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Entry, exit and productivity growth: Spanish manufacturing during the eighties

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Abstract. This paper analyses the role played by both competitive pressure (increasing imports) and the restructuring of industries through entry and exit in productivity growth of Spanish manufacturing during the eighties, the key period of its accession to the EEC economy. A GMM panel estimation of the determinants of corrected Solow residual for 75 manufacturing during 1979–1990, shows that these forces accounted for 80% of productivity growth, playing an important role the displacement of inefficient firms by competitive entry.

JEL Classification: D24, C33

Key words: Productivity, Solow residual, entry, exit

1 Introduction

This paper studies the role played by competitive pressure (increasing imports) and the restructuring of industries through entry and exit in productivity growth of Spanish manufacturing during the eighties. During this period, Spanish manufacturing suffered from intense competitive pressure (before, during and after the 1986 EEC integration) derived from a continuous increase of the penetration of imports while markets opened at an extraordinary pace, and underwent an extensive restructuring related to a high rate of firm turnover (with high entry and exit). Manufacturing productivity increased at high rates, and the impact of the opening and restructuring of the markets is a relevant question that has not been previously investigated.[1]

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[1] Our subject is closely related to the question of the effects of increased competitive pressure on productivity growth. See Caves and Barton (1990) and Vives (1993) for surveys on the subject. Siotis

Table 1. International comparison of productivity growth and entry and exit rates in manufacturing

Country	TFP[1] (%)	Entry rate[2] (%)	Exit rate[2] (%)
Belgium	3.4	5.8	6.3
Canada	0.4	4.0	4.8
France	1.9	5.0	3.9
Germany	1.3	3.8	4.6
Japan	2.5	N.A.	N.A.
Norway	1.0	8.2	8.7
Portugal	N.A.	12.3	9.5
UK	3.0	6.5	5.1
USA	1.3	7.7	7.0
Spain	2.7	7.3	9.7

Notes:
[1] Annual cumulative rates for the period 1978–1990. TFP is computed here with the manufacturing aggregates in each country, using value-added as output, and the number of workers as labour input. Calculations based on "The OECD Stan Data Base for Industrial Analysis 1974–1993" and "Flows and Stocks of Fixed Capital" (OECD).
[2] Averages of annual industry rates for different time periods: Belgium (1980–1984), Canada (1971–1979), France (1980–1982), Germany (1983–1985), Norway (1980–1985), Portugal (1983–1986), UK (1974–1979), USA (1963–1982), and Spain (1979–1990). *Source:* Cable and Schwalbach (1991) for all the countries but France and Spain, Armington (1986) for France, and our sample for Spain.

The basic facts are as follows. Firstly, manufacturing productivity increase was aligned with the highest rates experienced by manufacturing in industrial countries. Table 1 documents this fact with comparable TFP calculations performed with aggregate data. Secondly, markets of manufactured goods opened at an extraordinary pace. The share of imports in domestic demand (import penetration) almost doubled, and the fraction of production that domestic firms sold abroad (export intensity) also increased sharply (see Table A1 in the Data appendix). Thirdly, manufacturing industries experienced high gross rates of entry and exit, with a high displacement component (replacement of low productivity firms by more efficient firms).

Table 1 shows, despite the difficulties in finding fully comparable figures, Spanish entry and exit rates were relatively high and, at the same time, unbalanced (the total number of firms was reduced by about 25% from the beginning of the period

(2003) has recently examined the symmetric question of the effects of the competitive pressure during 1983–1996 on the firm's margins.

Table 2. Correlations between manufacturing entry and exit rates across subperiods[1]

	No correction for fixed industry effects		
	Exit rate		
	1979–1982	1983–1986	1987–1990
Entry rate			
1979–1982	0.73	0.58	0.57
1983–1986	0.53	0.83	0.76
1987–1990	0.37	0.66	0.92
	Correction for fixed industry effects		
	Exit rate		
	1979–1982	1983–1986	1987–1990
Entry rate			
1979–1982	0.83	0.15	−0.79
1983–1986	0.10	0.66	−0.46
1987–1990	−0.76	−0.44	0.89

Notes:
[1]We do not report yearly correlations for the sake of brevity, but very similar results are obtained.

until the moment at which entry and exit redress). Table 2 provides strong evidence of displacement. While entry and exit are found everywhere to be positively correlated across industries (see, for example, Geroski 1995, or Caves 1998), entry and exit controlling for fixed effects (the industry averages over time of entry and exit) are expected to be negatively correlated under the usual hypothesis of shared expectations (what makes entry higher than average must also make exit lower, and conversely).[2] Entry and exit in Spanish manufacturing during the eighties turn out to be, on the contrary, positively related, even controlling for fixed effects. In addition, almost 3/4 of intraindustry correlation coefficients give a positive relationship.

To assess the sources of productivity growth, we measure productivity increases at the industry level for 75 of the 81 industries in which manufacturing is disaggregated by the yearly Spanish industrial survey (Encuesta Industrial) of the Instituto Nacional de Estadística (INE). We use the Solow residual controlled for the effects of market power, non-constant returns, and varying utilisation, and we decompose it according to the role played by a number of explanatory variables in a GMM panel data regression.[3] Previously, we show how an industry Solow residual consists of two parts: a weighted average of firm-level productivity growth, and the effect derived from output reallocation among firms, and we discuss how entry and exit rates are likely to impact the second term of this decomposition and the way to identify displacement effects.

There has been an increasing interest in the impact of turnover on productivity growth (for an overview see Tybout 1996, and also Caves 1998). Theoretical works

[2] This is, for example, what Dunne et al. (1988) found for US manufacturing.

[3] In this sense, our paper is close to Geroski (1989), Nickell et al. (1992) or Harrison (1994).

on industry dynamics provide models in which firms' entry and exit decisions are interrelated with their differentials in productivity, and hence they matter for productivity growth.[4] An increasing number of empirical papers have examined in different contexts the role played by turnover in productivity growth.[5] However, these studies share the use of firm-level data. In this paper, we argue that identification of the basic effects is possible using regression methods and information on the industries' entry and exit rates. In addition, the relationship to be expected between entry and exit is largely undetermined.[6] We have already pointed out the evidence in favour of strong displacement effects in our sample. Our exercise sets a simple but useful framework to distinguish and identify these effects.

Results give a clear picture of the evolution of Spanish manufacturing efficiency during the eighties. Productivity growth was strongly linked to competitive pressure and the restructuring of industries through two channels: incumbent firms sharply increased efficiency to survive, and the replacement of less efficient firms by new entrants also greatly increased efficiency. The role of displacement is confirmed: exits were closely linked to the emergence of new, more efficient competitors in the marketplace. The exhaustion of this extraordinary context by the middle of the 90's may partially explain the productivity growth slowdown that seems to have followed this period.

The rest of the paper is organised as follows. Section 2 describes the framework for productivity growth measurement. Section 3 discusses the firm-level determinants while Sect. 4 analyses the relationship of industry-level productivity growth with the entry and exit rates. Section 5 explains the econometric specification and results and Sect. 6 presents some concluding remarks. A Data appendix documents the data and variables used, and three technical appendices explain details on the measurement of industry composition effects on productivity, the identification of entry and exit effects and possible relationships between entry and exit.

2 Framework of measurement

Our goal is the measurement of productivity growth effects stemming from two sources: (i) the increases in the efficiency of the firms that form the industry, given their shares; and (ii) the changes in the allocation of the industry output among firms with different efficiency levels. We proceed as follows. Firstly, we compute the conventional Solow residual θ_{jt}^{S} for every industry j and year t. Secondly, we regress these residuals on the necessary corrections to obtain the "true" increases of productivity as a remaining factor and then we split them into two parts explained by the "firm efficiency" and "composition" factors, respectively. Let us explain the details.

[4] See Jovanovic (1982) and Hopenhayn (1992). See also Pakes (1999) for a recent summary of the framework developed in a series of works to study industry dynamics.

[5] See, among others, Baldwin and Gorecki (1991), Baily et al. (1992), Griliches and Regev (1995), Olley and Pakes (1995), Baldwin (1995), Liu and Tybout (1996) and Aw et al. (2001). Turnover has been found in general to have a positive contribution to productivity growth, but only quantitatively important in certain circumstances (deregulation, low sunk costs...).

[6] See, for example, Geroski (1995) and Caves (1998).

An industry Solow residual can be computed using the log-differences of output (y), labour (l), capital (k) and materials (m), provided that the unobservable elasticities ε_L, ε_K and ε_M are approximated. Traditional productivity analysis replaced them by income shares under the assumption that technology is linearly homogeneous and firms are in a long-run competitive equilibrium. This can still be used, provided that one simultaneously employs the corrections for the presence of market power and non-constant returns to scale developed by Hall (1988, 1990). Let μ be the ratio price/marginal cost, ω_L and ω_M the income shares of labour and materials, and γ the returns to scale parameter. We will then regress the Solow residuals on the term $-(\mu-1)[\omega_L(k-l)+\omega_M(k-m)]$ in order to correct for market power, and will include a term in the form $(\gamma-1)k$ to estimate the effect of non-constant returns to scale. In addition, we will use a measure v_{jt} of the degree of capacity utilisation to deal with the effects of a varying utilization of quasifixed inputs.[7] All this will leave as a residual the remaining "true" productivity growth θ_{jt} unexplained.

The determinants of θ_{jt} can be analysed by specifying these values as a mix of systematic and stochastic components. In particular, industry "true" residuals can be split up into two additive terms reflecting the two sources of productivity growth.

Assume that the typical industry consists of N firms that show different degrees of efficiency, specified by idiosyncratic terms that multiply a common basic technology represented by the production function $f(.)$ that, for the moment, we will assume that is linearly homogeneous.[8] Write $q_i=[1/(1-a_i)]f(x_i)$ for the firm i, where q_i represents output, x_i is a vector of K inputs, and a_i gives the (approximate) proportional difference in efficiency of firm i with respect to the benchmark firm ($a_i=0$), or its (exact) proportional advantage on unit or marginal costs. Aggregating across firms, we obtain the production relationship $q=[1/(1-\sum\limits_i a_i s_i)]f(x)$, where q and x stand for the aggregated output and vector of inputs, respectively, $s_i=q_i/q$ represents the market share of firm i, and $1/(1-\sum_i a_i s_i)$ is an aggregate efficiency index (see Appendix A). Given this, industry productivity growth measured by the industry Solow residual can be written as

$$\theta \equiv \frac{dq}{q}-\sum_k \varepsilon_k \frac{dx_k}{x_k}=\sum_i s_i da_i+\sum_i a_i ds_i \tag{1}$$

The first term of the last equality in (1) amounts to the weighted sum of firms' changes in efficiency or individual Solow residuals ($da_i=\frac{dq_i}{q_i}-\sum_k \varepsilon_k \frac{dx_{ki}}{x_{ki}}$); the second term gives the composition or turnover effect.

Let us now use the specification $\theta_{jt}=\theta_j+\theta_t+x_{jt}\beta+\xi_{jt}$, where θ_j represents time-invariant, individual (industry) specific components of the productivity increases, θ_t stands for industry-invariant, time productivity effects (stemming from macroeconomic factors) and ξ_{jt} are residual productivity shocks that we will assume are uncorrelated across industries and time. In turn, x_{jt} is a vector of productivity growth determinants including two very different types of variables: the micro

[7] See, however, Delgado et al. (1999) for a more structural approach to the problem.

[8] The effects of the absence of linear homogeneity here are likely to be of second order (Appendix A).

or firm-level determinants of the efficiency increments, and the variables included to pick up the industry composition change effects. Our complete specification can now be written as

$$\theta_{jt}^{s} = \theta_j + \theta_t - (\mu_{jt} - 1)WR_{jt} + (\gamma_j - 1)k_{jt} + \alpha v_{jt} + x_{jt}\beta + u_{jt} \quad (2)$$

where $WR_{jt} = \omega_{Ljt}(k_{jt} - l_{jt}) + \omega_{Mjt}(k_{jt} - m_{jt})$ and u_{jt} is a zero mean uncorrelated disturbance that includes ξ_{jt} as a component.

Equation (2) must be seen as an accounting relationship, fully consistent with different firms' behaviour across industries and varying patterns of entry and exit. Productivity growth (and profitability) as well as the determinants we are going to detail in the following sections (R&D activities, imports, entry and exit) must, of course, be taken as jointly determined in long-run equilibrium for each industry, with values that depend on the specific context where firms operate. However, the estimation of (2) as a separate relationship is useful and legitimate due to two features. Firstly, the specification is flexible enough to accommodate individual differences; for instance, it allows for time- persistent heterogeneity in productivity growth across industries, which our estimation method allows for to be freely correlated with the explanatory variables. Secondly, explanatory variables can be assumed to be predetermined and hence the estimation procedure is robust to endogeneity.

3 Firm-level productivity growth determinants

Let us specify the factors that are likely to generate productivity increases at the firm level: innovative activities, demand and competitive pressure exerted by imports.[9]

Productivity growth is related to knowledge capital increases (Griliches 1995). We use two indicators adding up total technological effort: the R&D expenditures/value-added and technological-payments/value-added ratios (RDVA and TPVA). But some productivity-enhancing innovations are embodied in new machinery (OECD 1996). As a (rough) indicator, we use the variation in the ratio stock of capital/number of workers (II).[10] High demand states are likely to encourage innovations, reorganisations of the work processes, and greater effort. We assume that these effects depend on the pace of growth of firms' demand measured by a weighted sum of the growth rates of buyers' demand (DEM).[11]

The most important environmental factor is competitive pressure derived from foreign competition and, for this purpose, we include the ratio imports/domestic-demand (IMP). A low degree of competition is likely to sustain productive inefficiencies in different ways:[12] X-inefficiencies, lower information flows hampering efficiency; enhanced market power favouring socially inefficient decisions. Weak

[9] These are the basic firms' productivity growth sources considered in Geroski (1989), Caves and Barton (1990) and Nickell et al. (1992). Harrison (1994) focuses on a trade reform.

[10] In using this variable we follow Caves and Barton (1990). Of course this ratio also enters the productivity growth computations, but with a constrained coefficient.

[11] This demand variable avoids the endogeneity problems presented by the output growth measures.

[12] See Caves and Barton (1990) and Vives (1993).

competition may be the result of a low degree of foreign interaction in markets (tariffs and other restrictions on trade.) Moves toward free trade are then expected to have an effect on profitability (well documented) and on efficiency (less studied).[13]

4 Entry, exit, and productivity growth

Let us establish the relationships between productivity growth and gross entry and exit rates (GENR and GEXR). On the one hand, productivity growth is expected to be positively related to both rates, with a direct effect stemming from productivity changes associated with entry or exit of firms with differing productivity, and an indirect effect derived from sharpened competition, with a lower impact in the case of the exit rate due to its additional market concentration effect. On the other hand, if displacement effects are important, entry and exit rates provide the same information and their effects are expected to melt. Let us briefly detail these two insights in turn.

Entrant firms are supposed to have some productivity advantages, or at least gain them after some market experience, and surviving entrants expand their shares during their first years of life. Exiting firms are supposed to suffer productivity disadvantages, and their shares fade away.[14] Entry and exit are also likely to induce changes in other shares. If all the firms (entrant, continuing and exiting firms) were of an identical and invariable size, changes in shares following entry and exit would be proportional to the entry and exit rates. But firms' sizes differ and they must be considered endogenously determined according to the competition framework that entry and exit contribute to create. Models of imperfect competition, however, invariably relate output advantages to cost advantages and to the toughness of competition. This can be used to obtain the definite impact. Appendix B shows that productivity growth is expected to be positively related to both rates, with a direct productivity effect, and an indirect effect derived from sharpened competition, with a lower impact of exit because of market concentration.

Now, let us discuss the relationship between the rates of entry and exit. It is customary to distinguish at least two different sources of entry and exit (see Geroski 1995). One source is market enlargements or contractions, with origin in demand or cost changes. Market enlargements would allow the entry of new firms, while market contractions would induce the exit of redundant firms.[15] The other source is the competitive process, i.e., the replacement of firms already established in the industry by new entrants, typically because the latter enter the market with superior technologies. Entry of this type is said to have a displacement effect. Appendix C formalises these concepts in the simplified context of a market with two types of firms where, given competition, a fixed cost raises a frontier of possibilities of the number of firms in the market.[16] Competitive entry displaces the less efficient

[13] Caves and Barton (1990) find an efficiency effect of imports and productivity growth effects of lagged imports. Harrison (1994) also finds growth effects of the reform. Tybout (1996) quotes other examples.

[14] Entrant firms can also be less productive than the average but more productive than exiting firms.

[15] One source of market contractions may be the increase of imports of equivalent products.

[16] We also derive, as an example, the frontier when demand is linear and firms compete à la Cournot.

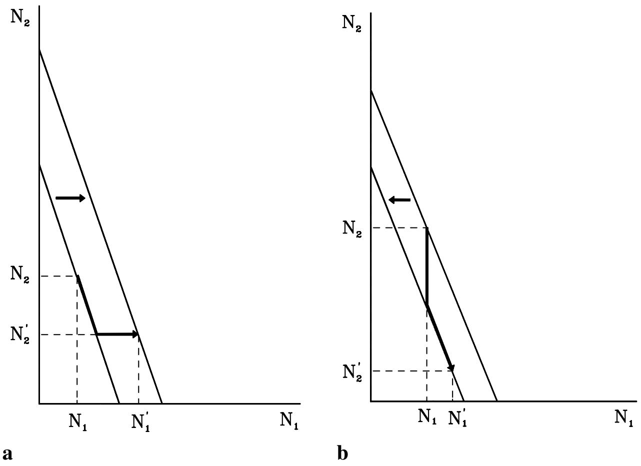

Fig. 1a,b. Entry and exit: displacement and market effects. **a** Competitive entry and market enlargement; **b** Market contraction and competitive entry

firms along the frontier. Market enlargements or contractions are determined by corresponding frontier movements. Panels a and b of Fig. 1 depict the mix of effects for two supposedly observed changes of firm numbers in the industry.

These two types of entry and exit raise the possibility of very different relationships between industry entry and exit rates over time. Call α_t the displacing entry rate at time t, λ the rate of displacement, and d_t the (absolute value) rate of change in the number of firms induced by demand. Then, entry and exit rates will be generated over time according to the expressions $e_t = \alpha_t + 1(d_t \geq 0)d_t$ and $s_t = \lambda\alpha_t + 1(d_t < 0)d_t$, where $1(.)$ stands for the indicator function. If demand effects dominate, entry and exit rates will be negatively correlated. By contrast, if competitive entry dominates, entry and exit rates will be strongly positively correlated over time.

5 Econometric estimation and results

Table 3 summarises the results of estimating Eq. (3) with data on 75 manufacturing industries from 1979 to 1990. The Data appendix offers a detailed description of the variables. Given the presence of individual effects θ_j (individual time-invariant effects in the growth rates) that are likely to be correlated with explanatory variables, we always estimate differencing out these effects by using the first differences' transformation of the equation. We also include a set of time dummies, and we instrument the variable which accounts for market power with cross-section lagged values at $t - 2$ and $t - 3$, in the framework of the general method of moments (see Arellano and Bond 1991). Estimates 1 to 6 present selected alternatives of specification. Columns include the Sargan test of overidentifying restrictions as well as the residual autocorrelation tests $m1$ and $m2$. The validity of instruments is always accepted.

Estimation of (2) is carried out by substituting the expression $PCM/(1 - PCM)$ for $(\mu - 1)$, where PCM stands for the usual price/cost margin, and by forming the compound variable $MWR_{jt} = PCM_{jt}/(1 - PCM_{jt})WR_{jt}$. Its coefficient, very significant and not far from -1 in almost every equation, can be interpreted both as a confirmation of the presence of market power and the reliability of the correction. On the other hand, we group the sectors in which increasing, constant or decreasing returns to scale can be expected and we construct a set of three dummies (IRD, KRD and DRD) that, interacted with the capital growth variable, give estimates of three average values for the scale parameter $(\gamma - 1)$.[17] The coefficients corresponding to the industries with increasing and constant returns to scale are in general not significantly different from zero, and hence the restriction that they are equal to unity may be accepted at the 5% level. However, all the return parameters cannot be constrained to have a value of one (estimate 2). The indicator of the degree of utilisation, when included, is not significant (estimate 3). This probably suggests that the demand indicator is enough to pick up changes induced by fluctuations in utilisation.

Estimation reveals the following findings. Firstly, R&D expenditures have a positive and significant impact with a lag, though it is impossible to find a significant impact of technological payments. This suggests an asymmetric impact on productivity during the period of the innovative activities carried out by the firm, with respect to the acquisition of licenses of available technologies. On the contrary, investment intensity tends to show a positive and significant contemporaneous impact on productivity, which seems to confirm the role of embodied innovations.

Secondly, import penetration attracts a strong and significant positive coefficient when included in the equation with a lag.[18] We interpret this effect as the increase in firms' productivity induced by competitive pressure, as explained in Sect. 3.

Finally, gross entry and exit rates are positive and significant determinants of productivity when included separately (estimates 1 to 3 and 4, respectively). In addition, the coefficient on the exit rates is lower. In any case, the effects tend to decrease and are imprecisely estimated when both rates are simultaneously included (estimate 5). These estimates are fully consistent with the theoretical insights developed in Sect. 4. They point out that turnover is an important determinant of productivity growth and that entry and exit rates are at the origin of the same productivity gains, confirming both the presence and importance of displacement. [19,20]

[17] Sectors' grouping is based on the cost function estimates in Velázquez (1993).

[18] Export intensity was also tried and did not show any additional effect.

[19] A more structural model would include separate entry and exit equations. Under the displacement hypothesis, exit is a function of demand growth and entry, and entry is a function of demand and profitability expectations. A very simple model along these lines give the following

$$GEXR = \underset{(12.5)}{4.60} - \underset{(-3.8)}{0.20}\, DEM + \underset{(15.9)}{0.81}\, GENR + u \; and \; GENR = \underset{(22.8)}{5.80} + \underset{(5.3)}{0.52}\, DEM + v$$

[20] Structural change tests of the imports and entry impact have been performed by allowing a different coefficient in the post-entry subperiod (1987–1990). A change in the impact of imports is clearly rejected, but the test on turnover suggests that its role was somewhat more important before 1986.

Table 3. Productivity growth corrections and determinants. Dependent variable: θ^S_{jt}. Estimation method: Instrumental variables of the first differences.[1] No. of industries: 75. Sample period: 1981–1990

Variables	1		2		3		4		5		6	
	Estimates[2]											
MWR	−0.84	(−4.88)	−0.74	(−3.81)	−0.93	(−5.58)	−0.80	(−4.70)	−1.02	(−5.99)	−0.89	(−6.54)
KID	0.14	(1.15)	–		0.13	(1.10)	0.14	(1.07)	0.08	(0.63)	0.10	(0.87)
KCD	−0.14	(−1.70)	–		−0.13	(−1.51)	−0.01	(−0.12)	−0.06	(−0.73)	−0.12	(−1.57)
KDD	−0.61	(−3.79)	–		−0.59	(−3.58)	−0.61	(−3.72)	−0.59	(−3.63)	−0.61	(−3.84)
K	–		−0.17	(−1.64)	–		–		–		–	
V	–		–		0.02	(0.91)	–		–		–	
RDVA(−1)	0.03	(2.93)	0.03	(2.60)	0.03	(2.45)	0.04	(3.53)	0.04	(2.72)	0.04	(4.04)
TPVA	−0.02	(−1.13)	−0.02	(−1.06)	−0.01	(−0.79)	−0.01	(−0.45)	0.00	(0.33)	−0.01	(−0.71)
II	3.14	(2.13)	0.75	(0.79)	3.21	(2.13)	2.65	(1.76)	3.10	(2.14)	3.10	(2.09)
GENR	0.12	(4.00)	0.13	(4.91)	0.13	(3.76)	–		0.08	(1.46)	0.18	(4.22)
GEXR	–		–		–		0.05	(2.77)	0.03	(0.83)	–	
											−0.09[3]	(−3.18)
DEM	0.07	(1.34)	0.06	(1.11)	0.08	(1.56)	0.09	(1.82)	0.06	(1.24)	0.08	(1.56)
IMP(−1)	0.08	(3.14)	0.09	(3.06)	0.09	(3.50)	0.07	(2.69)	0.08	(2.79)	0.09	(3.38)
SARGAN TEST[5]	$S(18) = 16.5$		$S(18) = 14.6$		$S(18) = 18.9$		$S(18) = 17.8$		$S(18) = 23.2$		$S(18) = 17.81$	
m_1	−3.541		−3.477		−3.626		−3.579		−3.646		−3.570	
m_2	1.404		1.408		1.424		1.397		1.452		1.512	

	Corrections[4]
Conventional Solow residual	0.968
Market power	0.043
Decreasing returns to scale	0.567
Average corrected productivity growth	1.578
	Decomposition[4]
R&D expenditures	13.3
Investment intensity	3.2
Entry	30.7
Import penetration	52.7

Notes:
[1] GMM instruments for the MWR variable (see the text).
[2] All the estimates include time dummies. Robust t-statistics in parentheses.
[3] Coefficient estimate for the variable GENR multiplied by a dummy variable that takes the value 1 when the year belongs to the period 1987–1990 and the value 0 elsewhere.
[4] Estimates based on parameter estimates in (1).
[5] Test of overidentifying restrictions. m_1 and m_2 are statistics of first and second order serial correlation.

It seems natural to define the expression $\bar{\theta} = \frac{1}{JT}\sum_j \sum_t x_{jt}\hat{\beta} = \sum_k \hat{\beta}_k \bar{x}_k$, where $\bar{x}_k$ is the sample mean of the k-th variable and $\hat{\beta}_k$ its estimated coefficient, as an estimate of the systematic component of productivity growth.[21] This estimate can be used to evaluate the role of each determinant. The bottom right part of Table 3 presents the decomposition of productivity growth. This decomposition gives a nice picture of the sources of the productivity increase in the Spanish manufacturing sector during the eighties. There is an extremely important influence of the pressure stemming from imports on productivity growth (50% of the average productivity growth), but another important source is the structural change in industries stemming from entry and exit (30%). Lastly, the contribution of R&D emerges as the remaining important determinant (13%).

Equation (2) can also be used to assess the role of the corrections to the conventionally computed Solow residual and hence to evaluate the true overall productivity growth. The top right part of Table 3 summarises the results of this decomposition. The average of the conventional Solow residual (our dependent variable) is 0.97%. Average corrected productivity growth is evaluated at 1.58% per year. Therefore, the conventional Solow residual is, in this case, a downward biased approximation of the true productivity growth.

6 Conclusion

This paper examines productivity growth in a sample of 75 Spanish manufacturers during the eighties, the period in which Spanish manufacturing was under intense competitive pressure derived from the EEC integration and showed an extensive structural change, reflected mostly in high and unbalanced gross rates of firm entry and exit.

Results show the important role of competitive pressure and structural change through a process of creative destruction with the displacement of inefficient firms. From the point of view of industrial policy, the results firstly confirm the accumulation of productive inefficiencies when competition is weak, particularly in the case of insufficient interaction with a more competitive environment, as was the case for Spanish manufacturing in relation to Europe by the beginning of the eighties. But they also indicate that the easing of market constraints, together with agents' expectations of the irreversibility of this process, may generate a much more market dynamic environment capable of changing market structure and performance in a relatively short time.

[21] It also seems natural to define $\bar{\theta}$ including a constant $\hat{\beta}_0$, whose value cannot be estimated separately from θ_j and θ_t except under the assumption $E(\theta_j) = E(\theta_t) = 0$. In practice we operate as if there were a constant with a value proportional to $\sum_k \hat{\beta}_k \bar{x}_k$.

Data appendix

The sample consists of 75 of the 81 industries in which manufacturing is disaggregated by the yearly Spanish industrial survey (Encuesta Industrial) of the Instituto Nacional de Estadística (INE). There are no entry and exit data for the other six industries. The variables v, RDVA and TPVA are available only for a lower level of disaggregation of manufacturing. Variable sample means are reported in the Data appendix Table.

Productivity growth (θ^S): Computed using a Tornqvist index using the log differences (%) of real gross product, total hours of work, real capital stock and real consumption of materials. Shares are computed as the average shares of labour costs and material expenditures in gross production between years t and $t-1$.

Capital stock (K): Computed recursively starting from an initial estimation based on official engineering estimates of capital-product ratios at the time, and referring its value to 1980 prices.

Price-cost margin (PCM): Calculated as (gross production-labour costs-subsidies-cost of materials) over total sales.

Utilisation indicator (v): Yearly average of an indicator of use of capacity.

R&D intensity (RDVA): Ratio R&D expenditures/value added (‰).

Technological payments intensity (TPVA) : Ratio technological payments/value added (‰).

Investment intensity (II): Ratio real capital stock variation/number of workers.

Gross entry rate (GENR): Plant creation divided by the total number of plants in the preceding year.

Gross exit rate (GEXR): Plant exit divided by the total number of plants in the preceding year.

Import penetration (IMP): Ratio imports/domestic demand (sales+imports-exports).

Industry demand (DEM): Industry demand rate of change indicator computed as a weighted average of the rates of change of production in the industries that buy from that industry, and the rates of change of consumption of the final consumers that buy the produced goods.

Appendix A. Firms' heterogeneity, industry composition and productivity growth

Let $q_i = [1/(1-a_i)]f(x_i)$ be the production function of firm i, $i = 1,..,N$, with $f(x_i)$ linearly homogeneous. The associated cost function is $C(w, q_i) = c(w)(1-a_i)q_i$, where w represents the vector of input prices, and input demands can be written as $x_i = \frac{\delta c(w)}{\delta w}(1-a_i)q_i$ (Shephard's lemma). Using linear homogeneity,

Table A1. Variable statistics (sample means)

	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Productivity growth (%)	0.76	0.9	0.8	0.2	1.4	−0.3	1.2	1.3	1.6	1.4	0.8	1.3
Capacity utilisation (rate of change %)	−1.2	−3.3	1.9	2.3	−1.7	−0.2	−0.8	0.0	−2.1	1.3	4.9	−2.7
R&D expenditures/value-added (‰)	5.5	6.6	6.9	8.8	7.6	12.6	18.1	19.7	21.2	20.7	20.1	26.2
Technological payments/value-added (‰)	7.6	7.6	8.8	9.9	9.5	8.4	13.7	13.7	11.2	16.3	23.5	21.0
Investment intensity (thousands ptas. per worker)	16.0	−20.7	−7.8	−0.6	−13.6	−31.6	−3.0	71.4	41.1	75.2	87.4	113.4
Gross plant entry rate (%)	4.4	3.3	4.6	6.1	7.3	7.8	7.4	8.8	11.0	10.7	9.4	9.0
Gross plant exit rate (%)	7.1	7.1	9.3	12.3	9.3	11.1	10.1	11.1	13.7	10.0	9.3	9.4
Number of plants (rate of change %)	−2.6	−1.8	−5.6	−6.0	−2.3	−4.0	−2.5	−2.4	−2.4	0.0	0.6	0.2
Industry demand (rate of change %)	0.6	1.6	0.0	0.8	2.4	1.0	3.0	3.6	7.6	6.6	6.8	4.7
Import penetration (%)	15.9	16.3	16.5	17.6	18.7	20.5	20.4	23.0	25.2	25.7	27.2	27.6
Export intensity (%)	12.8	13.0	16.2	16.9	19.8	24.6	25.5	24.6	22.8	21.4	19.9	20.7

it can be immediately shown that $\sum_i f(x_i) = f(x)$, where $x = \sum_i x_i$. Hence, $q = 1/(1-\sum_i a_i s_i) f(x)$. Taking logs, using $\ln(1+x) \approx x$ and differencing, we obtain expression (1). Now let $f(x_i)$ be homogeneous of degree γ. Then $\sum_i f(x_i) = [(1-\sum_i a_i s_i)/(\sum_i (1-a_i)^{1/\gamma} s_i^{1/\gamma})^\gamma] f(x) \approx [1 - I(a,s)(\gamma-1)] f(x)$, where $I(a,s) = \ln \sum_i (1-a_i)s_i - \sum_i \frac{(1-a_i)s_i}{\sum_i (1-a_i)s_i} \ln(1-a_i)s_i$ and the last (approximate) equality is obtained using a first-order approximation around $\gamma = 1$. If all firms were equally efficient ($a_i = a$), $I(a,s)$ would take the value of the entropic index $-\sum_i s_i \ln s_i$, and if all firms were of the same size ($s_i = 1/N$), the index would simply be $\ln N$.

Appendix B. Productivity growth and the rates of entry and exit

A market consists of two types of firms. Firms of type 1 present a productivity or cost advantage "a" over the firms of type 2. For simplicity, there is no way to transform a type 2 firm into a type 1 firm. Entry consists of type 1 firms and exit affects type 2 firms. Let N_1 and N_2 be the numbers of firms, $N_1 + N_2 = N$, and s_1 and s_2 their market shares. Call the joint shares $N_i s_i$, S_1 and S_2. Productivity change derived from a change in the industry composition of firms is adS_1 or $-adS_2$. S_1 can be written as a function of the proportion of firms of type 1 in the marketplace, $w = N_1/N$, and the relative advantage in output of this type of firm, $v = (q_1 - q_2)/q_1$, as $S_1 = w/(1-(1-w)v)$. At the same time, given the productivity or cost advantage of firms of type 1 and the behaviour in the market, v itself can be considered an increasing function of w and N. This is the case, for example, when market demand is either linear or of the constant elasticity type and firms compete à la Cournot. Therefore S_1 can be expressed as $S_1 = S_1(w, v(w,N))$, where $\frac{\delta S_1}{\delta w} > 0$, $\frac{\delta S_1}{\delta v} > 0$, and we can assume $\frac{\delta v}{\delta w} > 0$ and $\frac{\delta v}{\delta N} > 0$. Differencing S_1 and expressing dw and dN/N in terms of the entry and exit rates, $e = dN_1/N$ and $s = dN_2/N$, an equation of the type $ds_1 = \beta_e e + \beta_s s$ is easily obtained, where the β's depend on three effects of the entry and exit rates: "direct", "competition" and "concentration". The effect of entry is always expected to be positive, while the effect of the exit rate will be positive if the direct and competition effects of exit prevail over the concentration effects (as we can expect).

Appendix C. A case of the frontier of possibilities of firm numbers

Assume the same two-firms setting of Appendix B. Suppose in addition that operation in the industry implies some fixed cost or minimum profits. Then, given demand, cost conditions and conduct, there will be a maximum number of firms of type 2 that will be able to operate with non-negative profits for each number of type 1 firms. This defines a frontier of possibilities of firm numbers in the market (see Fig. 1). Entry with displacement effects refers to the entry and exit associated with movements along this frontier. The rate dN_2/dN_1 reports the number of type

2 firms that will be replaced by a firm of type 1. Entry and exit by market enlargements or contractions refer to the entry and exit associated with movements of the frontier. As an example, assume that N_1 type 1 firms and N_2 type 2 firms compete à la Cournot with constant marginal costs c_1 and c_2. The inverse market demand function is then $p = d - bQ$, with $Q = N_1 q_1 + N_2 q_2$. Assuming a fixed cost F, profits of a type 2 firm can be written as $\pi_2 = \frac{1}{b}\left[\frac{d-c_2}{N+1} - \frac{N_1(c_2-c_1)}{N+1}\right]^2 - F$. Equating this expression to zero, we obtain the equation for the frontier

$$N_2 = \left(\frac{d - c_2}{\sqrt{bF}} - 1\right) - \left(1 + \frac{c_2 - c_1}{\sqrt{bF}}\right) N_1$$

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