018	-0.019
Q4 in t-1 x Expansion	-	-	-	-	0.007	0.007	0.01	0.010
Q5 in t-1 x Expansion	-	-	-	-	0.080***	0.051*	0.081***	0.053*
Incorporated company in t-1 (dummy)	0.015***	0.013***	0.015***	0.013***	0.014***	0.012***	0.014***	0.012***
Foreign Capital in t-1 (fraction)	0.018***	0.013***	0.018***	0.013***	0.016***	0.012***	0.016***	0.012***
Human Capital in t-1 (fraction)	0.147***	0.111***	0.148***	0.112***	0.147***	0.111***	0.148***	0.112***
Process Innovation in t-1 (dummy)	0.007***	0.007***	0.007***	0.007***	0.006***	0.006***	0.007***	0.007***
Age (in logs)	-0.016*	-0.017	-0.017*	-0.018	-0.017*	-0.018	-0.018**	-0.019*
Age Squared (square of logs)	0.003**	0.003*	0.003**	0.003*	0.003**	0.003*	0.004**	0.003*
Medium Size Firms	0.006*	0.002	0.006*	0.002	0.005	0.002	0.006*	0.002
Large Firms	0.008**	0.005	0.008**	0.005	0.008**	0.005	0.008**	0.005
Exporter t-1 (dummy)	-		-		-		-	-
Debt t-1 (logs)	-		-		-		-	-
Capital t-1 (logs)	-		-		-		-	-

Table 8b: Firm's productivity β-Convergence: Differential effects in recessions and expansions of "technological" followers and leaders' productivity growth rate controlling for sample selection; selection equation (10)

	[1]	[1']	[2]	[2']	[3']	[3']	[4]	[4']
$P_{i,\ t-1}$ (in logs)	0.621***	0.864***	-	-	0.566**	0.724**	-	-
$P_{i,\ t-1}$ (in logs) x d9195	-	-	0.447**	0.736***	-	-	0.381	0.585*
$P_{i,\ t-1}$ (in logs) x d9600	-	-	0.809***	0.979***	-	-	0.731**	0.813**
$P_{i,\ t-1}$ (in logs) x d0105	-	-	0.682***	0.807***	-	-	0.613**	0.658**
$P_{i,\ t-1}$ growth rate	-	0.172	-	0.182	-	0.173	-	0.182
Recession	-1.551***	-1.529**	-1.242**	-1.252*	-	-	-	-
Followers in t-1 x Recession	0.617**	0.999**	0.448	0.880**	-	-	-	-
Q1 in t-1 x Recession	-	-	-	-	-0.899	-0.422	-0.846	-0.338
Q2 in t-1 x Recession	-	-	-	-	-0.554	-0.313	-0.423	-0.174
Q3 in t-1 x Recession	-	-	-	-	-1.012*	-0.548	-0.854	-0.382
Q4 in t-1 x Recession	-	-	-	-	-1.244**	-0.881	-1.048*	-0.685
Q5 in t-1 Recession	-	-	-	-	-1.484***	-1.381**	-1.183**	-1.118
Expansion	0.009	-0.146	-0.068	-0.196	-	-	-	-
Followers in t-1 x Expansion	0.496	0.738**	0.630**	0.813**	-	-	-	-
Q1 in t-1 x Expansion	-	-	-	-	0.338	0.349	0.439	0.389
Q2 in t-1 x Expansion	-	-	-	-	0.353	0.574	0.396	0.591
Q3 in t-1 x Expansion	-	-	-	-	0.92	1.391**	0.947	1.396**
Q4 in t-1 x Expansion	-	-	-	-	0.738	0.798	0.724	0.784
Q5 in t-1 x Expansion	-	-	-	-	0.082	0.041	0.013	0.001
Incorporated company in t-1 (dummy)	-0.099	-0.174**	-0.099	-0.173**	-0.101	-0.176**	-0.101	-0.175**
Foreign Capital in t-1 (fraction)	-0.263**	-0.341**	-0.263**	-0.339**	-0.264**	-0.354***	-0.265**	-0.351***
Human Capital in t-1 (fraction)	-0.344	-0.373	-0.336	-0.351	-0.362	-0.409	-0.352	-0.387
Process Innovation in t-1 (dummy)	0.277***	0.313***	0.276***	0.313***	0.274***	0.313***	0.274***	0.313***
Age (in logs)	0.439***	0.655***	0.425***	0.650***	0.439***	0.658***	0.424***	0.651***
Age Squared (square of logs)	-0.084***	-0.109***	-0.082***	-0.108***	-0.085***	-0.110***	-0.082***	-0.109***
Medium Size Firms	-0.161	-0.225*	-0.155	-0.226*	-0.169*	-0.234**	-0.163*	-0.235**
Large Firms	0.077	0.079	0.079	0.073	0.073	0.078	0.075	0.072
Exporter t-1 (dummy)	0.109*	0.122	0.109*	0.121	0.102	0.113	0.103	0.113
Debt t-1 (logs)	0.006	0.001	0.006	0.001	0.006	0.001	0.005	0.001
Capital t-1 (logs)	0.093***	0.116***	0.091***	0.117***	0.093***	0.116***	0.092***	0.116***
Statistics								
Number of Observations	15779	13116	15779	13116	15779	13116	15779	13116
Number of Censored Observations	230	175	230	175	230	175	230	175
chi2 [p-value]	882.63 [0.000]	843.0 [0.000]	907.42 [0.000]	876.3 [0.000]	1525.36 [0.000]	1319.1[0.000]	1532.20 [0.000]	1334.0 [0.000]
Wald test of Ind. Eqns. (rho=0), p-value	0.782		0.998		0.733		0.999	

Notes: (i) Dependent variable is $\Delta p_{it} = \log P_{it} - \log P_{it-1}$. (ii) In this Table the explanatory variables Recessions (Expansions) measure the percentage of firms in the industry reporting that their markets are in recession (Expansion). (iii) Followers are those firms in quintiles 1,2,3, and 4 of the productivity distribution; see equation (7). (iv) d9195, d9600, and d0105 are dummy variables that take value one in the period 1991-1995, 1996-2000, and 2001-2005, respectively. (v) All regressions include a constant, entry rates, mergers, scissions and year and industry dummies. (vi) Columns [i´] for i=1, 2, 3 and 4 are the same regression models as [i] but controlling for autocorrelation by including a lag of the dependent variable as additional regressor. (vii) Heteroskedasticity robust standard errors. (viii) Significance levels: *= 10%; **= 5%; ***= 1%
.

Table 9: The speed of β-Convergence: Trend versus cycle, see Equation (12)

	[1]	[2]	[1']	[2']
Percentage of firms in recession	-0.237*	-0.340*	-0.236**	-0.288**
yr1993	-0.007	-0.008	-	-
yr1994	-0.032	-0.058	-	-
yr1995	-0.004	-0.030	-	-
yr1996	-0.002	-0.045	-	-
yr1997	0.044	0.013	-	-
yr1998	0.008	-0.037	-	-
yr1999	-0.008	-0.042	-	-
yr2000	0.025	0.006	-	-
yr2001	0.063	0.057	-	-
yr2002	0.013	0.003	-	-
yr2003	-0.015	-0.024	-	-
yr2004	0.036	0.012	-	-
yr2005	0.151	0.123	-	-
yr1992 to yr1995	-	-	-0.061	-0.066
yr1996 to yr2001	-	-	-0.036	-0.052
Non Metallic Products	-	0.066	-	0.068
Chemical Products	-	0.033	-	0.035
Metallic Products	-	-0.019	-	-0.019
Agricultural and Industrial Machinery	-	0.008	-	0.009
Office Machinery, Data Processing Machinery, etc.	-	-0.100	-	-0.106
Electrical Material and Electrical Accessories	-	0.081	-	0.085
Vehicles and Motors	-	0.107	-	0.105
Other Transport Material	-	0.145	-	0.149
Meat and Meat Products	-	0.164**	-	0.166***
Food and Tobacco	-	0.068	-	0.068
Beverages	-	0.302***	-	0.295***
Textiles and Apparels	-	0.159**	-	0.151**
Leather products and shoes	-	0.046	-	0.034
Wood and Furniture	-	0.010	-	0.012
Paper, Paper Products and Printing Products	-	0.103*	-	0.103*
Plastic Products and Rubber	-	0.088	-	0.090
Constant	-0.272***	-0.301**	-0.223***	-0.276***
Number of observations	211	211	211	211
Number of industries	17	17	17	17
R-squared	0.08	0.21	0.05	0.19

Notes: (i) The dependent variable is the time varying β-convergence coefficient (b_{jt}) by industry obtained form equation (11). (ii) Heteroskedasticity robust standard errors. (iii) Significance levels: *=10%; **= 5%; ***=1%.

Table 10: The effects of human capital and innovation on productivity growth: Differential effects in recessions and expansions of "technological" followers and leaders

	[1]	[2]	[3]	[5]	[4]	[6]
$P_{i,\ t-1}$ (in logs) x d9195	-0.270***	-0.271***	-0.270***	-0.290***	-0.289***	-0.289***
$P_{i,\ t-1}$ (in logs) x d9600	-0.253***	-0.253***	-0.253***	-0.273***	-0.271***	-0.272***
$P_{i,\ t-1}$ (in logs) x d0105	-0.249***	-0.248***	-0.248***	-0.268***	-0.266***	-0.267***
$P_{i,\ t-1}$ growth rate	-0.224***	-0.224***	-0.224***	-0.224***	-0.224***	-0.223***
Recession	-0.087**	-0.083**	-0.090**	-	-	-
Followers in t-1 x Recession	0.014	0.028	0.023	-	-	-
Q1 in t-1 x Recession	-	-	-	-0.079**	-0.064*	-0.074*
Q2 in t-1 x Recession	-	-	-	-0.078**	-0.061*	-0.073**
Q3 in t-1 x Recession	-	-	-	-0.086***	-0.068**	-0.081***
Q4 in t-1 x Recession	-	-	-	-0.069**	-0.050*	-0.063**
Q5 in t-1 x Recession	-	-	-	-0.076**	-0.073*	-0.080**
Expansion	0.033	0.038	0.027	-	-	-
Followers in t-1 x Expansion	-0.042**	-0.052***	-0.037*	-	-	-
Q1 in t-1 x Expansion	-	-	-	-0.028	-0.029	-0.028
Q2 in t-1 x Expansion	-	-	-	-0.019	-0.022	-0.019
Q3 in t-1 x Expansion	-	-	-	-0.015	-0.02	-0.015
Q4 in t-1 x Expansion	-	-	-	0.015	0.009	0.015
Q5 in t-1 x Expansion	-	-	-	0.044	0.048	0.038
Human Capital in t-1 (fraction)	0.163***	0.105***	0.160***	0.168***	0.105***	0.164***
Human Capital in t-1 (fraction) x Followers	-0.161**	-	-0.159**	-0.172**	-	-0.169**
Human Capital in t-1 (fraction) x Followers x Recession	0.492*	-	0.503*	0.511*	-	0.519**
Process Innovation in t-1 (dummy)	0.006***	0.014**	0.013*	0.006**	0.014**	0.013*
Process Innovation in t-1 (dummy) x Followers	-	-0.006	-0.005	-	-0.007	-0.005
Process Innovation in t-1 (dummy) x Followers x Recession	-	-0.018	-0.021	-	-0.016	-0.019
Incorporated company in t-1 (dummy)	0.012***	0.012***	0.012***	0.012***	0.012***	0.012***
Foreign Capital in t-1 (fraction)	0.014***	0.014***	0.014***	0.013***	0.013***	0.013***
Age (in logs)	-0.019	-0.019	-0.019	-0.020*	-0.020*	-0.020*
Age Squared (square of logs)	0.004*	0.004*	0.004*	0.004*	0.004*	0.004*
Medium Size Firms	0.002	0.002	0.002	0.002	0.002	0.002
Large Firms	0.004	0.004	0.004	0.004	0.004	0.004
Observations	13154	13154	13154	13154	13154	13154
R-squared	0.209	0.208	0.209	0.21	0.209	0.21

Notes: (i) Heteroskedasticity robust standard errors. (ii) All regressions include a constant, entry, exit, merger, scission and industry and year dummies. (iii) Dependent variable is Δp_{it}=logP_{it}-Log $P_{i,t-1}$ (iv) Significance levels: *= 10%; **= 5%; ***= 1%.

Table 11: Number of productivity (TFP) observations corresponding to the number of years firms are in the sample: 1991-2005

Numbers of years firms are in the sample	Number of observations corresponding to the number of years firms are in the sample	Proportion in percentage
0	3043	13.28
1	920	4.01
2	638	2.78
3	717	3.13
4	752	3.28
5	845	3.69
6	1218	5.31
7	1183	5.16
8	952	4.15
9	1692	7.38
10	1070	4.67
11	759	3.31
12	1596	6.96
13	1222	5.33
14	2310	10.08
15	4005	17.47
Total	22922	100.00

Table 12: Number of available and missing firm's observations by industry and size

Industry	Small	Medium	Large	Total
Ferric and Non Ferric Metals	166 (26)	105 (16)	287 (106)	558 (148)
Non Metallic Products	662 (116)	269 (53)	464 (82)	1395 (251)
Chemical Products	446 (42)	217 (55)	647 (183)	1310 (280)
Metallic Products	1088 (241)	309 (62)	323 (89)	1720 (392)
Agricultural and Industrial Machinery	604 (140)	221 (67)	391 (109)	1216 (316)
Office Machinery, Data Processing Machinery, etc.	98 (17)	71 (5)	100 (35)	269 (57)
Electrical Material and Electrical Accessories	333 (282)	276 (78)	481 (104)	1090 (464)
Vehicles and Motors	186 (36)	179 (39)	498 (148)	863 (223)
Other Transport Material	68 (48)	72 (36)	156 (44)	296 (128)
Meat and Meat Products	312 (43)	67 (17)	165 (38)	544 (98)
Food and Tobacco	1164 (118)	273 (82)	512 (148)	1949 (348)
Beverages	124 (27)	67 (11)	187 (61)	378 (99)
Textiles and Apparels	1268 (140)	370 (58)	464 (97)	2102 (295)
Leather products and shoes	554 (73)	75 (10)	17 (14))	646 (97)
Wood and Furniture	1206 (134)	159 (44)	219 (32)	1584 (210)
Paper, Paper Products and Printing Products	961 (119)	250 (55)	406 (126)	1617 (300)
Plastic Products and Rubber	492 (67)	223 (49)	266 (70)	981 (186)
Other Manufactured Products	304 (41)	55 (14)	82 (16)	441 (71)
Total	10036 (1710)	3258 (751)	5665 (1502)	18959 (3963)

Notes: Firms with TFP observations for more than 2 consecutive years. Firms with a maximum of 0 and 1 years in the sample are considered missing observations and are reported in parenthesis.

Table 13: Number of available observations by industry and year

Industry	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Total
Ferric and Non Ferric Metals	31 (22)	36 (14)	34 (12)	35 (10)	34 (10)	35 (9)	44 (7)	41 (10)	47 (4)	46 (5)	38 (9)	40 (6)	34 (6)	33 (6)	30 (18)	**558 (148)**
Non Metallic Products	96 (48)	108 (30)	101 (16)	97 (13)	86 (15)	94 (7)	101 (10)	96 (7)	95 (11)	106 (9)	98 (7)	91 (5)	79 (4)	77 (5)	70 (64)	**1395 (251)**
Chemical Products	109 (41)	118 (31)	115 (16)	106 (18)	96 (14)	86 (14)	93 (13)	87 (13)	81 (12)	86 (14)	82 (11)	76 (10)	62 (9)	61 (9)	52 (55)	**1310 (280)**
Metallic Products	99 (44)	114 (27)	110 (20)	107 (26)	104 (17)	95 (21)	128 (23)	122 (14)	128 (12)	138 (25)	135 (22)	128 (16)	108 (11)	108 (11)	96 (103)	**1720 (392)**
Agricultural and Industrial Machinery	84 (68)	100 (31)	92 (18)	87 (22)	84 (17)	81 (17)	94 (15)	90 (12)	87 (12)	89 (16)	76 (16)	73 (13)	63 (8)	63 (8)	53 (43)	**1216 (316)**
Office Machinery, Data Processing Machinery, etc.	21 (18)	24 (8)	24 (3)	19 (6)	19 (1)	14 (5)	24 (0)	21 (0)	19 (1)	20 (0)	18 (2)	14 (0)	11 (0)	11 (0)	10 (13)	**269 (57)**
Electrical Material and Electrical Accessories	85 (73)	94 (49)	85 (44)	77 (41)	74 (34)	70 (32)	88 (32)	86 (22)	77 (24)	74 (20)	72 (15)	64 (15)	50 (9)	49 (10)	45 (44)	**1090 (464)**
Vehicles and Motors	51 (19)	55 (14)	54 (8)	46 (20)	45 (18)	53 (16)	72 (14)	66 (13)	73 (9)	72 (17)	66 (13)	65 (10)	50 (8)	49 (10)	46 (34)	**863 (223)**
Other Transport Material	18 (28)	24 (14)	23 (8)	19 (10)	18 (7)	18 (5)	24 (7)	25 (4)	22 (4)	21 (3)	19 (4)	20 (3)	16 (3)	16 (3)	13 (25)	**296 (128)**
Meat and Meat Products	27 (24)	35 (14)	35 (14)	36 (12)	38 (5)	38 (6)	44 (4)	42 (2)	35 (2)	43 (3)	39 (0)	37 (0)	33 (0)	33 (0)	29 (12)	**544 (98)**
Food and Tobacco	149 (55)	163 (38)	164 (25)	146 (27)	139 (19)	138 (19)	142 (15)	135 (15)	129 (9)	132 (19)	114 (17)	117 (10)	97 (9)	97 (9)	87 (62)	**1949 (348)**
Beverages	27 (20)	36 (14)	35 (9)	32 (7)	29 (6)	27 (6)	27 (2)	26 (2)	21 (3)	23 (5)	21 (3)	21 (2)	17 (1)	18 (0)	18 (19)	**378 (99)**
Textiles and Apparels	161 (64)	180 (35)	165 (28)	156 (19)	143 (16)	144 (13)	159 (18)	151 (10)	156 (10)	152 (10)	136 (9)	131 (6)	95 (5)	92 (5)	81 (47)	**2102 (295)**
Leather products and shoes	38 (22)	50 (8)	53 (7)	53 (2)	42 (5)	51 (7)	61 (3)	54 (5)	47 (4)	45 (4)	41 (3)	40 (1)	25 (1)	24 (2)	22 (23)	**646 (97)**
Wood and Furniture	92 (46)	110 (18)	107 (14)	104 (9)	87 (8)	91 (12)	120 (11)	112 (4)	116 (7)	126 (16)	119 (6)	120 (1)	96 (5)	97 (4)	87 (49)	**1584 (210)**
Paper, Paper Products and Printing Products	98 (53)	118 (28)	109 (22)	102 (17)	97 (12)	100 (19)	119 (18)	117 (6)	115 (9)	126 (24)	126 (11)	115 (13)	93 (11)	91 (12)	91 (45)	**1617 (300)**
Plastic Products and Rubber	61 (32)	65 (16)	65 (9)	62 (12)	61 (9)	65 (11)	76 (12)	70 (10)	75 (8)	78 (11)	73 (9)	71 (6)	54 (7)	54 (7)	51 (27)	**981 (186)**
Other Manufactured Products	36 (13)	36 (9)	37 (4)	34 (7)	33 (3)	30 (4)	37 (5)	32 (5)	34 (0)	29 (1)	27 (1)	26 (1)	18 (2)	18 (2)	14 (14)	**441 (71)**
Total	**1283 (690)**	**1466 (398)**	**1408 (277)**	**1318 (278)**	**1229 (216)**	**1230 (223)**	**1453 (209)**	**1373 (154)**	**1357 (141)**	**1406 (202)**	**1300 (158)**	**1249 (118)**	**1001 (99)**	**991 (103)**	**895 (697)**	**18959 (3963)**

Notes: Firms with TFP observations for more than 2 consecutive years. In parenthesis is the total number of missing observations (firms with a maximum of 0 and 1 years in the sample)

Table 14: Bias correction of the initial capital stock

	Coefficient
Dependent Variable: log(KNRBE)	
K (in logs)	0.930 ***
Entry	-0.489 ***
Scission	-0.281 ***
Age (in logs)	-0.181 ***
Age Squared (square of logs)	0.041 ***
Constant	0.925 ***
R^2	0.91
Number of observations	2553
Dependent Variable: KNRBE	
$\hat{m}_i = exp\left(\hat{\log} KNRBE\right)$	1.216 ***
R^2	0.645
Number of Observations	2553

$K_{i0}^* = \hat{\alpha}\hat{m}_i$, where $\hat{m}_i = \exp\left(\hat{\log} KNRBE_{i0}\right)$ and $\hat{\alpha}$ is bias correction obtained from the coefficient of the regression of KNRBE on $\hat{m}_i$ (without a constant).

Notes: These regressions are performed only with the data on the first year of each firm of the sample.

Table 15: Descriptive statistics of the old (KNRBE) and the new measure (K) of the capital stock during the period 1991-1999

	N. Obs	Mean	SD	Min	Max
		Before the bias correction in K0			
Individual Sample (a)					
Level					
K	14274	12500000	66300000	569	2150000000
KNRBE	13637	7472299	31700000	23	1030000000
Growth Rate					
K	11461	0.062	0.255	-0.12	6.35
KNRBE	11039	0.088	0.318	-2.15	7.28
Common Sample(b)					
Level					
K	13254	9791900	44300000	624	1690000000
KNRBE	13254	7274858	30400000	23	1030000000
Growth Rate					
K	10638	0.058	0.244	-0.12	6.35
KNRBE	10638	0.090	0.319	-2.05	7.28
		After the bias correction in K0			
Individual Sample(a)					
Level					
K	14085	8867073	44300000	679	1520000000
KNRBE	13637	7472299	31700000	23	1030000000
Growth Rate					
K	11333	0.070	0.249	-0.12	6.19
KNRBE	11039	0.088	0.318	-2.15	7.28
Common Sample(b)					
Level					
K	13118	7343061	31400000	771	1390000000
KNRBE	13118	7255718	30500000	23	1030000000
Growth Rate					
K	10544	0.066	0.238	-0.12	6.19
KNRBE	10544	0.089	0.315	-2.05	7.28

Notes: (a) Individual sample refers to the descriptive statistics obtained with all the observations for which there is information. (b) Common sample refers to the descriptive statistics obtained using the same observations for both variables.

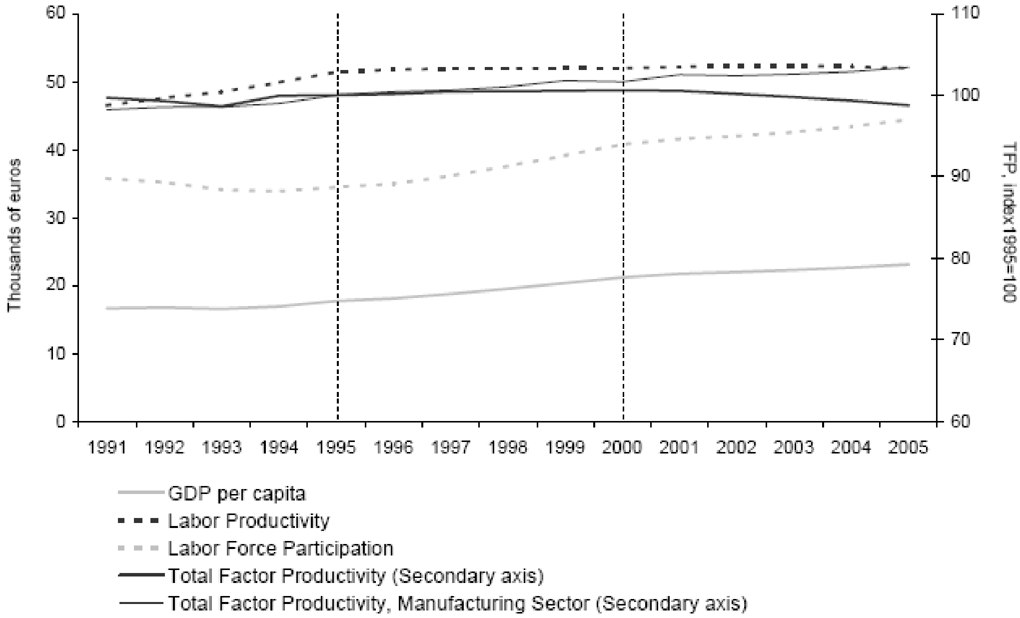
Table 16: Correlation between K and KNRBE

	Levels (K)	Growth rate ($\Delta \log K$)
Before the correction in K_0	0.85	0.79
After the correction in K_0	0.87	0.80

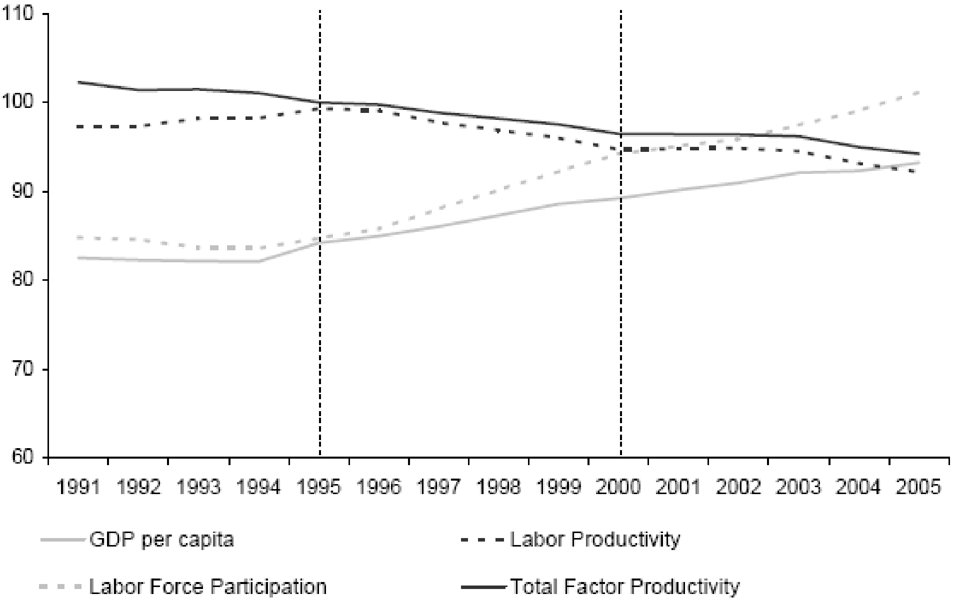
Appendix F: Figures

Figure 1: Evolution of TFP and GDP per capita, Labor Productivity, and Labor Force Participation

(a) Spain



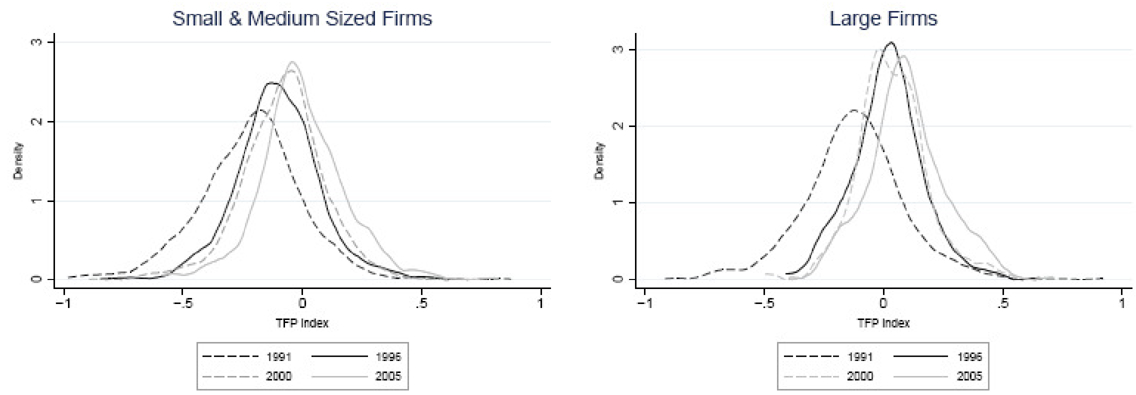
(b) Spain vs. European Union (EU-27)



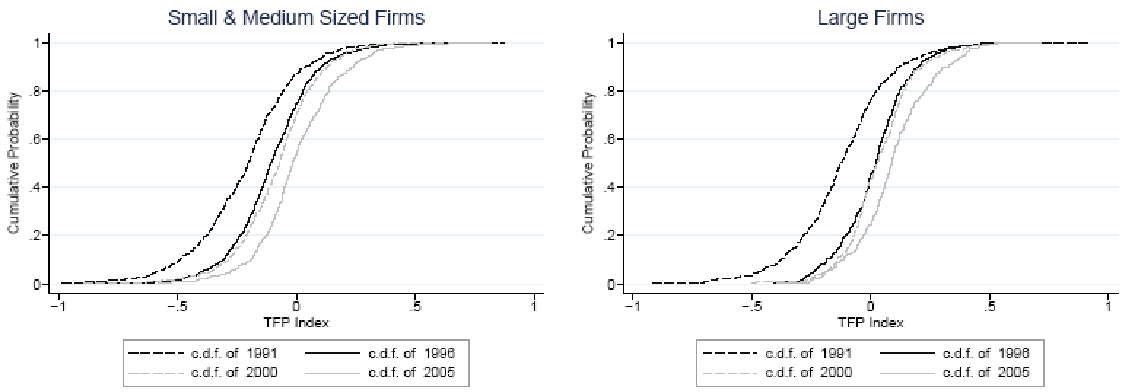
Source: Authors' elaboration with data from Bank of Spain and ESEE.
Notes: Labor force participation is obtained as the ratio of GDP per capita and labor productivity. Total Factor Productivity, Manufacturing Sector is the average of TFP defined in equation (1).

Figure 2: Evolution of the Total Factor Productivity distribution; by Size and Year

Panel (a): Density functions

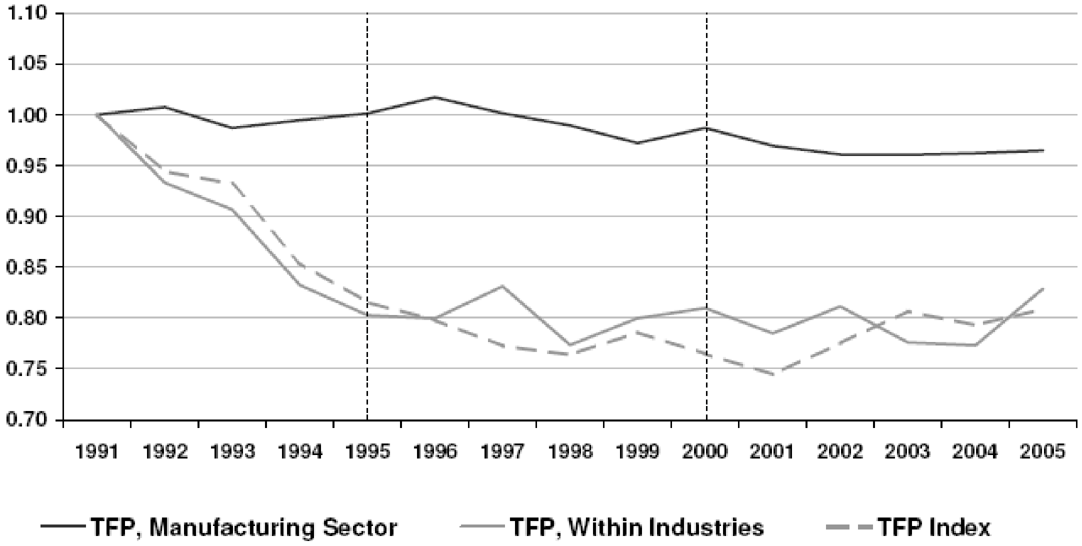


Panel (b): Cumulative distribution functions



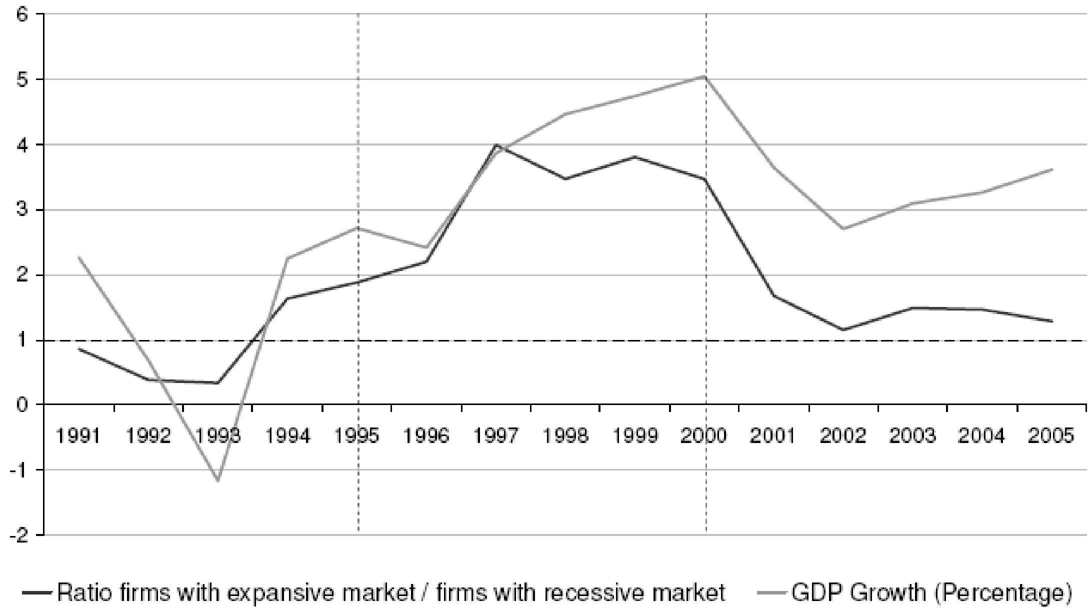
Notes: Total Factor Productivity in this Figure is measured by the TFP index, ω, defined in equation (2) therefore differences across industries are removed.

Figure 3: Evolution of σ-Convergence of firm's productivity (TFP); 1991=1



Notes: "TFP, Manufacturing sector" is the productivity measure defined in equation (1); "TFP, within industries" is the productivity defined in equation (1) minus the industry mean of each year of this variable and "TFP Index" is the productivity index ω defined in equation (2).

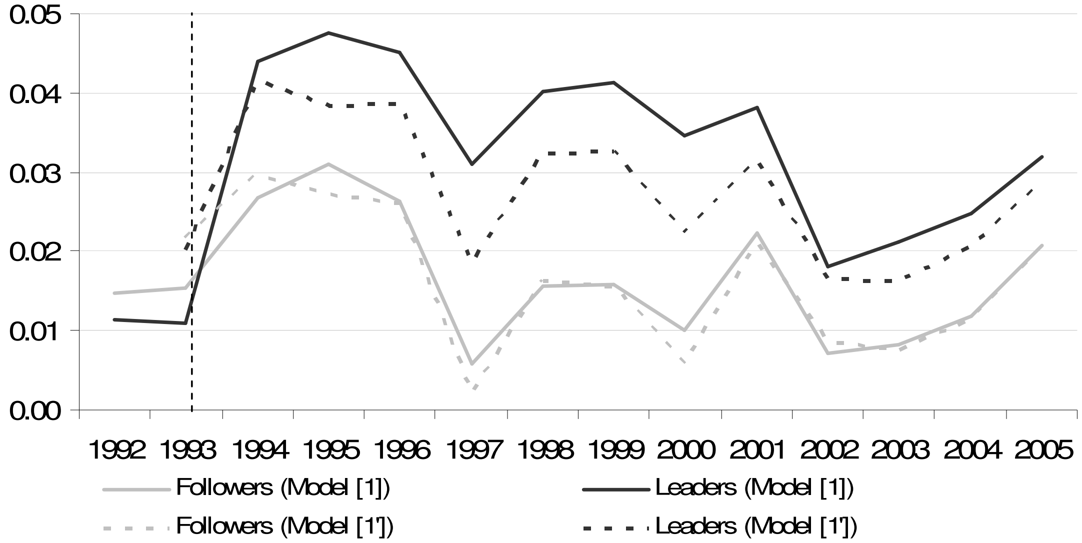
Figure 4: Evolution of the ratio of the number of firms producing in markets in expansion relative to recessions and evolution of the GDP growth rate



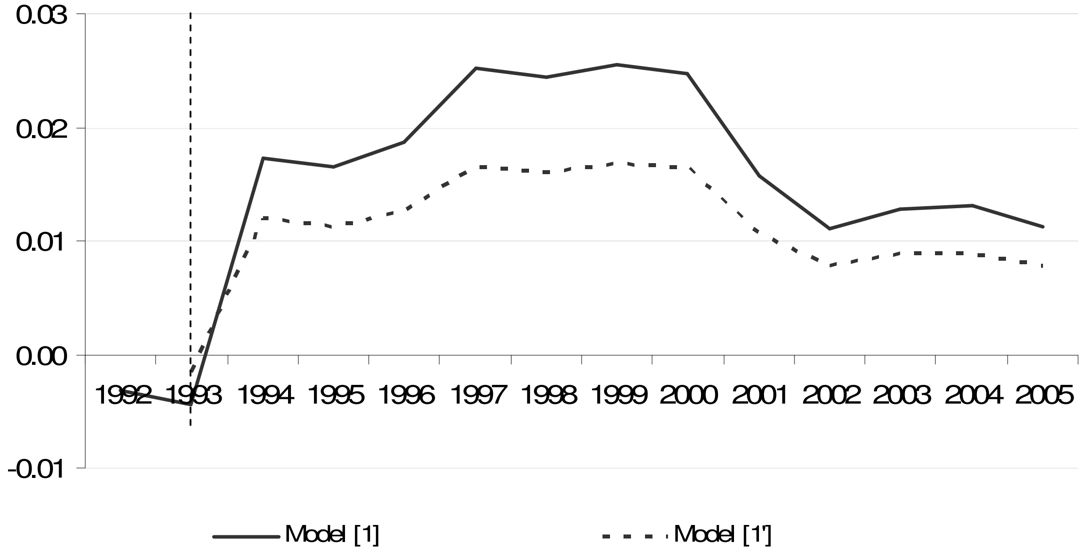
Source: Ratio of the number of firms producing in a market in expansion over the number firms in recession, E_t / R_t : ESEE surveys; Growth of GDP: National Institute of Statistics of Spain, INE.

Figure 5: Evolution of firm's productivity growth rates

(a) Evolution of productivity growth rates of "technological" leaders and followers

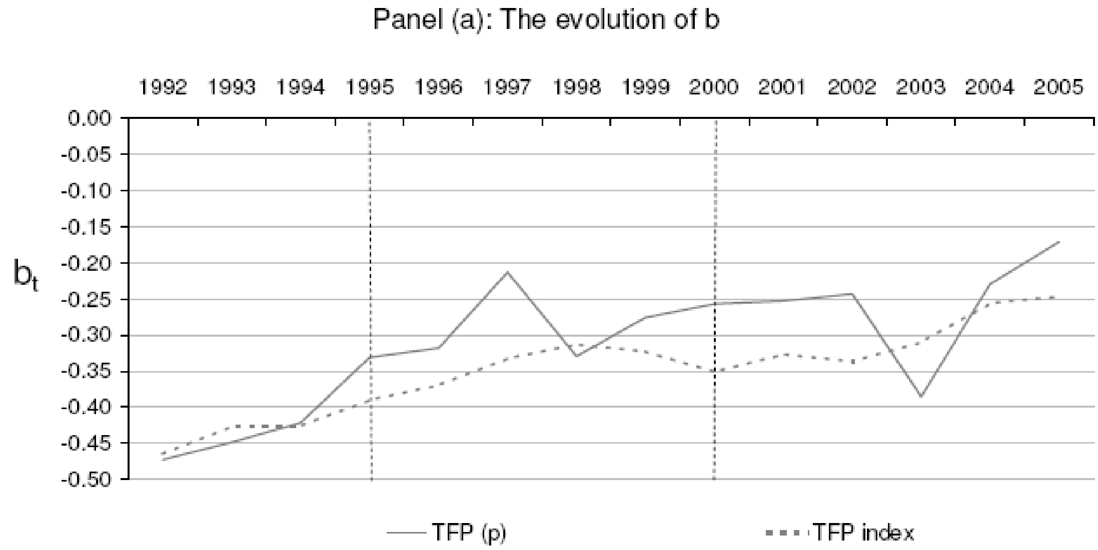


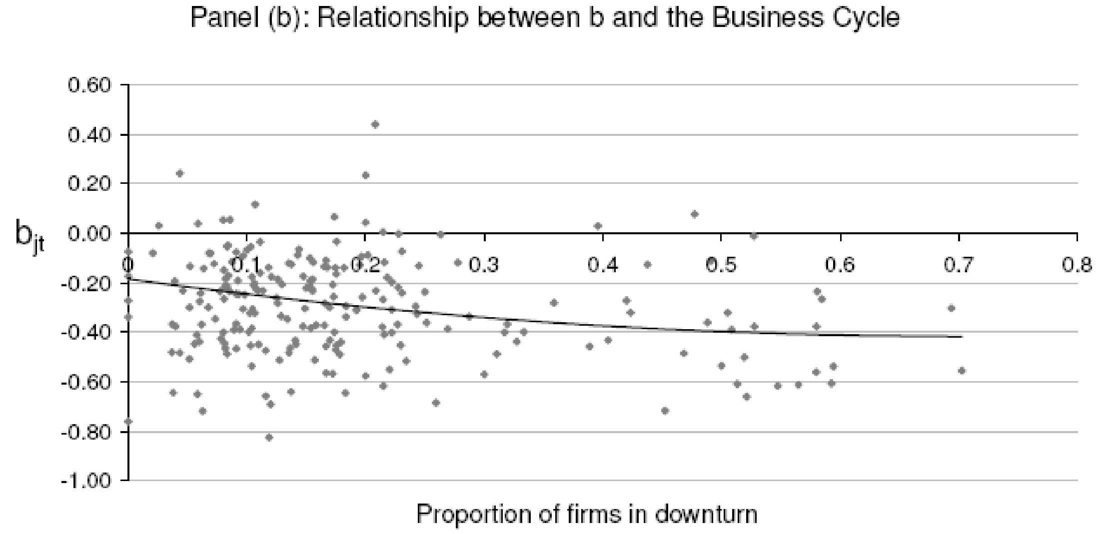
(b) Evolution of the differences of productivity growth rates of "technological" leaders and followers



Notes: Growth rates obtained from models [1] and [1´] in Table 7. The continued line and the dashed line correspond to the estimation without and with the lag of the growth rate of productivity, models [1] and [1´] respectively.

Figure 6: The evolution of the speed of β-Convergence of firm's productivity through the business cycle; parameter b of equation (10)





Notes:

Panel (a): Coefficient b_t in the following regressions: $\Delta z_{it} = c_t + b_t z_{i,t-1} + \alpha_t x_{it} + v_{it}$, t =1992, 1993, …, 2005 and z = {*p*, TFP index}. Note that this is the same equation than the β-convergence equation but considering consecutive periods, therefore, in x_{it} we include the same controls used in the β-convergence test. The closer the value of b_t to zero the lower the speed of convergence.

Panel (b): Coefficient b_{jt} in the following regressions: $\Delta p_{ijt} = c_{jt} + b_{jt} z_{ij,t-1} + \alpha_{jt} x_{ijt} + u_{ijt}$, t =1992, 1993, …, 2005; j=1,2, …,18. Note that this is the same equation than the β-convergence equation but considering consecutive periods and estimated for each industry j, therefore, in x_{ijt} we include the same controls used in the β-convergence test (except industry dummies). The closer the value of b_{ijt} to zero the lower the speed of convergence.

Figure 7: Depreciation rate of the capital stock

Source: Authors' elaboration using data from Martin-Marcos and Suarez (1997).