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PRODUCTIVITY GROWTH AND COMPETITION IN SPANISH MANUFACTURING FIRMS: WHAT HAS HAPPENED IN RECENT YEARS?

Agustí Segarra-Blasco [*], Mercedes Teruel-Carrizosa[†] [‡]

Abstract

This paper addresses the issue of the relationship between productivity and market competition. In comparison to the economies of other European countries, the Spanish economy has been growing, while productivity growth has stagnated. Here we provide empirical evidence about the relationship between productivity and market competition from Spanish manufacturing firms at firm level between 1994 and 2004. Correcting for selection bias, our study pays special attention to the patterns of productivity growth between openness and non-openness firms. When market competition increases the effect on firms operating in domestic markets is positive but when the level of competition is high incentives to invest in innovation and productivity gains disappear. The empirical relationship between competition and productivity is an inverted U-shape, where productivity growth is highest at intermediate levels of competition. The productivity growth of firms operating in international markets is higher than that of non-openness firms, but when market competition rises they moderate their productivity growth. Our empirical results suggest that the correct competition policy in the Spanish economy should remove the barriers to competition in internal markets in order to increase the incentives for manufacturing firms to invest in innovation and productivity growth.

Keywords: Manufacturing industries, innovation, competitiveness, international trade, Heckman equation.

JEL classification: L25, o14, o33

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1. Introduction

The lower productivity performance of European countries relative to the US has been an important focus of interest in recent years. Many academics and policy makers believe that GDP per capita in the EU has stagnated at about 70 per cent of the US level because of a lack of the productivity growth due to the presence of competition barriers in the EU single market. Since the nineties the European Commission has promoted competition in both the product and factor markets –competition policy- and investment in R&D and innovation –the Lisbon Agenda programme- through market liberalisations and public grants. Despite the importance of these topics, so far we have obtained little empirical evidence of the relationship between market competition, innovation and productivity performance in European countries at firm level.

Understanding the effect of market competition on productivity is of particular interest to the Spanish economy. Since Spain joined the European Union in 1986, its economy has achieved higher average economic growth than the other European countries. However, Spanish productivity has also been in constant decline since the nineties, particularly in the manufacturing sectors. During the period 1990-1995 Total Factor Productivity recorded an average growth rate of -0.2% and during the period 2000-2005 zero per cent (OECD, 2006). Nevertheless many scholars are surprised by the rapid growth of the Spanish economy in recent years. In the words of Olivier Blanchard "*How is Spain doing it? The ambiguous miracle: no labour productivity growth, negative TFP growth… But employment and investment growth*" (Blanchard, 2005).[1] What has happened in recent years? A simple answer is not easy.

In order to answer the question, "Why has Spanish productivity slowed down in recent years?", a range of factors such as firm size, number of large firms, private R&D investment and capital per worker ratio have been analysed by scholars. However, the role of market competition in promoting productivity gains has received little attention to date. For this reason this paper analyses the effect of market competition on productivity growth in Spanish manufacturing firms.

[1] In recent years Spanish economic growth has been based on intense labour growth, a scarcity of capital per worker and human capital. This has caused a slow down in productivity growth. However, the macroeconomic results of recent years are satisfactory due to improvements to financial markets, salary moderation and demand growth.

In particular, our aim is to study the link between market competition, measured as one minus the value of sales less payroll and material costs divided by the value of sales (the inverse of the Lerner Index), and productivity growth, measured by Total Factor Productivity (henceforth TFP) in manufacturing Spanish firms during the period 1994-2004. In recent years, empirical literature has measured competition with a range of variables such as industry concentration, market share, price-cost margin ratios and profits and has measured innovation in a number of ways, including TFP, patents, R&D investments, product or process innovation number (see a survey of this literature in Boone, 2000). Our database from the Spanish Business Register allows estimation of TFP and price-cost margin ratio proxies through the Lerner Index yearly at firm level.

This paper deals with the literature on how competition affects innovation and productivity. In recent years a range of theoretical research has highlighted the relationship between competition and firms' incentives to innovate and improve productivity gains (Vickers, 1995; Boone, 2001). There is a great deal of literature on the effect of competition on firms' innovative activities, but relatively little on theoretical analysis and empirical econometric calibration. It has been stressed that competition acts as a driving force because it incentivizes efficiency and productivity in firms. Gerosky (1995), Nickell (1996), Blundell et al (1999) and Disney et al (2000), among others, suggest that there is a positive relationship between competition, innovation and productivity growth. However, recent empirical research finds that the relationship between competition and innovation or productivity describes an inverse U-shape. This means that the productivity rate is highest at intermediate levels of competition (Aghion et al, 2001; Aghion et al, 2002). Hence, empirical evidence reveals a trade-off between the displacement effect and the Schumpeterian effect, which depends on the intensity and characteristics of the market.

It is a well-known fact that nowadays the engine of economic growth is a firm's incentives for innovation and productivity growth. The critical driving force of economic growth is the intensity and the nature of market competition to provide an incentive for innovation and productivity growth at firm level. The Schumpeterian models and new growth theories emphasised the firms' heterogeneity, imperfect competition and the central role of the innovation driving technological change and productivity growth. In this sense, to create new ideas and apply innovations firms must be able to charge prices greater than marginal cost. How Jones (1998) remarks the wedge between price and marginal cost provides the economic "fuel" for the engine of growth.

This argument is particularly important in economies like Spain, which has opened intensively to foreign markets in recent years in spite of being far from the world's technological frontier. In fact, the main objective of competition policies is to improve firms' incentives to increase innovation and productivity growth, and to bridge the transition to international competitiveness by first reducing protective trade barriers in local or regional markets such as the EU single market (Scherer, 2000). Barriers to innovation are particularly evident in economies such as Spain's which in recent years has opened up to foreign markets in spite of being a long way from the world technological frontier.

In Spain the increased availability of micro-level data in recent years has promoted research on the sources of a firm's growth and productivity. Some works reveal a close relationship between innovative activities and productivity growth in manufacturing firms. For a sample of Spanish manufacturing firms Huergo and Jaumandreu (2004a) find that the innovation process at some point leads to extra productivity growth, which persists over time but decreases with the years. Other works have found a positive correlation between market dynamics–entry and exit of firms- and productivity growth in Spanish manufacturing (Callejón and Segarra, 1999, Fariñas and Ruano, 2004); differences in productivity levels between exporting and non-exporting firms (Delgado et al, 2002), between importing and non-importing firms (Fariñas, 2006), between different sized firms (Castany et al, 2005), and between age firms (Huergo and Jaumandreu, 2004b). Other works analyse the external determinants of the efficiency level in Spanish firms (Gumbau and Maudos, 2002). In conclusion, these studies highlight the heterogeneity levels of productivity in accordance with external factors, such as competition pressure, market turbulence and market structure, and internal firm factors, such as export and import propensity, size, age and location, among others.

In addition, this research addresses four questions: (1) when market competition improves productivity gains in the Spanish manufacturing firms, (2) the empirical evidence on the relationship between market competition measured by the profitability index and productivity growth; (3) how the geographical dimension of the markets, distinguishing between foreign and domestic markets, determine different competitive environments which cause differences in productivity growth patterns, and (4) what effect individual firm characteristics, such as financial pressure, size, age or debt have on productivity growth.

The data is provided by the Business Register where Spanish firms present their accounts every year. We selected all manufacturing firms with more than 250 employees. We obtained a large unbalanced panel of 1,327 companies. The exhaustive panel data provides accurate analysis of the relationship between competitive pressure and productivity growth for two different samples of firms in relation to the geographical dimension of the markets. We have a first group with 816 companies oriented towards foreign markets (firms that usually import and export), and a second group with 511 companies with fewer links to international markets (firms without import and export activities, only import or only export). Our research aims to analyse the relationships between productivity and innovation but also to obtain a better understanding of characteristics that enhance a firm's productivity. The debt pressure and the ownership structure of the firm are some of the characteristics mentioned in the literature.

The rest of paper is organised as follows. The second section describes the theoretical framework of the relationship between the intensity of competition and the innovation performance of firms and productivity growth. The third section reveals the characteristics of the panel data used and presents the main descriptive statistics obtained from the accounting information companies, paying special attention to the differences between openness and non-openness firms. Section four presents the formal specification of the production function at individual level and the econometric tools applied. Section five presents the results of the econometric work and some robustness checks applying the GMM method and the Heckman equation, and section six concludes the paper with main results obtained and the implication of the results for competition policy.

2. Market Competition and Productivity: Theoretical Background

This section offers a theoretical survey about the role of market competition in promoting efficiency gains and productivity growth at firm level. It is well known that for several decades, the growth accounting approach was the dominant methodology for empirical studies of productivity. Solow's model (1957) decomposes growth into contributions from the growth rates of factor inputs weighted by competitive factor shares plus a 'residual' term interpreted as exogenous technological progress. However, as Griliches points out, Solow's residual is a "measure of our ignorance" because many factors can cause a shift in the production function, such as technical, organisational and institutional change. The growth accounting approach does not identify the mechanism through which real-world growth is actually sustained. In this sense, neoclassical growth theory does not explain the different patterns of growth and productivity rates across countries, industries and firms (Carlaw and Lipsey, 2003). The real world of the markets differs from the theoretical models when the agents are similar, because in the markets the heterogeneity of firms predominates.

However, in the accounting approach, the sources of economic growth have been concerned mainly with the analysis of technical change and aggregate growth in modern economies with identical agents. Usually, in this framework the concept of competition is interpreted as a state of apparent equilibrium in which well-informed agents treat prices parametrically and promote allocative efficiency for the whole economy. Yet the mechanism of perfect competition is quite divorced from the original and real concept of competition as a process of rivalry (Vickers, 1995). The second concept of competition originally appears in the works of classical economists –Smith, Mill, among others. In this second perspective the competition is interpreted as a process where the agents react to incentives conditioning their performance and affecting the productive and dynamic efficiency of industries. Competition is a dynamic process of rivalry that promotes the exit of low-productivity firms, provides incentives for incumbents to reduce shortcomings and invest in R&D to increase their efficiency and promotes market dynamics[2].

In spite of the empirical evidence, traditional frameworks of Industrial Organization and Growth Theory offer little information about firm heterogeneity, the intensity of market turnover and the relationship between market competition and growth. The leading theoretical models in industrial organization (see Tirole, 1988) and economic growth (see Barro and Sala-i-Martín, 1995) predicted that more intense market competition discourages innovation and growth.

The traditional industrial organization models assume that when market competition increases the income of innovative firms decreases and it discourages firms to invest in R&D activities. Usually, in this framework, the entry of new firm captures the notion of innovation and reduces the expected income of incumbents. But the trade-off between incumbents and entrants is ambiguous. If we ask ourselves who will invest more in R&D in the innovation race, the incumbent or the entrant, the answer is ambiguous (Aghion and Griffit, 2005). Here, there is a tension between static and dynamic efficiency. Sometimes, the barriers of mobility reduce the dynamic forces of creation and innovation in new firms, but it is necessary to distinguish between a firm being able to innovate in a new field, and being able to imitate what others have done. In the first case, market dynamics promotes the innovation and, in the second case, market dynamics decreases the incentives of incumbents to innovate[3].

In recent years new information has appeared in the theoretical literature of endogenous growth provided by Romer (1986), Lucas (1988), Jones (1995) and Aghion and Howitt (1992), among others. They offer a new view when interpreting innovation as a significant engine of growth. In these models a decentralized market economy provides adequate incentives for the rapid accumulation of technology and they show how investments in knowledge play a critical role in the long-run growth process (see a survey in Cameron, 1998). As Grossman and Helpman (1991) point out, new growth theory has taken a step in the right direction by including aspects of reality – imperfect competition, firm heterogeneity, incomplete apropiability, international interdependence and increasing returns- that are clearly important to understanding how the economies provide incentives in firm profits to create knowledge and develop innovations.

From a Schumpeterian perspective, in recent years different models of new theory growth have appeared. Aghion and Howitt (1992) present a model where firms make intentional investments in R&D and these may produce new types of goods or improve the quality of existing goods. The innovative activities of firms are the main source of economic growth in the long run (Aghion and Howitt, 1998). From this perspective the creative destruction process is the main driving force of economic growth because innovative firms discover new goods and make old products obsolete and therefore firms go bankrupt and their capital equipment also becomes obsolete. A great deal of attention has been paid to how the innovative process may differ across countries and across industries, either in terms of differing levels of human capital, physical capital, public infrastructures, and market competition (Aghion and Griffith, 2005).

In addition, various recent contributions (Aghion and Howitt, 1998; Howitt and Aghion, 1998; Howitt, 1999) have combined capital accumulation with R&D and the innovation process. Capital accumulation and innovation should not be treated as distinct causal factors because they are two aspects of the same process. On the one hand, physical and human capital plays a crucial role in

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2 See a survey about market competition in Vickers (2001) and Boone (2000).

3 Structural and strategic barriers reduce entry, intra-industry mobility, and exit. In so doing, they do not merely impede the ability of markets to weed out the inefficient, they also reduce the competitive pressures which promote innovation as the mechanism of, or the response to, entry by new firms (Geroski and Jacquemin, 1988).

innovation activities and in the application of new technologies resulting from innovation activities. On the other hand, new technologies open up new economic opportunities for investment in physical and human capital. Howitt and Aghion (1998) develop an integrated model with innovation and physical capital accumulation, where long-run growth depends on both innovation and physical capital accumulation technologies; and government policies that affect these two activities have permanent effects on growth.

In contrast to the first neo-Schumpeterian models in which innovations are always made by outsider firms which earn no income if they fail to innovate and become monopolies if they do innovate (Aghion and Hovitt, 1992; Caballero and Jaffe, 1993), the new models find that the usual Schumpeterian effect of more intense market product competition (MPC) is almost always outweighed by the increased incentive for firms to innovate in order to escape competition (Aghion et al, 2001). Now we are in a new technological environment where information and communication technologies play a central role in technological change in a wide range of markets, where the dynamic competition for the market is more important than static price/output competition in the market (Evans and Schmalensee, 2001).

The role of market competition

The theoretical framework predicts that there are three fundamental channels through which competition may affect a firm's performance (Bucci, 2003). Firstly, the discipline effect of competition shifts the price towards the marginal cost, which forces the exit of low-productivity firms from the market and facilitates a more efficient allocation of factors –capital and labour- across high-productivity firms (*allocative efficiency*). Secondly, pressure on profit margins influence firms' incentives to reduce slack (*productive efficiency*). Thirdly, changes in the level of market rivalry promote innovation and dynamic markets –entry, exit, selection or adaptation of firms- (*dynamic efficiency*). In this sense, dynamic competition will force firms to innovate in order to survive. Schumpeter's "creative destruction" notion is a classical example of the trade-off between static and dynamic efficiency. Dynamic competition is a process where new firms develop innovations and compete with incumbents,[4] and dynamic efficiency is a key factor in productivity growth (Nicolletti and Scarpetta, 2003).

However, the relevant issue is not the market competition *per se* but firms' incentives to innovate and change. Some basic questions to address with regard to this point: When does market competition encourage innovation and when does it not? What are the levels of market competition at which the incentive effect or disincentive effect on innovation predominates? Do the effects of market competition on productivity growth differ between markets –external and domestic markets- and firm characteristics? Evidently, the relationship between market competition and productivity is not a simple one. On the one hand, considerable interactions may exist between market competition and a firm's productivity growth. The theoretical predictions on the effects of competition on a firm's incentives are *a priori* ambiguous. On the other hand, competition provides an incentive for technological change and innovation, but competition discourages laggards to adapt to outsiders' innovations if the differences in productivity levels are important[5].

In recent years, interest in understanding the relationship between market competition and a firm's incentives to innovate has increased considerably[6]. In a first sample of industrial organization papers firms usually were symmetric and the number of firms in the market was exogenous (Arrow, 1962; Dasgupta and Stiglitz, 1980). Later, a new sample of models appeared where firms differed in efficiency levels, and the role of the dynamic market was highlighted (Aghion and Howitt, 1992; Boone, 2001).

These new theoretical contributions and the access of individual panel data in industrialized countries offered an interesting opportunity to explore the empirical relationship between market

[4] Gerosky (1989) using a sample of 79 UK industries during 1976-1979 explores the effects of competition on productivity growth rates, and finds competition plays a significant role in stimulating productivity. Domestic entry rates accounts for at least 30 per cent of TFP growth.

[5] The impact of MPC on dynamic efficiency is ambiguous and more difficult to identify, because it changes during the market life-cycle. In this sense firm dynamics play a central role in the innovation process and the productivity growth (Ahn, 2003).

[6] The relationship between price-cost margins and the intensity of competition is not simple. On the one hand, some of the most competitive markets with large sunk investments or large R&D investments have high price-cost margins. On the other hand, in the market it is price rather than innovation that is the principal driver of competition. The relationship between concentration and competition is ambiguous, except at very high levels of concentration. An increase in competition can lead to increased concentration as

competition, innovation and productivity growth. Along these lines, Gerosky (1995), Nickell (1996), Blundell et al (1999), Aghion et al (2005) and other scholars produced some interesting results. Recent empirical studies indicate that competition promotes the productivity growth because it exerts pressure on firms to reduce costs and innovate in order to maintain market position, by introducing new products or new production processes. From the dynamic perspective, competition pressure has a positive effect of an incumbent's innovation activities and promotes market dynamics –entry, exit, selection, growth, failure of firms- and reveals a positive correlation between market competition and productivity growth. Aghion et al (2005) observe a range of industries using the data of UK firms over the period 1968-1996. They find that an inverted U-shaped relationship exists between PMC and innovation.

In general, these empirical analyses differ from Schumpeter's conjecture in that they find that a positive or inverse U-shaped relationship may exist between competition, innovation, productivity and growth at firm and industry level (see the survey in Boone, 2000). Empirical research finds that when the level of market competition is low, firms may have few incentives to improve efficiency and productivity growth; but when the level of competition rises, a positive impact on productivity appears. At the other end of the competition spectrum, when competition is strong enough to keep price equal to marginal costs, firms do have not the incentives to recoup investments in productivity enhancement and productivity tends to stagnate.

The empirical evidence supporting the theoretical framework is not always unequivocal, and we need to provide empirical evidence from different countries and markets in order to understand more clearly what happens when the level of competition rises in relation to a firm's incentives to improve productivity gains. The following section provides empirical evidence for a range of Spanish manufacturing firms.

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aggressive competition reallocates profits from inefficient firms to more efficient firms, causing inefficient firms to exit and market concentration to increase.

3. Data and Descriptive Statistics

The sample of firms used belongs to the Spanish Business Register. The Business Register database contains data on employment, the activity sector, sales, exports and imports, debts and profits for all the firms with more than 10 employees and sales in excess of 60,000 euros. The panel data used in this paper covers all manufacturing firms with more than 250 employees registered on the Spanish Business Register. Our panel data collects yearly information from 1994 to 2004. Here we used an unbalanced panel of 9,441 observations of 1,327 manufacturing firms from 1994 to 2004. On average the available data for each firm was observed for 7.11 years.

Our source data contains information on the firm's accounts, foreign market behaviour, shareholder capital distribution, location, asset value, number of employees, sales, income, profits, financial and labour expenditures.

This study applied econometric techniques to analyse two aspects of market competition: the relationship between market competition and productivity growth rates and the determinants of productivity growth at firm level. In this sense, we pay special attention to two aspects of dynamic markets. On the one hand, the openness of the firm to foreign markets. We consider an openness firm one that usually exports and imports and non-openness firm one that does not. On the other hand, market turbulence is measured by the entry of new firms and the exit of incumbent firms.

(Table 1)

We begin with the data description of openness and non-openness firms between 1994 and 2004. The annual average TFP growth in Spanish manufacturing firms during the period 1994-2004 was 0.91 per cent; the annual rate of output growth measured by added value was 7.82 per cent and the annual rate of input growth was 6.91 per cent. In manufacturing industries the TFP growth is the highest in the Spanish economy, but smaller than that of other EU members. This is a critical point that explains why the Spanish economy has lost its level of competitiveness, particularly in external trade. In fact, in recent years the gap between exports and imports has increased and the balance of payments presents a deficit that is untenable in the long term.

A comparison of TFP growth among openness and non-openness firms reveals that openness offers a slight premium in terms of productivity. In openness firms the annual rate of TFP growth is 0.92 per cent compared to 0.90 per cent for non-openness firms. However, there are important differences in the sources of productivity[7]. The output growth of openness firms recorded an average rate of 7.82%, lower than the 8.54% recorded for non-openness firms. On the other hand, the input growth of openness firms is the 6.46%, lower than the 7.65% recorded for non-openness firms. The sources of inputs reveal notable differences in the labour input measured by number of workers, given that labour growth in openness firms is 0.98% compared to the 1.49% recorded by non-openness firms.

Spanish manufacturing firms display notable differences in internal characteristics. Our database offers interesting information about the size, age, profitability, firm level and financial pressure. Openness firms are older and larger than non-openness firms. In addition, there are slight differences with regard to profitability and financial pressure. On the one hand, firm profitability levels are higher in openness firms. On the other, financial pressure is lower than in non-openness firms.

The database contains information on dynamic firms and reveals the patterns of new firms and incumbents during the period 1994-2004. If we observe the descriptive statistics of two samples – the surviving firms and the entrants- the differences are very clear: entrants ensure higher TFP growth, especially through sales growth compared to incumbent firms. Table 1 shows the descriptive statistics of surviving and failing incumbents and entrants. On the one hand, the first group refers to incumbents during the period 1994 to 2004. These firms were created before the initial observed period and survived until 2004. The second group refers to firms created before 1994 but failing during the period 1994 to 2004. Finally, the third group refers to entering firms during the observation period. We expect a different pattern among these three groups.

[7] Openness firms have a higher average TFP level than non-openness firms, but the differences in the evolution of the TFP growth rate between these samples are more moderate. For TFP level differences between exporting and non-exporting firms in Spain see Delgado et al (2002) and for Germany see Matthias and Hussinger (2005).

Results provide strong evidence of the displacement effect. In fact, new entrants perform better than incumbents. New entrants obtain TFP growths of 2.02% while incumbents on average obtain a TFP growth of 0.79%. New entrants seem to display better behaviour. However, their larger standard deviation shows that there are heterogeneous firm patterns within this group. In fact, theoretical and empirical literature points out that entrants have a dual effect. On the one hand, a disciplinary effect on the market because they diminish excessive profits. On the other hand, they pressure innovation because they introduce innovations or because they pressurise the rest of the firms to innovate (Gerosky and Jacquemin, 1985).

Moreover, competition plays an important role in selecting more efficient firms from less efficient ones (Boone, 2000). In markets with more competitive pressure, firms are punished more severely in terms of profits for a drop in efficiency. When competition increases, the selection effect plays an important role in determining the survival possibilities of the firms (Vickers, 1995). In this sense our sample shows different patterns between surviving and failing incumbents. Due to the restrictions of our database, we do not know whether a firm has closed completely or whether it has been acquired by another firm. The difference between such firms is important. The first case is related to the inefficient behaviour of firms. In the second case, firms may be acquired due to their good performance. Given that our sample contains firms with more than 250 employees, incumbents should be firms with a certain market power in the market, and new entrants with more than 250 employees must be firms with positive expectations for their future behaviour. Our results show that failing incumbents have a higher TFP growth rate with a value of 0.98%, while surviving firms' TFP growth rate is 0.73%. However, heterogeneity obtains a large value for failing incumbents.

With regard to output growth, new entrants obtain larger output growth than incumbents. On the one hand, new entrants' output growth achieves 14.61% on average while for incumbents the average value is 7.11%. On the other hand, we should also highlight differences in firm profitability measured with the Lerner index. While incumbents obtain an average value of 2.18%, new entrants obtain -0.71%. These results show that incumbents may increase the price over the cost, while new entrants find it more difficult to compete in the market and have to fix a lower price.

4. Productivity, Market Competition and Firm Characteristics

The division between theory and empirical evidence provides an interesting setting for understanding the effect of market competition over the driving forces of economic growth. To tackle this division, in a first step we pay special attention to the relationship between competition and productivity growth at firm level. Then, in a second step we will incorporate a range of firm and sectoral characteristics.

4.1. Determinants of firm productivity

In our model, the representative firm has a technology with constant scale economies of productive factors and its level of productivity depends on its efficiency level from its technology (Campbell, 1997). The production function of the *i'th* firm at period *t* is given by,

$$Q_{i,t} = F\left(A_{i,t}, K_{i,t}, L_{i,t}, M_{i,t}\right) \qquad [\ 1\ ]$$

where *Q* measures output (in this case total sales), *K* is a measure of physical capital, *L* is the number of employees, *A* is a productivity index and M is the value of other intermediate inputs. Applying logarithms and taking differences respect the time; the output growth rate has the following expression:

$$dq_{i,t} = \varepsilon_{A,t} da_{i,t} + \varepsilon_{K,t} dk_{i,t} + \varepsilon_{L,t} dl_{i,t} + \varepsilon_{M,t} dm_{i,t} \qquad [\ 2\ ]$$

where dq_t , da_t , dk_t , dl_t and dm_t are growth rates calculated as differences of the logarithmic value of the sales, Hicks' neutral technical change, the capital stock, number of employees and the intermediate materials. Finally, $\varepsilon_{X,t}$ is the elasticity of output in respect of each factor from the production function.

If the production function does not exhibit constant scale economies (Hall, 1986), the production function F(.) will be homogeneous to degree γ, in respect of the capital stock, labour and the intermediate materials ($\varepsilon_{K,t} + \varepsilon_{L,t} + \varepsilon_{M,t} = \gamma$) and homogeneous to degree one in respect of the technical progress ($\varepsilon_{A,t} = 1$). Firms have a certain level of market power (Hall, 1986) and their price-demand elasticity is ε_t. Incorporating this assumption within the production function[8]:

$$dq_{i,t} = da_{i,t} + \gamma dl_{i,t} + \mu_i \alpha_{K,t} \left(dk_{i,t} - dl_{i,t}\right) + \mu_i \alpha_{M,t} \left(dm_{i,t} - dl_{i,t}\right) \qquad [3]$$

Therefore, the output growth from a firm *i* in period *t* depends on four different factors: variations in the global productivity; the elasticity of scale; the variations from the capital-worker relationship weighted by the price-cost margin and the factor contribution in the output; and the variations from the material-worker relationship weighted by the price-cost margin and the factor contribution in the output.

In expression [3] the productivity captures the improvements in technical efficiency in the presence of elasticities of scale and market power. The rate of change in the global productivity of the factors will differ from Solow's residual to a greater or lesser extent, depending on the magnitude of the returns to scale and the presence of market power in the industrial sectors. Taking into account that Solow's residual includes the variations in output not accounted for by the changes in the use of the productive factors from the above expression we can easily derive an equation in which the dependent variable is not the output but Solow's residual:

$$TFP_{i,t} = dq_{i,t} - \alpha_{L,t} dl_{i,t} - \alpha_{K,t} dk_{i,t} - \alpha_{M,t} dm_{i,t} \qquad [4]$$

From equation [3]:

$$TFP_{i,t} = da_{i,t} + (\gamma - 1) dl_{i,t} + (\mu_i - 1)\alpha_{K,t} \left(dk_{i,t} - dl_{i,t}\right) + (\mu_i - 1)\alpha_{M,t} \left(dm_{i,t} - dl_{i,t}\right) \qquad [5]$$

[8] If μ_i is the price-cost margin from firm "i" ($\mu_i = P_i / CM_i$), elasticities may be expressed as a function of price-cost margin and the contributions of the factors to the *output*:

$$\varepsilon_{Xij} = \frac{P_{Xij} \cdot X_{ij}}{CM_{ij} \cdot Y_{ij}} = \frac{P_{Xij} \cdot X_{ij}}{P_{ij}/\mu_{ij} \cdot Y_{ij}} = \mu_{ij} \cdot \alpha_{Xij}$$

where P_{Xi} and X_i represent the price and the number of productive factors, μ_i is the price-cost margin and α_i is the contribution of each factor to the output.

However, the productivity change ($da_{i,t}$) may be decomposed into different variables related to the level of competence in the markets in which a firm operates and different explanatory variables of the firm's characteristics:

$$da_{ij} = \theta_{ij} + \beta_1 MC_{i,t} + \beta_2 MC_{i,t}^2 + \beta_3 dX_i + u_{ij}$$

Where MC and MC^2 is a degree of competence and its quadratic value in the industry and X is a vector of individual and sectoral variables. If we introduce those parameters in [5], we obtain:

$$TFP_{i,t} = \theta_i + \beta_1 MC_{i,t} + \beta_1 MC_{i,t}^2 + \beta_3 X_{i,t} + (\gamma - 1) dl_{i,t} + (\mu_i - 1)\alpha_{K,t}(dk_{i,t} - dl_{i,t}) + (\mu_i - 1)\alpha_{M,t}(dm_{i,t} - dl_{i,t}) + u_{i,t} \quad [6]$$

This will be our main equation of interest where the *TFP* growth depends on the market competence, a vector of individual and sectoral variables, the growth rate of the number of employees, the growth of the intensity of capital per worker, and the growth of the intensity of intermediate materials per worker.

4.2. Econometric estimation

As we have seen previously, our sample shows a heterogeneous behaviour which may affect the estimations of β's due to sample attrition bias. In particular, if a firm's productivity goes under a certain threshold level, this usually implies a serious profitability problem for the firm. Therefore, this firm is likely to be closed down and will drop out of the data set. Conversely, if the firm's productivity goes over a certain threshold level, then the firm is likely to be acquired by another firm and will also drop out of the data set. This correlation between data truncation and productivity may produce a sample selection bias if we apply an ordinary least squares equation.

In order to deal with this bias, we classify firms into three types depending on their entry and exit patterns between year 0 and year T. Type-1 firms are survivors that remain in the market between year 0 and year T. Type-2 firms are exiters that are present in year 0 but exit the market before year T. Type-3 firms are entrants that start their business after year 0. Whether or not productivity is observed depends on the patterns of entry and exit. The entry and exit variations lead to the missing data for the dependent or independent variables.

Classification of firms depending on the date of birth and death.				
	Year 0	**Year T**	**Independent variables at 0**	**Dependent variables at T**
Type-1 Survivors	observable	observable	observable	observable
Type-2 Exiters	observable	missing	observable	missing
Type-3 Entrants	missing	observable	Missing	observable

We first consider the firms that are observed in year 0 (Type-1 and Type-2 firms). For these two types of firms, the independent variables x_{i0} are always observable. The problem is that the TFP at the end of the period is not observed for Type-2 firms because they exit between year 0 and year *T*. Thus, our regression equation may be rewritten as:

$$y_{iT} = x'_{i0}\beta + \mu_{iT}$$

Where y_{iT}, x'_{i0} and β are the TFP_{iT}, the explanatory variables and a vector of the parameters of the explanatory variables from our equation of interest [6]. Suppose that the firm *i*'s survival in year *T* depends on the productivity and other firm characteristics in year 0, $Z'_{i0} = (1, x^1_{i0}, x^2_{i0}, x^3_{i0}, \ldots)$:

$$SURVIVAL_{iT} = \begin{cases} 1 & if \quad Z'_{i0}\gamma + \upsilon_{iT} \geq 0 \\ 0 & otherwise \end{cases}$$

Where

$$E(y_{iT} | Z_{i0}) = 0 \quad and \quad \upsilon_{iT} \approx N(0,1)$$

It is possible to estimate consistently through a maximum likelihood (ML) method. The log-likelihood function of the sample selection model for firm *i*, *lnLi*, is:

$$\ln L_i = \begin{cases} \ln \Phi\left\{ \dfrac{Z'_{i0} + \left(y_{iT} - x'_{i0}\beta\right)\rho / \sigma}{\sqrt{1-\rho^2}} \right\} - \dfrac{1}{2}\left(\dfrac{y_{iT} - x'_{i0}\beta}{\sigma}\right)^2 & if \quad s_{iT} = 1 \\ n\Phi\left\{-Z'_{i0}\gamma\right\} & if \quad s_{iT} = 0 \end{cases}$$

where $\Phi(\cdot)$ is the standard cumulative normal distribution function. The key estimate β is obtained from the ML estimate of the parameters of the previous equation using the data set including both surviving (Type-1) firms and exiting (Type-2) firms.

So far, the effect of entry has not been considered. However, entrants (Type-3 firms) are not likely to introduce bias. In the case of entries, exiting firms dropping out of the observed data set are not likely to be correlated to their productivity level. If there is no systematic relationship between entry and productivity after entry, or entry is randomly determined independently of subsequent development, then the aforementioned ML method yields a consistent estimator.

Therefore, the appropriate econometric method to resolve this problem is the two-step method suggested by Heckman (1979). This requires the introduction of an additional explanatory variable in the least squares regression – the inverse Mill's Ratio – obtained from a probit model on firm survival. The probit equation we use is

$$SURVIVAL_{i,2000} = \alpha + \beta_1 Size_{i,1994} + \beta_2 Age_i + \beta_3 GXR + \beta_4 GER + \beta_5 MES + u_{i,t}$$

Where *SURVIVAL* is 1 if the firm *i* has survived until 2004, and 0 if it has closed. Although this Heckman estimator is consistent, it is not fully efficient. Efficient estimates can be obtained by applying an iterative procedure that uses the estimates from the Heckman procedure as starting values and will lead, on convergence, to maximum likelihood estimates (Maddala, 1983; Weiss, 1998). Our estimations find that Mill's ratio is not significant, which would suggest that there is not a significant sample selection bias. However the significance of parameters ρ and σ in the ML estimation shows that we have to consider an important bias introduced by the existence of firms that disappeared over the period of analysis. This alternative set of estimators are reported in the following section.

5. Results

This section presents the econometric results in two stages. Firstly, we reveal the relationship between the level of market competition and the TFP growth rate. Secondly, we introduce in the econometric specification a vector of individual characteristics of the firms and a vector of industry variables.

5.1. Productivity and Market Competition

As we have seen previously the relationship between market competition and productivity is not simple. Competition can increase productivity rates through a more efficient relocation of factors, an increase in the turnover of firms in the market and also through more innovation in new firms or incumbents. However, these effects differ according to market characteristics, the life cycle and internal characteristics of the firms. This section applies an econometric specification to measure the effect of market competition on the productivity growth in Spanish manufacturing firms during the period 1994-2004. The information contained in our database allows us to obtain an index of TFP and market competition at firm level. Productivity growth is measured as the Solow residual, and the market competition is estimated as one minus the Lerner Index. When the value of the market competition variable is close to zero, the level of competition is low; when its value rises, the market competition increases **(see Annexe 1)**.

In order to estimate the relationship between productivity and competition, we apply a Heckman equation and a Generalised Method of Moments (GMM) estimation. The GMM estimator, developed by Arellano and Bover (1990, 1991), is based on analysing the distribution of the diverse moments that characterise a variable. The main advantage of GMM is its control over the presence of unobserved firm-specific effects and over the endogeneity of the current-dated explanatory variables[9]. However, our data may suffer from sample attrition bias because we have

[9] Our GMM estimator reveals that there is a significant U-shaped relationship between productivity and competition. However, this relationship changes to an inverted U-shaped relationship between both variables when the non-openness of firms is analysed. This change reinforces our argument that openness and non-

some incumbents exiting the market. Therefore, we decided to apply a Heckman equation with iterative ML estimates. Our ML estimations show that parameters ρ and σ have to be considered because there is an important bias introduced by the existence of firms that disappeared during the period of analysis.

We also apply a Granger causality test to check for the direction of causality between the TFP and the level of competition. Results show that the competition level Granger causes the level of industrial relationship because the F-test is equal to 53.69 (with a p-value of 0.000) while TFP does not Granger cause the competition level because the F-test is equal to 1.43 (with a p-value of 0.2311).

Table 2 offers the estimation of equation [6] where the TFP equation depends on the competition variables and the scale economies of the product function at firm level. In the first place, the competition index has an inverted U-shape effect on the TFP equation. That means that the competition index has a positive effect on productivity until it reaches a point where competition does not provide an incentive for the introduction of innovation in the market. The empirical evidence of the relationship between competition level and innovation or productivity growth is rather ambiguous and still far from conclusive. The empirical literature may be grouped in two different waves.

The first wave is the preliminary set of empirical studies by Gerosky (1995), Nickell (1996), Blundell et al (1999) and Disney et al (2000) and suggests that a positive relationship may exist between competition, innovation and productivity growth. Nickell (1996), with a sample of 676 UK firms over the period 1975-1986, found that: i) market power reduces productivity levels, ii) competition is associated with higher rates of TFP growth and iii) competition measured with the level of firm income is associated with a higher level and faster growth rates of TFP. And Disney et al. (2000), with a larger data set of around 143,000 UK establishments over the period 1980-1992, found that market competition significantly increased productivity levels as well as productivity growth rates. However, Scherer (1965) for 448 US firms in the base year 1955 found

openness firms behave differently. The different sign between openness and non-openness may be due to the fact that the selection process in the market is not taken into account. The reason is that exiters have a higher TFP growth than surviving incumbents. Therefore, their impact on our equation of interest is larger than the effect of the incumbents remaining active in the market until 2004.

that inventive output measured by patents is not systematically related to variation in market power or prior profitability.

In recent years, new studies have found empirical evidence in favour of the competition-productivity relationship. However, they point out that when market competition is low, increase in pressure promotes productivity growth but when it is high the increased pressure has a negative effect on productivity growth. Aghion et al (2001) find that the effect of PMC on growth is usually monotonically positive, but sometimes inverse-U shaped. Aghion et al (2002) developed a Schumpeterian growth model in which firms innovate ‘step-by-step’ and for the sample of 330 UK firms during the period 1991-1994 the empirical results confirm that the relationship between product market competition at industry level and innovation is an inverted U-shaped curve. In this respect our results are in line with this second wave of empirical studies.

In the second place, the parameters related to the scale economies of the product function show that an increase in the growth of workers has a negative effect on the TFP. This is a reasonable result given higher labour intensity has a negative effect on firm productivity. Conversely, the effect of the growth of the capital and the materials per workers on the TFP is positive.

With regard to the difference between openness and non-openness firms, some interesting differences appear in the values of the coefficients. On the one hand, firms open to foreign markets present lower coefficients for the parameters related to competition than non-openness firms. On the other hand, firms open to foreign markets present higher coefficients for the parameters related to the production function than non-openness firms. Our results show that firms operating in the domestic market react more when competition increases but decrease their TFP growth when competition is high. In fact, Aghion et al (2005) find that the inverted U-shape is steeper when industries are more neck-and-neck.

Therefore, the Competition index offers a positive relationship between competition and TFP growth. But the level of significance of the value of the parameters differs between openness and non-openness firms. Of course, for openness firms the parameter is positive but not significant at the usual level, and for non-openness firms the result is very clear, the value of parameter increases and the level of significance is high. The Square of Competition index shows that the relationship between competition level and productivity growth describes a inverted U-shaped curve, especially in non-openness firms. The level of significance is high in the three groups of firms and shows the presence of Schumpeterian effect when the level of competition market is higher.

(Table 2)

An important extension of econometric estimation would be to calculate the Kernel equation between market competition and TFP growth. The graphical representation of the Kernel equation differs between openness and non-openness firms. For the firm oriented towards foreign markets the TFP growth rate is stable at lower levels of market competition, but when competition rises TFP growth falls. We find that when openness firms operate in markets with high levels of competition the Schumpeterian effect appears and the capacity of firm to invest in new equipment and R&D activities decreases. Finally, in the group of non-openness firms the results of the Kernel equation confirm the existence of an inverted U-shaped relationship between market competition and TFP growth.

(Graph 1)

These results indicate that at the lowest levels of market competition an escape-competition effect predominates, whereas at high levels of market competition the Schumpeterian effect appears. Our results describe the inverted U-shaped relationship, particularly when the firm operates in domestic markets.

5.2. Productivity and firm determinants

The next step of our analysis identifies the firm characteristics that affect productivity growth. The database offers information about firm size measured by employees, age measured in years, financial pressure measured by debt, and capital firm structure measured by the proportion of total capital represented by the three main shareholders **(see Annexe 1)**. The econometric Heckman estimation offers interesting results, which are shown in table 3.

The relationship between firm size and TFP growth is negative at the level of significance in our three samples. These results show that medium-sized firms obtain higher productivity growth, in addition to a range of empirical works than show that small and medium-sized firms increased their productivity levels. Furthermore, firm age has a negative and significant relationship with TFP growth. Firm age normally correlates with other variables at firm level such as size, wages, capital structure, financial pressure and productivity. However, our results suggest that medium and young firms increase their productivity levels more.

(Table 3)

In the empirical estimations we included financial pressure, measured by the firm's level of debt in relation to total liabilities. The results are statistically significant and show the a positive link between financial pressure and productivity growth. This positive effect of financial pressure on productivity is especially relevant in openness firms. When the firm operates in external markets, an increase in debt repayment obligations increases the tension in the organization and causes an improvement in the efficiency of managers and employees. Furthermore, when financial pressure increases the managers work harder to minimize bankruptcy risks (Aghion and Griffith, 2005).

Our results are in line with the preliminary empirical works. Nickell and Nicolitsas (1999) found that firms faced with financial pressure respond by increasing their efforts to increase productivity. When financial pressure increases at firm level they found this had a large negative effect on employment, a small negative effect on wage increases and a small positive effect on the level of productivity. The aforementioned paper by Aghion et al (2002) found empirical evidence that firms with greater financial pressure innovate more than those with lower financial pressure, as predicted by the theoretical framework, and higher debt pressure reinforces the escape-competition effect and enhances innovation incentives at lower levels of market competition.

Finally, we incorporate a proxy measure of the ownership structure at firm level. The variable used is the share of three main firm shareholders. Our results show that the effect of the ownership concentration has a positive impact on productivity growth. However, the coefficient is not significant probably due to the static nature of this variable. Our results coincide with previous empirical works which found that ownership concentration affects the efficiency of strategic orientation, reduces agency tension and increases firm productivity. In a sample of UK firms, Nickell, Nicolitsas and Dryden (1997) f0und that the effect of larger shareholders on productivity growth is positive. However, the current results for Spanish manufacturing firms found a moderately positive but not statistically significant relationship between shareholder concentration and productivity growth.

However, the empirical evidence is far from agreement on the link between shareholder concentration and productivity. For a sample of Scottish firms, Acs and Isberg (1991) observed that innovation is not related to ownership structure. Conversely, Leech and Leahy (1991) analysed UK firms and found that there is a positive relationship between firm growth and ownership concentration and the control of the manager. In reference to different samples of Spanish manufacturing firms, Galve and Salas (1993) observed a positive relationship between ownership concentration and firm results, while Ortega, Moreno and Suriñach (2005) found that a high degree of ownership concentration and the use of debt financing serve to dissuade a firm from incurring R&D expenditure.

In reference to the cyclical variables, we find that there is an anticyclical evolution of GDP growth and TFP growth. Therefore, positive GDP growth has a negative effect on TFP growth. Concerning the sectoral variables, import penetration and medium efficient size have a positive impact on TFP growth. However, their effect is not significant.

6. Conclusions

The results presented in the paper indicate that market competition is a key factor in improving productivity growth in Spanish manufacturing firms. In order to analyse the role of competition in productivity growth we first asked some questions: What is the relationship between firm productivity and competition? Why has Spanish productivity in manufacturing industries slowed down since the nineties? Why do Spanish firms suffer from productivity stagnation? All these questions have driven our analysis of the relationship between productivity and competition. Overall the results confirm the positive and complex effect of market competition on productivity growth at firm level. Despite the complexity between both variables, we think that we have cast some light on the empirical evidence.

Our results show that competition has a dual effect for Spanish manufacturing firms. When competition levels are low, a rise in competition has a positive impact on firm productivity, yet once a productivity level is reached, competition has a negative impact on productivity. This inverted U-shaped impact is absolutely clear with non-openness firms, but the effect seems to be more ambiguous with openness firms. This result shows that much of the domestic market still has low levels of competition, but when competition pressure rises it generates firms' incentives to improve productivity growth. At the other end of the competition spectrum, in domestic markets with high competition levels when competition pressure rises it discourages firms to raise productivity levels. The displacement effect and the Schumpeterian effect play an important role in domestic markets and the relationship between market competition and productivity growth produces an inverted U-shape in the sense that the productivity rate is highest at intermediate levels of competition.

The effect of market competition when firms operate in international markets is different. In general, productivity growth in openness firms is higher than in non-openness firms, and when opening firms operate in markets with low competition levels productivity growth is higher. In this case, we found no evidence of the displacement effect when the competition pressure rises. However, in high levels of market competition an increase in competition pressure produces a fall in the productivity rate.

In fact, it seems that openness firms depart from higher productivity growth rate than non-openness firms but they slowdown their productivity growth more rapidly in competitive markets. Therefore, it seems that the increase in the openness of Spanish market, first in 1986 with Spain's entry in the European Economic Community and later by joining the Monetary European Union has been crucial for firm productivity. Higher competition implies lower productivity growth, particularly for openness firms.

In relation to firms' determinants of productivity growth we find clear evidence that internal characteristics play an important role in productivity growth. Young and small firms tend to increase productivity quicker. And financial pressure at firm level has a disciplinary and positive effect on productivity dynamics, particularly when the firm operates in external markets. Finally, the results show that the effect of ownership concentration has a positive and moderate impact on productivity growth.

European competition policy aims to increase market flexibility, reduce barriers to entry and stimulate adaptability within large bureaucracies. This policy may erode the incentives of Spanish firms to increase their productivity in the short run. In this sense, the increase in competition and the incentive for productivity are the major challenges for Spanish policy makers. Perhaps the answer to Spain’s sluggish productivity growth lies in the behaviour of Spanish firms. Perhaps the policy makers should try to modify the “animal spirits” driving firms, in order to improve productivity results.

The involvement of policy makers is very interesting; especially in European countries when the barriers to market integration and competition policies play a crucial role in providing sufficient incentives to increase productivity growth at firm level. Our results find that competition policy needs to eliminate the competition barrier in domestic markets in order to achieve productivity improvements and that excessive external competition plays a negative role in productivity growth in economies like Spain which are far from the world’s technological frontier.

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Annexe 1 - "The Variables"

This Annexe describes the variables included in the empirical evidence. We have classified the variables into two different groups: i) Individual variables, ii) Sectoral variables.

- **Total Factor Productivity (TFP)***:* Proxy of innovation which represents the increases of Total Factor Productivity. This measure adopts an output perspective because it takes into account the outcome from the production and not the expenses in R&D and other possible externalities. Source: SABI database.

$$TFP_{i,t} = \ln Q_{i,t} - \ln Q_{i,t-1} - \left[0`5 \times \left(\alpha_{K_{i,t}} - \alpha_{K_{i,t-1}}\right) \times \left(K_{i,t} - K_{i,t-1}\right)\right] + \\ - \left[0`5 \times \left(\alpha_{L_{i,t}} - \alpha_{L_{i,t-1}}\right) \times \left(L_{i,t} - L_{i,t-1}\right)\right] - \left[0`5 \times \left(\alpha_{M_{i,t}} - \alpha_{M_{i,t-1}}\right) \times \left(M_{i,t} - M_{i,t-1}\right)\right]$$

  where α_K, α_L and α_M, are the contributions of the capital (K), labour (L) and the materials (M). L is the number of employees, M is the value of the intermediate consumptions and K is the capital stock in the firm. In order to estimate the capital stock we have used the Methodology of the Permanent Inventory with the following equation:

$$K_{i,t} = K_{i,t-1} + I_{i,t} - \delta \times K_{i,t-1}$$

  where $K_{i,t}$ is the stock of capital in period "t", *I* is the firm investment and δ is the capital depreciation rate.

- **Growth workers (Δ (l_{it}))**: Difference of the logarithmic size between a period and the previous one. Source: SABI.

- **Growth capital per worker (Δ (k_{it} - l_{it}))**: Difference between the growth in the capital and the growth in the number of employees over the same period of time. The growth in capital and workers is measured as the difference between the logarithmic value of capital and intermediate consumption. Source: SABI.

- **Growth materials per worker (Δ (c_{it} -lk_{it}))**: Difference between the growth of the logarithmic intermediate consumptions and the growth in the number of employees over the same period of time. The growth of intermediate consumptions and workers is measured as the difference between the logarithmic value of capital and intermediate consumption Source: SABI.

- **Competition index (MC)**: This variable measures the market competition in the market and it is calculated as 1 - the Lerner Index. Following Aghion et al. (2002), the Lerner Index is measured as operating profits net of depreciation and provisions minus an estimation of the financial cost of capital (cost of capital*capital stock) and divides this by the sales. This measure is similar to the Lerner Index but it has the advantage of avoiding the unobservable marginal cost. Source: SABI database.

$$MC_{i,t} = 1 - Lerner \quad index = 1 - \frac{operating \quad profit - financial \quad \cos t \quad by \quad firm \quad "i" \quad in \quad "t"}{sales \quad in \quad "t"}$$

- **Size**: Logarithmic number of employees in a firm. The effect is ambiguous: some empirical studies find a positive relationship between firm size and innovation, but there are others which find a non-linear relationship (Scherer, 1965). Furthermore, this line follows the two Schumpeterian perspectives: 'Schumpeter Mark I' and 'Schumpeter Mark II'. In these two groups innovative activities are structured and organized in different ways. 'Schumpeter Mark I' implies a low concentration of innovative activities, innovators are of small economic size, there is an unstable ranking of innovators and high entry of new innovators. 'Schumpeter Mark II' presents a high concentration of innovative activities, innovators are of larger economic size, there is a stable ranking of innovators and the entry rate is low. Source: SABI.

- **Age**: Logarithmic firm' experience in the market. This variable is the logarithm of the difference between each year the firm is active and the year of creation. The relationship between age and innovation is unexpected: on the one hand, some industries will have technological breaks with the entrance of new firms; on the other hand, some industries introduce innovation with the research and innovation of older incumbents. This difference is due to industrial characteristics (sunk costs to develop technologies) or the existence of barriers to entry (artificial oligopolies). Source: SABI.

- **Financial pressure (FP)**: Firms with a large amount of debt may have more incentives to innovate in order to be face up to their debts. Conversely, those firms with large amount of debts may encounter more problems since they may not be able to choose freely where to invest their capital (The will to maintain independence restricts financial resources for innovation, conversely, dependence may restrict the capacity to choose whether to invest in a risky project). Source: SABI.

$$FP_{i,t} = \frac{Financial \quad \exp enditures \quad in \quad firm \quad "i" \quad during \quad "t"}{Total \quad passive \quad in \quad firm \quad "i" \quad during \quad "t"} \times 100$$

- **Capital structure:** Percentage of the capital owned by three largest shareholders. This variable represents the agency problems caused by asymmetrical information between managers and owners. Firms controlled by large shareholders may have less capacity to innovate due to problems of agency. Agency theory predicts that managers will act largely out of self-interest unless they are closely monitored by large block shareholders. Source: SABI.

$$CS_i = \% \quad shares \quad belonging \quad to \quad the \quad three \quad principal \quad shareholders \quad in \quad firm \quad "i"$$

- **Medium Efficient Size (MES)**: It measures the average of the number of employees by firm in the industry in which the firm operates. The existence of large average size implies the existence of barriers to entry in the industry. These barriers (natural or artificial in the industry) may stimulate the creation of innovations in order to deter the entrance of new firms. Source: Encuesta Industrial.

$$MES_{s,t} = \frac{number \quad of \quad employees \quad in \quad \sec tor \quad "s" \quad in \quad "t"}{number \quad of \quad firms \quad in \quad \sec tor \quad "s" \quad in \quad "t"}$$

- **Import penetration**: Ratio of imports and domestic sales in the industry. It measures the value of imports over home demand in the firm's industry. Therefore, it is a measure of the foreign competition. Source: Encuesta Industrial and Agencia Tributaria (Departamento de Aduanas e Impuestos Especiales).

$$IP_{s,t} = \frac{\operatorname{Im} ports \quad in \quad \sec tor \quad "s" \quad in \quad "t"}{Total \quad sales \quad in \quad \sec tor \quad "s" \quad in \quad "t"} \times 100$$

- **Sectoral dummies:** *Manuf1* identifies firms belonging to *food products and beverages* sectors (CNAE 15), *Manuf2* identifies firms belonging to the *textile, leather clothing, leather tanning and preparation manufacturing* sectors (CNAE 17 to 19), *Manuf3* identifies firms belonging to the *wood and cork* sector (CNAE 20), *Manuf4* identifies firms belonging to the *paper products, publishing, printing and reproduction of recorded media* sector (CNAE 21 and 22), *Manuf5* identifies firms belonging to the *chemical manufacturing* sector (CNAE 24), *Manuf6* identifies firms belonging to the *rubber and plastic products* sector (CNAE 25), *Manuf7* identifies firms belonging to the *other non-metallic mineral products* sector (CNAE 26), *Manuf8* identifies firms belonging to the *basic metals and fabricated metal products* sector (CNAE 27 and 28), *Manuf9* identifies firms belonging to the *machinery and equipment* sector (CNAE 29), *Manuf10* identifies firms belonging to the *electrical, electronic and optical equipment* sector (CNAE 30 to 33), *Manuf11* identifies firms belonging to the *Transport equipment* sector (CNAE 34 to 35) and *Manuf12* identifies firms belonging to the *Furniture* sector (CNAE 36). Source: SABI.

- **GDP growth**: Percentage of GDP growth in the economy. This variable captures the effect of the Spanish economy on the PTF growth.

- **Gross Entry Rate (GER)**: Percentage of entrants' sales each year over the total value in each industry. It represents the internal competition in the market as well as the degree of barriers to entry. Low barriers to entry foster innovation in neck-and-neck competitive industries, but it can discourage the creation of innovation when the threat of the entrance of new firms is unlikely. Source: SABI and Encuesta Industrial.

$$GER_{s,t} = \frac{Sales \;\; of \;\; new \;\; entrants \;\; during \;\; period \;\; "t"}{Total \;\; sales \;\; in \;\; the \;\; \sec tor \;\; during \;\; period \;\; "t"} \times 100$$

- **Gross Exit Rate (GXR)**: Percentage of exiters' sales in the market each year and in each industry. This variable shows the selection process in the market. It is expected that those firms facing up to lower productivity will have to leave the market or innovate to survive. Source: SABI and Encuesta Industrial.

$$GXR_{s,t} = \frac{Sales \;\; of \;\; new \;\; exiters \;\; in \;\; \sec tor \;\; "s" \;\; in \;\; "t"}{Total \;\; sales \;\; in \;\; \sec tor \;\; "s" \;\; in \;\; "t"} \times 100$$

Annexe 2. Tables and Graphs

Table 1:

Descriptive Statistics of our data sample of firms.

Period 1994-2004.

	All firms	*INCUMBENTS-ENTRANTS*				*OPENNESS*	
		Incumbents					
		Survivors and failures	Survivors	Failures	Entrants	Openness Firms	Non-openness Firms
TFP	0.0091	0.0079	0.0073	0.0098	0.0202	0.0092	0.0090
	(0.1118)	(0.107)	(0.0989)	(0.1295)	(0.1491)	(0.1086)	(0.1170)
Output growth	0.0782	0.0711	0.0717	0.0695	0.1461	0.0738	0.0854
	(0.2953)	(0.2691)	(0.2546)	(0.3101)	(0.4739)	(0.2848)	(0.3119)
Inputs growth	0.0691	0.0632	0.0643	0.0597	0.1259	0.0646	0.0765
	(0.2689)	(0.2490)	(0.2392)	(0.2776)	(0.4098)	(0.2592)	(0.2842)
Capital stock growth	0.0016	0.0017	0.0018	0.0015	0.0008	0.0016	0.0017
	(0.0146)	(0.0149)	(0.0135)	(0.0187)	(0.0113)	(0.0128)	(0.0173)
Labour growth	0.0117	0.0113	0.0118	0.0097	0.0154	0.0098	0.0149
	(0.0808)	(0.0792)	(0.0765)	(0.0869)	(0.0950)	(0.0729)	(0.0923)
Materials growth	0.0558	0.0502	0.0508	0.0484	0.1096	0.0533	0.0599
	(0.2306)	(0.2107)	(0.1991)	(0.2433)	(0.3670)	(0.2244)	(0.2405)
Average age	27.91	30.40	29.84	32.16	3.93	29.45	25.36
	(19.85)	(19.20)	(18.58)	(20.90)	(2.01)	(19.85)	(19.58)

Average size (employees)	665.92	661.20	593.84	871.05	711.32	710.72	591.88
	(1274.71)	(1279.04)	(18.58)	(1718.44)	(1232.02)	(1410.85)	(1007.13)
Firm Profitability (Lerner)	0.0218	0.0218	0.0267	0.0192	-0.0071	0.0229	0.0200
	(0.1126)	(0.1126)	(0.1126)	(0.1336)	(0.1235)	(0.1130)	(0.1119)
Debt pressure	0.0332	0.0342	0.0336	0.0361	0.0236	0.0329	0.0337
	(0.1235)	(0.1296)	(0.1478)	(0.0321)	(0.0176)	(0.0272)	(0.1980)
Firms	1,327	1113	742	371	214	816	511

Standard deviation in brackets.

Source: the authors from SABI database.

Table 2:

Productivity and Market Competition (Heckman estimation[a])

TFP equation	All firms	Openness Firms	Non-openness F
Δ (l_{it})	-0.0601	-0.0861	-0.0488
	(0.0053)*	(0.0068)*	(0.0089)*
Δ (k_{it} - l_{it})	0.0251	0.0291	0.0124
	(0.0036)*	(0.0043)*	(0.0060)**
Δ (c_{it} -lk_{it})	0.0471	0.0575	0.0334
	(0.0035)*	(0.0047)*	(0.0053)*
Competition index	0.1453	0.0913	0.3978
	(0.0724)**	(0.0847)	(0.1312)*
Square Competition index	-0.1182	-0.1081	-0.2249
	(0.0335)*	(0.0391)*	(0.0617)*
Sectoral dummies[b]	✓	✓	✓
Constant	-0.0191	-0.0008	-0.1937
	(0.0402)	(0.0465)	(0.0771)*
ρ	-0.0745	0.7772	0.6127
	(0.0977)	(0.0479)*	(0.0271)*
σ	-2.3021	-2.3008	-2.1292
	(0.0089)*	(0.0155)*	(0.0179)*
Loglikelihood	0.33	49.70	18.71
	(0.5654)	(0.0000)	(0.0000)
Observations	9441	5882	3559
Censored obs.	2256	1547	709

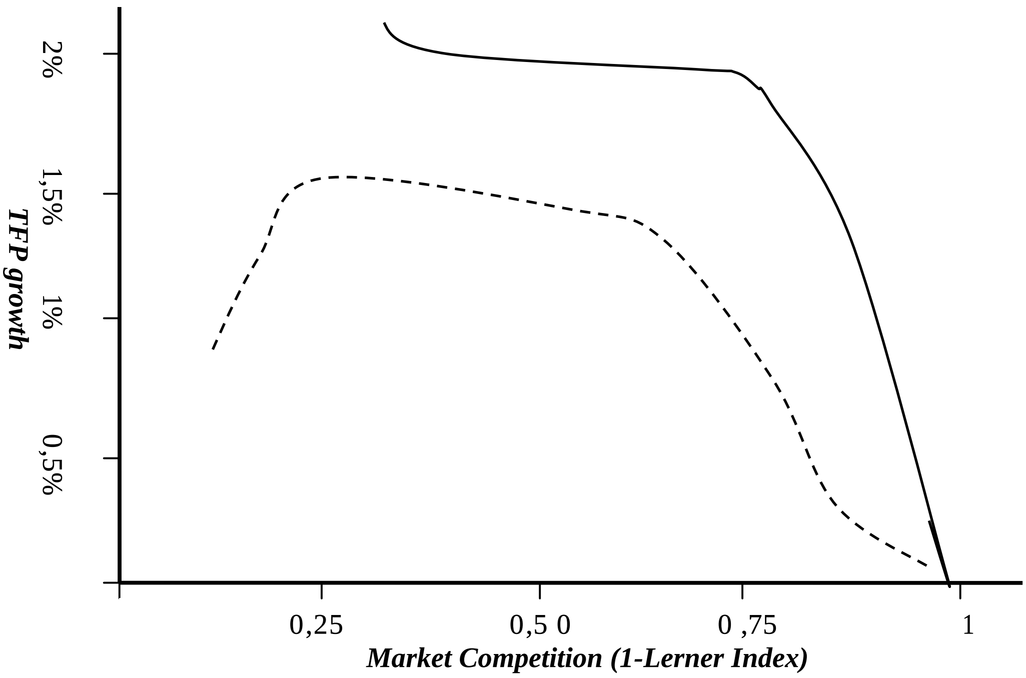
Standard deviation in brackets.

[a] The selection equation includes the variables Size (logarithmic number of workers), Age (logarithmic firm age), GXR (percentage of sales of exiters), GER (percentage of sales of entrants) and MES (medium efficient size).

[b] See Annexe 1 for a description of the sectoral dummies.

* significant at 1%, ** significant at 5% and *** significant at 10%.

Graph 1
Kernel regression in openness and non-openness firms



Note: Competition measure is normalized to one at the highest level of competition

Table 3.

Determinants of Productivity Growth (Heckman estimation)

TFP equation	All firms	Openness Firms	Non-openness Firms
Δ (l_{itt})	-0.0722	-0.0880	-0.0513
	(0.0054)*	(0.0068)*	(0.0089)*
Δ (k_{it} - l_{it})	0.0234	0.0285	0.0112
	(0.0035)*	(0.0043)*	(0.0059)***
Δ (c_{it} -lk_{it})	0.0459	0.0547	0.0343
	(0.0035)*	(0.0048)*	(0.0053)*
Competition index	0.2267	0.0575	0.3761
	(0.0725)*	(0.0851)	(0.1310)*
Square Competition	-0.1640	-0.0984	-0.2208
index	(0.0336)*	(0.0391)*	(0.0614)*
Size	-0.0103	-0.0082	-0.0112
	(0.00153)*	(0.0018)*	(0.0026)*
Age	-0.0085	-0.0084	-0.0084
	(0.0014)*	(0.0018)*	(0.0024)*
Financial Pressure	0.0370	0.2338	0.0312
	(0.0082)*	(0.0573)*	(0.0094)*
Capital Structure	0.00003	0.00001	0.00006
	(0.00003)	(0.00004)	(0.00006)
Sectoral Variables			
MES	-0.00002	0.00006	0.0009
	(0.0009)	(0.0009)	(0.0029)
Import Penetration	0.00001	0.000001	0.000001
	(0.00002)	(0.00003)	(0.00003)
Sectoral dummies	✓	✓	✓
Cyclical variable			
GDP growth	– -0.0026	-0.0026	-0.0024
	(0.0014)***	(0.0016)	(0.0025)
Constant	0.0085	0.0892	-0.0815
	(0.0413)	(0.0482)***	(0.0795)

ρ	0.7329	0.8050	0.6061
	(0.0342)*	(0.0451)*	(0.0621)*
σ	-2.2199	-2.3002	-2.1379
	(0.0114)*	(0.0152)*	(0.0177)*
Loglikelihood	113.66	69.97	22.78
	(0.0000)	(0.0000)	(0.0000)
Observations	9441	5882	3559
Censored obs.	2256	1547	709

Standard deviation in brackets.

[a] The selection equation includes the variables Size (logarithmic number of workers), Age (logarithmic firm age), GXR (percentage of sales of exiters), GER (percentage of sales of entrants) and MES (medium efficient size).

[b] See Annexe 1 for a description of the sectoral dummies.

* significant at 1%, ** significant at 5% and *** significant at 10%.

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