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Relations between External and Internal R&D, Capital Investments and Profitability: The Case of the Agri-Food Spanish Industry

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Abstract

This paper studies the effects of external and internal expenditures on research and development on the profitability of industrial agri-food enterprises. For this purpose a data sample from the Encuesta de Estrategias Empresariales en España [Survey of Business Strategies in Spain] was used which includes information on more than 400 businesses over the period 2000-2008. The econometric analysis uses quantile regressions to address the vast asymmetry of the variables and to identify non-linear relationships.

The results reveal interesting new findings on the impact of R&D on the agri-food industry. The most evident, though not the most immediately apparent, relationship concerns the positive effects of external R&D spending on profitability. The influence of internal R&D spending is indirect, through spending on capital goods. No support was found for the inverse relationship, that the most profitable firms are not those that spend the most on R&D. It was found that a certain level of profitability or being a large firm has a positive impact on the possibility of external R&D having a favorable impact on company results. This greater effect of external by comparison with internal R&D spending seems logical in a context of increasing competition in research and development. Another conclusion is that external R&D and investment in capital goods appear simultaneously at low investment levels but not at high ones.

Keywords: *Business Profitability, Agri-food industry, External and Internal R&D, Quantile regressions.*

JEL classifications: L66, Q16, M10, C21

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1. Introduction

Empirical research on the relationship between innovation and profitability helps to identify actions and policies to improve the competitive position of companies. Along these lines, de Jong and Vermeulen (2006) point out that many empirical studies have mixed firms from different sectors and this leads to not detecting the effects of R&D. These authors stress the need for a differentiated analysis in order to reveal sectoral strategies, especially in small businesses.

Other studies point to the desirability of further research on low technological intensity sectors such as the agri-food industry (Garcia-Martinez and Burns, 1999 and Capitanio et al., 2009) due to its specific characteristics and social impact, i.e. capacity to generate employment and regional location. Thus, Traill and Meulenberg (2002) and Filippaios et al., (2009) argue that the biotechnology revolution and the growing demand for quality, ecological and functional products is leading to an increase in research in this industry. De Noronha et al. (2006) highlight its importance in the economy of rural areas and identify various types of enterprises in terms of their innovative behavior, with large interactions with the environment in which they operate. Furtan and Sauer (2008) for their part, emphasize the importance of the dominant orientation (product, process or market) on added value as well as human capital. Brickau et al. (1994) suggest that strategies oriented towards the long-term and alliances with competitors should be implemented to improve the results obtained by agri-food SMEs. Fortuin and Omta (2009) hold that the food industry should manage its innovations with criteria similar to those used by high technology sectors in order to increase communication between departments of R&D and marketing. Karantininis et al. (2010) hold that vertical integration is one of the main determinants of innovative behavior in the Danish food industry, due to a greater degree of appropriability of innovation in that country. Finally, Bayona et al., (2012) analyze the effects of other options, such as open innovation practices, for Spanish agri-food firms on their innovation performance. The results showed the interest of these firms in process innovations and on the cooperation practices.

This literature provides information on the innovative behavior of the agri-food industry but does not provide an in-depth exploration of how R&D is integrated into agri-food businesses and the nature of its long-term effects on the obtaining of results. The objective of this paper is to examine what relations might exist between profitability and R&D spending in the agri-food industry. Through the use of dynamic models numerous studies have provided evidence of the bidirectional relations which exist between R&D spending and variables such as profitability, productivity and investment in capital goods (Branch, 1974; Mairesse and Hall, 1996 among others). This present study focuses on exploring the direct relations in both directions between profitability and R&D and considers R&D carried out internally separately from that acquired externally from other firms. No in-depth analysis is carried out of what other factors, jointly with R&D, have a positive effect on profitability, nor are indirect relations examined, that is, the effect of mediating variables (R&D output) such as process innovation, number of innovations in the product and the number of patents. These matters are no doubt of great importance but there is also interest in studying the dynamic structure and effects between external and internal R&D and profitability, with this being the differentiating objective of this paper, on the basis of its relative novelty and its possible relevance for R&D decisions in businesses. While we recognize the complexity involved in identifying and analyzing patterns of innovation (Buesa and Zubiaurre, 1999 and López-Mielgo et al., 2009), we believe it to be useful to show firms the kind of R&D that have the most positive effect on profitability as well as the possible synergies between R&D and investment in capital goods.

According to Lokshin et al. (2008), the fact that access to certain external sources of knowledge has accelerated and acquisition costs have declined in recent years, coupled with the disappearance of the internal departments of R&D in many firms has led to a growing interest in exploring the effects of both types of R&D. Thus the empirical research arising from this line of work allows for the exploration of the question of in which cases it is more appropriate to outsource R&D and in which to carry it out internally, as well as their interactions. Once again the approach to the question of internal and external R&D depends on the technological intensity of each industry and the size of the businesses concerned (Audretsch et al., 1996; Veugelers y Cassiman, 1999; Lokshin et al., 2008; Vega-Jurado et al., 2008 and Lazzarotti et al., 2011).

These more novel objectives are combined with a more classic one related to the time it takes for R&D to have an effect on the profitability of the business and the sensitivity of this relationship to the size of the organization and the level of profitability achieved. The possibility that profitability has a promoting and generating role in R&D is also explored, as are the relations between it and investments in capital goods. These questions will be addressed in this study on the basis of a sample of agri-food businesses.

The source of information used was the *Encuesta sobre Estrategias Empresariales* (ESEE) [Survey of Business Strategies] produced by the *Fundación SEPI* in Spain. This database has the advantage over the accounting information in the *Registros Mercantiles* [Commercial Registers], as it provides more detail regarding the activities under examination here. For example it provides a breakdown of internal and external R&D spending. In other words the ESEE offers more detailed information on the results obtained from R&D spending, and also regarding how these activities are carried out, additional material of value for exploring the objective of this paper. The advantage of having information with a temporal dimension (period 2000-2008) and also a cross-cutting one (449 companies) is the ability to explore and discriminate among the possible bi/directional relationships mentioned above.

This study contributes to the empirical literature both in terms of the information it provides and the techniques used: (1) it uses information from the ESEE, which has been little exploited for the agri-food sector but which is a source of crucial importance for the study of the behavior of this industry over the last 20 years, (2) external and internal R&D are examined separately which allows for the differentiation of their effects and (3) robust econometric models are used and this leads to a position where it is possible to explore in more detail the dynamics, interactions and effects of these variables in different situations.

The rest of the paper is structured as follows: the next section briefly summarizes the focus and treatment given by micro-economic studies to the effects of R&D with a special emphasis on the agri-food sector but also on contributions that use a temporal structure, panel data and quantile regressions. Section 3 describes the source of the data and the variables used. On the basis of this knowledge in Section 4 details are given of the econometric techniques used. Section 5 sets out the results while Section 6 is devoted to responding to the questions asked in the Introduction and to exploring some practical applications.

2. Background, Hypothesis and Expectations

2.1. Theoretical framework

Solow's neoclassical model shows (1957) how technical progress is a key factor in the achievement of economic growth along with investment in labor and capital. With this model, Solow estimated that four fifths of U.S. growth was attributable to technical progress. Thus, he explains how in advanced nations technological innovation offsets diminishing returns, obtaining more output, even with the same amount of capital and labor. However, not only the rates of investment in capital and labor affect technological progress, there is a wide variety of factors that influence the diffusion and adoption of innovations (Nelson, 1981), and several authors have contributed theories and evidence on them.

Thus there is the evolutionary theory of economic change (Nelson and Winter, 1982) which emphasizes the dynamic, evolving and accumulative nature of technology, as well as the particular features intrinsic to each sector and firm (Pavitt, 1984). The ability to appropriate the rents generated by innovation is a function of factors dependent on the structure of each industry, the nature of technology and the protection regime (Teece, 1986, 2006).

The relationship between innovation and results has also been examined from the perspective of business management. Thus the resource-based view, (RBV) (Penrose, 1959; Wernerfelt, 1984; Barney, 1991 among others) delves into how companies achieve competitive advantage through strategies that promote the development of resources and capabilities in contrast with the more traditional view of analyzing the strengths and weaknesses of the products offered by the company. These resources comprise assets, capabilities, attributes, information, knowledge, organization processes, etc. that allow the company to formulate and implement its strategies. These resources must also meet certain specifications to prevent them from being copied by competitors. That is, they must be valuable, rare, inimitable and non-substitutable. The impact of company resources on results depends on the intensity of these features. Among the different categories of resources investigated are, obviously, those related to innovation and spending on research and development.

This present work focuses on studying precisely these connections and specifically the dynamic relationships of the costs of internal and external R&D on the profitability of the company as well as possible interactions with physical capital.

2.2. Hypothesis and Expectations

Some authors (e.g. Brown, 1974, Griliches, 1979) suggest that innovation in R&D leads to increased profitability and business growth but requires a maturation period and fine-tuning which leads to delays in its effects being felt. Based on this idea the first hypothesis is formulated which establishes the possibility that the effects of R&D are not immediate but rather exhibit a time lag before reaching maturity and having an effect on results.

Hypothesis 1a: Internal and external R+D have a positive effect on business results in the medium term.

Profitability is ultimately a source of funding and is capable of being used for R&D. Since these projects are riskier than others and take longer to become consolidated it is normal that difficulties arise in finding funding for them outside the firm, both in the form of loans and capital expansion (Brown, 1974). Funding for R&D by way of undistributed profits is a cheaper alternative to the above mentioned ones. It has the disadvantage that probably neither all companies nor all shareholders and partners will be keen on giving up a share of profits. However it is probable that many will be willing to give up part of their entitlement to a share of profits to finance R&D projects. It would thus seem appropriate to expect a positive relationship to exist between profitability and R&D. With the aim of establishing the direction of this relationship the following hypothesis was also proposed:

Hypothesis 1b: The most profitable firms invest the most in internal and/or external R&D.

A situation where these two relations mutually reinforce each other and generate a sustainable and successful model would also be plausible. Using panel data from firms Rouvinen (2002) and Frazen (2003) concluded that R&D causes increases in productivity but not vice versa. For their part, Brown (1974) and Mairesse and Hall (1996) found evidence of the relationship in both directions.

In the food industry, most firms which remain in the sector do so as a result of progressively modernizing their processes, incorporating more efficient technologies and/or adjusting their product ranges to suit market trends. These actions involve the acquisition of capital equipment and are the basis for reducing production costs and winning (or not losing) market share, and ultimately ensuring profitability. This idea is expressed more succinctly in the following way:

Hypothesis 2a: Investments in capital equipment contribute to maintaining or improving business results.

This hypothesis has been confirmed by numerous empirical studies (Griliches, 1998; Sutton, 1998, among others) and it is expected that this study will demonstrate a positive effect without difficulty. Our interest here is in measuring the differentiated impact of capital on SMEs and large firms as well as the various levels of profitability.

The interaction between capital investment and spending on R&D has been examined in numerous studies and a variety of conclusions have been arrived at: positive and bi-directional (Chiao, 2002), no short-term connection but a connection in the long-term (Mairesse and Siu, 1984; de Jong, 2007), R&D leads to capital investments but not vice versa

(Lach and Rob, 1996) and no consistent relationship (Lööf, 2008). In any case these studies agree that R&D may have an indirect effect on business success by way of capital investments. In the same way, substitution relations can be found. The final hypothesis is set out in this broader way in the hope of finding some kind of interaction between R&D and capital:

Hypothesis 2b: Internal and/or external spending on R&D will have effects on spending on capital equipment.

3. Description of the data sample

We used data from the ESEE for the period 2000 to 2008, inclusive, relating to production activities in the meat sector (Sector 1 in the ESEE-20 classification and 151 en la CNAE[2]-93 classification), food products and tobacco (2 ESEE-20, 152, 158 and 160 CNAE-93) and beverages (3 ESEE-20, 159 CNAE-93). Drawn up by the *Fundación SEPI* (http://www.funep.es/), the ESEE provides annual information on strategies to improve the competitiveness of a panel of businesses (with more than 10 employees), representative of the industrial sector. The questionnaire includes questions about costs, employment, relationships with customers and suppliers, markets, trade, technological activities, as well as accounting data.

The initial sample extracted is an unbalanced panel made up of 449 different firms with information from one of the years between 2000 and 2008. There are a total of 2225 observations of which 66% come from food products and tobacco, 20% from the meat sector and 14% from Beverages. The amount of data in each year varies from 186 in 2003 and 2004[3] to 304 in 2008. However as models with delayed variables are used the operation panel is smaller, i.e. 341 businesses with data in 3 years or more and 252 businesses with data in 4 years or more.

The variables selected for the empirical application are discussed below, together with the basic statistical information, which is shown separately for SMEs (200 employees or less) and large firms (more than 200 employees) in Table 1.

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[2] CNEA: National Classification of Economic Activities (Spain).

[3] The decrease in the number of firms in these years was due to a halt in the survey that was corrected in 2006. (Rodríguez, 2009).

ROA (Return on Total Assets) was chosen as a measure of profitability due to its availability for all the firms in the sample and for being widely used in empirical studies (Geroski, 1990; Roberts, 1999; Bayona and García-Marco, 2010 and Lazzarotti et al., 2011). ROA was obtained as the ratio of EBITDA (earnings before interest, taxes, depreciation, and amortization) and total assets. No amortization expenses were deducted and nor was financial income or spending taken into account, in order for profit to be calculated solely on the basis of productive activity of the firm, without interference from the channels of financing or depreciation practices of the company. This would explain the high central values obtained of about 10%.

TABLE 1

Summary statistics

	Q1	Median	Mean	Q3	Standard Deviation	Proportion	Asymmetric Coefficient
SME [1]							
ROA	0.0302	0.0982	0.1212	0.1806	0.2150		2.2955
exRDS	0.0000	0.0000	0.0006	0.0000	0.0057		19.5077
exRDS>0	0.0006	0.0017	0.0062	0.0041	0.0166	0.1044	6.6419
inRDS	0.0000	0.0000	0.0009	0.0000	0.0050		8.7277
inRDS>0	0.0011	0.0035	0.0078	0.0081	0.0123	0.1180	2.9392
InvEA	0.0719	0.1958	0.2472	0.3538	0.2222		1.4533
TAL	17.00	30.00	62.21	73.00	74.41		2.3217
Large Firms							
ROA	0.0293	0.0831	0.1050	0.1598	0.1464		5.6790
exRDS	0.0000	0.0000	0.0011	0.0005	0.0055		19.5701
exRDS>0	0.0004	0.0010	0.0031	0.0032	0.0087	0.3679	13.8343
inRDS	0.0000	0.0004	0.0023	0.0028	0.0051		7.3742
inRDS>0	0.0012	0.0024	0.0041	0.0048	0.0063	0.5557	6.3740
InvEA	0.0831	0.1504	0.1887	0.2494	0.1519		1.8591
TAL	263.80	409.50	633.10	626.50	727.73		3.2143

[1]SME (small and medium enterprises), ROA (return on assets), exRDS (expenditures on external R&D divided by total sales), inRDS (expenditures on internal R&D divided by total sales). InvEA (investment on equipment divided by total assets), TAL (total average labor)

R&D is treated separately depending on whether it is done in house or acquired from other firms. Use is made of ratios of R&D spending over sales (the traditional measure of R&D spending, according to Traill and Meulenberg (2002)), exRDS (expenditures on external

R&D divided by total sales) and inRDS (expenditures on internal R&D divided by total sales). The majority of firms do not carry out these activities. For this reason Table 1 shows the statistics for all the firms and below for those that carry out R&D (*exRDS*>0 and *inRDS*>0). Thus in the agri-food industry only 19% buy external R&D and only 26.34% carry out internal R&D. However, size has an influence on the decision to invest in R&D so that these figures are much lower for SMEs (firms with less than 200 workers); only 10% and 12% show, respectively, positive *exRDS* and *inRDS* for the period studied, by comparison with 37% and 56% for the big firms. Traill and Meulenberg (2002) also hold that in the case of the agri-food sector in Europe it is the large firms that are more intensive in R&D. However, these ratios are not very high relative to other sectors of the ESEE. Thus, the percentages of R&D (external and internal) over sales in 2008 for the meat industry was 0.1% (SMEs) and 0.2% (large firms), 0.1% (SMEs) and 0.4% (large firms) for food and tobacco, and 0.7% (SMEs) and 0.4% (large firms) for beverages, ratios below the 1.5% and 4.5% that were recorded in the industrial and office machinery sectors (Rodríguez, 2009).

Accumulated investments in capital goods were taken as an indicator of the physical capital stock of companies (Lööf, 2008). This variable was constructed from the annual ESEE information. It was first deflated, then accumulated using the perpetual inventory method with a depreciation of 15% (Lööf, 2008), before being finally divided by total assets in order to obtain the InvEA ratio (investment on equipment divided by total assets). The total average labor (*TAL*) variable was used to capture company size.

All the variables show a high degree of asymmetry as can be seen in the final column of Table 1. Taking into account that the asymmetry coefficient would need to have a value of zero for a symmetric distribution, the high figures for all the variables are worthy of note, especially the ratios of internal and external R&D, in line with the results produced by other empirical studies (Nahm, 2001; Coad y Rao, 2008).

4. Methodology

To test the effects of internal and external R&D on profitability dynamic regression models with *ROA* as a dependent variable and *ROA*, *exRDS* and *inRDS* as regressors, lagged 1 and 2 years, *InvEA* and *TAL* were specified. Productive activity (G_2, G_3) and time invariant effects between firms (λ_t) were also examined using dummy variables:

$$\begin{aligned} ROA_{it} &= \beta_1 ROA_{it-1} + \beta_2 ROA_{it-2} + \beta_{E1} exRDS_{it-1} + \beta_{E2} exRDS_{it-2} \\ &+ \beta_{I1} inRDS_{it-1} + \beta_{I2} inRDS_{it-2} + \beta_{InvEA} InvEA_{it} + \beta_{TAL} TAL_{it} + G_2 + G_3 + \lambda_t + \varepsilon_{it} \end{aligned} \quad (1)$$

The inclusion of the lagged dependent variable allows us to investigate the persistence over time of corporate profitability (Branch, 1974, Mairesse and Hall, 1996; Lööf, 2008, Bayonne and Garcia-Marco, 2010, among others). The same specification with the same explanatory variables but changing the dependent variable for $exRDS_{it}$ and $inRDS_{it}$ is used to study the inverse relationship, i.e. the effects of returns on external or internal expenditure on R&D, and this also allows for the exploration of complementarities between them and with physical capital. A similar model is used to study the effects of R&D investment in equipment:

$$\begin{aligned} InvEA_{it} = {} & \beta_1 ROA_{it-1} + \beta_2 ROA_{it-2} + \beta_{E1} exRDS_{it-1} + \beta_{E2} exRDS_{it-2} \\ & + \beta_{I1} inRDS_{it-1} + \beta_{I2} inRDS_{it-2} + \beta_{TAL} TAL_{it} + G_2 + G_3 + \lambda_t + \varepsilon_{it} \end{aligned} \qquad (2)$$

These dynamic models are able to capture the effects of variables over time. They are a way of taking into account the fact that changes to variables do not take effect immediately, they require, rather, a period of adjustment. If the time dimension is short (as in the case of the sample) estimation using models using fixed or random effects panel data (within) is inconsistent because the lagged dependent variable is correlated with the error term.

One unbiased and efficient option is to use instrumental variables and the generalized method of moments (GMM) (Arellano and Bond, 1991, Arellano and Bover, 1995, among others). Given the difficulty of finding instruments that are correlated with the original regressors but not with the error term, the authors decided to use the same variables as the original instruments, but lagged. Moreover, the GMM estimation is performed in two stages, using in the second a weight matrix based on the residuals from the first stage. The procedure followed in this study is to jointly regress the system of equations in first

differences and levels (GMM-SYS) in order to reduce the weakness of the instruments (Arellano and Bover, 1995, Blundell and Bond, 1998). In addition it is necessary to apply a test to examine the absence of second-order autocorrelation as the GMM estimator is based on this assumption, as well as the Sargan overidentification test to validate the suitability of the instruments.

To further explore these relationships, the models (1) and (2) were also estimated by quantile regression (Koenker and Basset, 1978). In situations of asymmetric distributions and the presence of outliers, as is the case of variables in this study, it is appropriate to use estimation procedures that do not have restrictive underlying assumptions. Many proposals for robust estimators have been made but the quantile regression is a simple alternative and additionally identifies response rates for different levels of profitability, i.e., it models the effects of independent variables on the entire distribution of the dependent variable. This technique is suitable in the case of complex relationships, such as when the influence of certain factors only occurs after certain levels of the dependent variable. It is also noteworthy for its robustness in the case of samples with heteroscedasticity, interactions between the determinants and non-normal distributions of errors.

Quantile regressions are a tool with growing acceptance in applied economics. Thus, they are frequently used in studies of labor economics, education, health, demand analysis, productivity, etc. Nahm (2001) and Coad and Rao (2006, 2008) emphasize the need to use quantile regressions to model asymmetric distributions of R&D innovation in relation to sales or business growth. They justify this choice on the basis of the possibility of wrong results with estimates based on the average company.

The estimation procedure consists of minimizing by linear programming the weighted sum of the absolute deviations of the residuals. Simplifying the model (1) ($\sum_j \beta_j \cdot x_{ji} =$right side of regressors) the β_j coefficients are obtained by resolving the linear programming:

$$
\begin{aligned}
&Min \quad Z = \tau \cdot \sum_t \sum_i p_{it} + (1-\tau) \cdot \sum_t \sum_i n_{it} \\
&subject \text{ to}: \\
&ROA_{it} - \sum_j \beta_j \cdot x_{jit} = p_{it} - n_{it} \qquad \forall i,t \\
&p_{it}, n_{it} \geq 0 \qquad \forall i,t
\end{aligned}
$$

The error ε_{it} in each observation *it* is now considered in terms of its positive sign, p_{it}, or its negative one, n_{it}. The parameter τ weights the sum of these deviations, so that for each value of τ we obtain an estimate. Thus, $\tau = 0.5$, gives the conditional median regression, $\tau = 0.25$ the regression for the first quartile, and so on. Once the coefficients have been found, it is possible to obtain their standard deviations and inference. To this end, the covariance matrix of the coefficients are approximated by asymptotic methods or using various bootstrap procedures (Koenker, 2005).

5. Results

In a first approximation, the proposed models were estimated using GMM-SYS for SMEs (200 employees or less) and large firms (more than 200 employees). The results are shown in Table 2. The estimates included dummy variables for years and subsectors to control for temporary shocks and industry-specific effects, but their results are not shown.

In all cases the hypotheses of GMM estimator were satisfied. That is to say, the Sargan test validated the lagged variables as instruments given that the assumption that they are uncorrelated with the error term (e.g. for dependent variable ROA, p = 0.953 for the regression of SMEs and p = 0.737 for large firms) is not rejected. The tests AR (2) indicate no problems of second order autocorrelation.

The independent variables used are significant together (except for large firm *ROA)* as shown by the Wald tests (jointly) which reject, in all cases, the null hypothesis of joint insignificance of the regressors. Temporal and sectoral effects, however, do not seem to have an influence on the dependent variables as the Wald tests (dummies and time) do not reject, in most cases, the insignificance of the dummies to a level of 5%

As for the hypotheses proposed, statistical evidence is only found for Hypothesis 1a, mainly for SMEs and for external expenditure on R&D; in the regressions with dependent variable *ROA*, the $exRDS_{t-2}$ variable takes the value 5.721 for SMEs and is significant at 1%; for large firms the coefficient 0.579 is much smaller and only significant at 10%.

Quantile regressions, discussed below, allow for exploration in more detail of the impact of the explanatory variables.

5.1. Effects of R&D and capital on profitability

Quantile regressions were carried out considering 5 values of τ, i.e. the quantiles 10%, 25%, 50%, 75% and 90%. Table 3 presents the results offered by the response of the explanatory variables at different points in the conditional distribution of *ROA* ratio. Temporal and sectoral variables were included in all regressions, and are significant but are omitted for the sake of brevity. The dependent variable lagged one year, ROA_{t-1}, is always significant and positive, reflecting the persistence of corporate profitability. In this vein, several empirical studies have confirmed this hypothesis: Geroski and Jacquemin (1988) for manufacturing companies of various sectors of France, Germany and the UK, Odagiri and Yamawaki (1990) for Japanese manufacturers and Bentzen et al. (2005) for sectoral aggregates in Denmark.

The use to which quantile regressions are put in this study allows it to be shown, in addition, that the ROA_{t-1} is increasing. Thus profitability not only has a positive effect in the following years, this process becomes ever more important as the profitability of the firm increases. In the SMEs this persistence has an impact that is perhaps higher and more stable; the ROA_{t-1} remains stable, around 0.33, in the first three regressions and later increases to 0.38 and 0.55 in the last two. In large firms the amount is somewhat lower but the persistence of profitability continues to grow with coefficients ranging from 0.197 (25% quantile) to 0.443 (90% quantile).

More surprising still is that the dependent variable lagged two years, ROA_{t-2}, is also significant and positive. In the large firms this is the case in the 5 regressions and the coefficient also increases until the 0.75 quantile. In SMEs it is also significant and positive from the median regression. An interesting way to delve deeper into these issues is to study the factors that explain the persistence of profitability. In this regard, Waring (1996) from a large sample of U.S. companies, concluded that the intensity of R&D is, among others, one of the variables with the greatest impact on the persistence in time of high profits. Maruyama and Odagiri (2002), however, relate the persistence of the results to market power.

Regarding external R&D spending costs, it was found that lagged 2 years $exRDS_{t-2}$ has a positive impact on profitability, but with different effects on SMEs and large firms and in the higher and lower parts of the distribution. For example, in SMEs $exRDS_{t-2}$ is significant at the top, from quantile 0.50, and the coefficients are high. In large companies, the values are much smaller and $exRDS_{t-2}$ is significant only at the bottom of the distribution, but the effects of the external R&D impact earlier on profitability, and so $exRDS_{t-1}$ is shown to have a significant and positive influence, although slightly decreasing, on profitability. Therefore, the only companies for which Hypothesis 1a for external R&D is not confirmed are SMEs with low profitability. These results are consistent with those of Bonte (2003) who showed, at the sectoral level, a clearly positive relationship between external R&D and productivity in German manufacturing industries.

With regard to internal R&D hardly any evidence was found of its effects on profitability. Only in the case of SMEs were positive effects found for the less profitable amongst them: quantile 0.10 $inRDS_{t-2}$ is significant (p=0,012) and quantile 0.25 (p=0,073). Hypothesis 1a for internal R&D is rejected in line with other authors (Christensen, Rama, Von Tulzeman, 1996; Rama, 1996; Pavitt, 1984) who indicate that in the agri-food industry, R&D is normally acquired outside the sector in the form of biotechnology, process engineering or information technology.

In any case external and internal R&D were not found to be significant and positive together in any quantile. This may be explained by the fact that this kind of firm only has the capacity for one kind of R&D (as argued by Veugelers and Cassiman,1999, in the case of Belgian firms). However, this lack of simultaneity between external and internal R&D could be common in other low technology industries (Audretsch et al., 1996) and industries with internal R&D intensity (Lokshin et al.,2008).

However, it may also be the possible that internal R&D has an indirect influence on results through its role in the assimilation of new equipment and technologies (Griffith et al., 2004) and human capital formation. With regard to the *InvEA* variable, it can be seen that it is significant and positive in virtually all regressions. In the case of SMEs the *InvEA* coefficients grow until the 0.75% quantile. Its impact can thus be seen, in the form of an inverted U shape, with the bulk of the distribution increasing. In the large firms the effect on profitability is larger in size but decreasing. Hypothesis 2a is accepted: investment in equipment helps maintain or improve business results.

5.2. Profitability as a driver for R&D

Table 4 provides the results of some regressions that take external and internal R&D expenditures as dependent variables. Only those corresponding to large firms and the high part of the distribution are shown, quantiles 0.75 and 0.90. As is apparent, there is only significance for the lagged dependent variable. Hypothesis 1b, that holds that the most profitable firms invest more heavily in external and/or internal R&D is therefore rejected. Thus investment in R&D could also be motivated by other business objectives such as growth and competitiveness (Verhees et al., 2004; Blesa and Ripollés, 2005; Olavarrieta and Friedman, 2008), or by motives connected to the business environment (de Noronha et al., 2006; Gellynck et al., 2007).

5.3. Effects of internal and external R&D on capital investments

Table 5 presents the quantiles that take accumulated investment in equipment as a dependent variable. Hypothesis 2b on the effect of internal and external R&D on spending on capital equipment is not rejected but this effect is uneven across capital spending.

Thus in the lower part of the distribution it seems that external R&D has a positive influence: in SMEs $exRDS_{t-1}$ is significant in the 0.10 quantile and $exRDS_{t-2}$ in the 0.25 one while in the case of large firms both $exRDS_{t-1}$ and $exRDS_{t-2}$ are significant in the 0.10 quantile. Nevertheless, at the top of the distribution there are some significant negative values: $exRDS_{t-1}$ in the 0.75 quantile and $exRDS_{t-1}$ and $exRDS_{t-2}$ in the 0.90 quantile for SMEs and $exRDS_{t-2}$ for large firms in the 0.90 quantile. This would point to external R&D and investments in equipment being simultaneous for low investment levels but this relationship disappears when the latter variable reaches certain levels

Internal R&D also has a positive effect on capital but this is mainly in large firms and in the middle of the distribution: $inRDS_{t-1}$ is significant in the 0.50 and 0.75 quantiles and $inRDS_{t-2}$ to a lesser degree in SMEs, quantile 0.90. That internal R&D may have an indirect effect on profitability through physical capital.

These results are in line with those of Lach and Schankerman (1989) and Lach and Rob (1996) who found that R&D positively affects capital investment (but not vice versa). However, Traill and Meulenberg (2002), for European food companies, concluded that there is no such correlation. This would not be in contradiction with the results obtained in this present study, because the regression to the mean may hide different types of relationships that are revealed using quantile regressions and the breakdown of R&D.

TABLE 2

Generalized method of moments estimations, GMM-SYS (second step)

	SME			Large	
	DEPENDENT VARIABLE: ROA_t				
	coefficient	**std dev**		**coefficient**	**std dev**
ROA_{t-1}	0.360	0.068	**	-0.036	0.097
ROA_{t-2}	-0.024	0.057		0.012	0.071
$exRDS_{t-1}$	-1.471	0.273	**	0.843	0.373*
$exRDS_{t-2}$	5.721	0.236	**	0.579	0.319+
$inRDS_{t-1}$	0.042	0.762		-2.773	1.753
$inRDS_{t-2}$	0.596	0.980		-0.393	1.042
InvEA	0.089	0.154		0.430	0.249+
TAL	0.001	0.000		0.000	0.000
Tests	**value**	**prob**		**value**	**prob**
Wald (joint): $\chi^2_8 =$	896.8	0.000	**	16.11	0.041*
Wald (dummies): $\chi^2_9 =$	19.91	0.018	*	11.65	0.234
Wald (time): $\chi^2_7 =$	15.23	0.033	*	4.631	0.705
Sargan: $\chi^2_{76} =$	56.57	0.953		67.83	0.737
AR(2) : N(0,1)	-0.3895	0.697		0.4319	0.666
	DEPENDENT VARIABLE: $exRDS_t$				
	coefficient	**std dev**		**coefficient**	**std dev**
$exRDS_{t-1}$	0.062	0.089		0.005	0.014
$exRDS_{t-2}$	0.002	0.013		-0.062	0.019**
ROA_{t-1}	0.000	0.001		-0.003	0.003
ROA_{t-2}	-0.002	0.001		-0.001	0.003
$inRDS_{t-1}$	0.180	0.134		0.210	0.134
$inRDS_{t-2}$	0.109	0.150		0.106	0.093
InvEA	-0.001	0.004		0.006	0.011
TAL	0.000	0.000		0.000	0.000
Tests	**value**	**prob**		**value**	**prob**
Wald (joint): $\chi^2_8 =$	27.97	0.000	**	174.5	0.000**
Wald (dummies): $\chi^2_9 =$	4.328	0.889		10.61	0.303
Wald (time): $\chi^2_7 =$	4.259	0.749		9.411	0.224
Sargan: $\chi^2_{76} =$	74.89	0.515		75.4	0.498
AR(2) : N(0,1)	0.3425	0.732		-1.012	0.311

TABLE 2 (continuation)

Generalized method of moments estimations, GMM-SYS (second step)

	SME		**Large**	
	DEPENDENT VARIABLE**:** $\boldsymbol{inRDS_t}$			
	coefficient	**std dev**	**coefficient**	**std dev**
$inRDS_{t-1}$	0.237	0.101*	0.274	0.077**
$inRDS_{t-2}$	0.013	0.071	0.011	0.043
ROA_{t-1}	0.001	0.001	-0.004	0.003
ROA_{t-2}	0.000	0.001	-0.005	0.004
$exRDS_{t-1}$	0.027	0.041	-0.044	0.035
$exRDS_{t-2}$	0.005	0.006	-0.023	0.021
InvEA	0.003	0.003	0.002	0.010
TAL	0.000	0.000	0.000	0.000**
Tests	**value**	**prob**	**value**	**Prob**
Wald (joint): χ^2_8 =	28.5	0.000**	232	0.000**
Wald (dummies): χ^2_9 =	7.899	0.544	6.137	0.726
Wald (time): χ^2_7 =	6.933	0.436	4.2	0.756
Sargan: χ^2_{76} =	74.65	0.522	60.94	0.896
AR(2) : N(0,1)	-0.9571	0.339	0.1239	0.901
	DEPENDENT VARIABLE**:** $\boldsymbol{InvEA_t}$			
	coefficient	**std dev**	**coefficient**	**std dev**
ROA_{t-1}	0.033	0.082	-0.025	0.060
ROA_{t-2}	-0.048	0.050	-0.095	0.089
$exRDS_{t-1}$	-0.187	0.359	0.209	0.456
$exRDS_{t-2}$	-0.661	0.345+	0.274	0.653
$inRDS_{t-1}$	-0.372	0.852	2.580	1.740
$inRDS_{t-2}$	2.209	2.746	1.744	0.927+
TAL	0.000	0.000	0.000	0.000
Tests	**value**	**prob**	**value**	**prob**
Wald (joint): χ^2_8 =	50.58	0**	30.78	0**
Wald (dummies): χ^2_9 =	99.37	0**	35.32	0**
Wald (time): χ^2_7 =	71.21	0**	33.36	0**
Sargan: χ^2_{77} =	61.79	0.897	65.07	0.832
AR(2) : N(0,1)	1.047	0.295	0.3894	0.697

These estimates were obtained using Ox 5.10 software (Doornik 2007) jointly with the package DPD (Doornik et al., 2006).
All regressions include dummies for years and activities (3 dígits, CNAE-93).
Asterisks indicate significance at 10% (+), 5% (*) y 1% (**).

TABLA 3

Quantile regression estimations. Dependent variable ROA_t

		SME			Large		
Quantile	Variable	coefficient	std dev		coefficient	std dev	
0.1	ROA_{t-1}	0.338	0.035	**	-0.002	0.061	
	ROA_{t-2}	-0.012	0.048		0.129	0.042	**
	$exRDS_{t-1}$	-1.497	4.778		1.588	0.288	**
	$exRDS_{t-2}$	2.970	5.990		1.814	0.301	**
	$inRDS_{t-1}$	1.288	0.960		-0.167	0.543	
	$inRDS_{t-2}$	1.947	0.774	*	-0.729	1.123	
	InvEA	-0.008	0.038		0.196	0.048	**
	TAL	0.000	0.000		0.000	0.000	**
0.25	ROA_{t-1}	0.326	0.031	**	0.197	0.076	**
	ROA_{t-2}	0.069	0.044		0.134	0.054	*
	$exRDS_{t-1}$	-1.463	0.303	**	1.478	0.344	**
	$exRDS_{t-2}$	1.799	4.064		1.274	0.367	**
	$inRDS_{t-1}$	0.442	0.941		-0.268	0.607	
	$inRDS_{t-2}$	1.372	0.765	+	-0.159	0.712	
	InvEA	0.058	0.026	*	0.207	0.043	**
	TAL	0.000	0.000		0.000	0.000	**
0.5	ROA_{t-1}	0.331	0.027	**	0.343	0.107	**
	ROA_{t-2}	0.134	0.040	**	0.202	0.086	*
	$exRDS_{t-1}$	-1.719	0.326	**	1.275	0.385	**
	$exRDS_{t-2}$	5.693	0.331	**	0.901	0.420	*
	$inRDS_{t-1}$	-0.753	0.554		-0.333	0.643	
	$inRDS_{t-2}$	0.562	0.710		-0.194	0.745	
	InvEA	0.095	0.023	**	0.189	0.041	**
0.75	*ROAt-1*	0.384	0.052	**	0.398	0.103	**
	ROAt-2	0.129	0.047	**	0.325	0.097	**
	exRDSt-1	-2.084	0.277	**	1.047	0.334	**
	exRDSt-2	5.351	0.283	**	0.600	0.367	
	inRDSt-1	-1.130	0.522	*	-0.422	0.606	
	inRDSt-2	-0.005	0.589		-0.209	0.635	
	InvEA	0.125	0.025	**	0.150	0.037	**
	TAL	0.000	0.000	**	0.000	0.000	*
0.9	ROA_{t-1}	0.550	0.112	**	0.443	0.079	**
	ROA_{t-2}	0.069	0.041	+	0.247	0.087	**
	$exRDS_{t-1}$	-2.403	0.310	**	0.832	0.272	**
	$exRDS_{t-2}$	5.236	0.287	**	0.302	0.288	
	$inRDS_{t-1}$	-0.396	1.362		-0.646	0.534	
	$inRDS_{t-2}$	-2.240	0.624	**	2.243	2.675	
	InvEA	0.065	0.036	+	0.161	0.051	**
	TAL	0.000	0.000	**	0.000	0.000	**

These results were obtained with R program (R Dev. Core Team , 2008) and package quantreg (Koenker, 2008). Asterisks indicate significance at 10% (+), 5% (*) y 1% (**).

TABLA 4

Quantile regression estimations. Dependent variable $exRDS_t$ Y $inRDS_t$

Quantile	Variable	Large coefficient	std dev		Large coefficient	std dev	
		$exRDS_t$			$inRDS_t$		
0.75	ROA_{t-1}	0.000	0.000		0.000	0.000	
	ROA_{t-2}	0.000	0.000		0.000	0.000	
	$exRDS_{t-1}$	0.715	0.107	**	-0.002	0.002	
	$exRDS_{t-2}$	0.286	0.158	+	0.007	0.048	
	$inRDS_{t-1}$	0.018	0.038		0.885	0.033	**
	$inRDS_{t-2}$	-0.003	0.034		0.134	0.051	**
	InvEA	0.000	0.000		0.000	0.000	
	TAL	0.000	0.000		0.000	0.000	
0.9	ROA_{t-1}	0.000	0.000		0.000	0.001	
	ROA_{t-2}	0.001	0.001	*	0.000	0.001	
	$exRDS_{t-1}$	0.624	0.211	**	-0.004	0.005	
	$exRDS_{t-2}$	0.694	0.252	**	0.202	0.398	
	$inRDS_{t-1}$	0.257	0.248		0.882	0.072	**
	$inRDS_{t-2}$	-0.060	0.102		0.234	0.199	
	InvEA	0.000	0.000		0.000	0.001	
	TAL	0.000	0.000		0.000	0.000	

TABLA 5

Quantile regression estimations. Dependent variable $InvEA_t$

		SME			Large		
Quantile	Variable	coefficiente	std dev		coefficiente	std dev	
0.1	ROA_{t-1}	0.010	0.043		0.030	0.047	
	ROA_{t-2}	0.009	0.040		0.047	0.044	
	$exRDS_{t-1}$	1.331	0.444	**	1.156	0.378	**
	$exRDS_{t-2}$	-1.026	14.067		0.968	0.384	*
	$inRDS_{t-1}$	0.454	3.896		1.720	4.151	
	$inRDS_{t-2}$	-0.509	1.400		-2.604	4.176	
	TAL	0.000	0.000	**	0.000	0.000	
0.25	ROA_{t-1}	-0.020	0.049		0.077	0.055	
	ROA_{t-2}	0.036	0.039		0.066	0.056	
	$exRDS_{t-1}$	0.685	0.561		0.293	1.107	
	$exRDS_{t-2}$	1.303	0.567	*	0.699	0.554	
	$inRDS_{t-1}$	0.758	1.350		1.124	5.595	
	$inRDS_{t-2}$	-0.416	1.670		-3.262	5.579	
	TAL	0.000	0.000		0.000	0.000	
0.5	ROA_{t-1}	0.057	0.067		0.198	0.080	*
	ROA_{t-2}	0.044	0.044		0.160	0.074	*
	$exRDS_{t-1}$	0.075	0.737		0.533	0.724	
	$exRDS_{t-2}$	0.788	0.766		0.255	0.726	
	$inRDS_{t-1}$	0.915	1.797		4.117	1.221	**
	$inRDS_{t-2}$	1.194	2.256		-2.071	5.281	
	TAL	0.000	0.000	+	0.000	0.000	
0.75	ROA_{t-1}	0.023	0.058		0.251	0.160	
	ROA_{t-2}	0.124	0.070	+	0.257	0.170	
	$exRDS_{t-1}$	-1.054	0.593	+	-0.056	0.617	
	$exRDS_{t-2}$	-0.238	0.633		-0.409	0.627	
	$inRDS_{t-1}$	-0.518	1.517		3.089	0.959	**
	$inRDS_{t-2}$	1.512	2.111		4.325	5.794	
	TAL	0.000	0.000	*	0.000	0.000	**
0.9	ROA_{t-1}	0.047	0.068		0.497	0.236	*
	ROA_{t-2}	0.106	0.110		0.445	0.209	*
	$exRDS_{t-1}$	-1.914	0.498	**	-0.400	0.557	
	$exRDS_{t-2}$	-1.092	0.469	*	-1.156	0.629	+
	$inRDS_{t-1}$	-2.640	1.726		1.404	0.940	
	$inRDS_{t-2}$	11.256	6.603	+	7.931	6.782	
	TAL	-0.001	0.000	**	0.000	0.000	**

6. Conclusions

An empirical study was carried out on the relationship between internal and external R&D and profitability for a set of over 400 Spanish food companies in the period 2000-2008 using data from the *Encuesta de Estrategias Empresariales en España* [Survey of Business Strategies in Spain]. Given the asymmetry of the variables, the methodology chosen was to use quantile regression, which is more appropriate in cases of non-normality. Furthermore, this technique offers the possibility of quantifying the effect of the regressors at different points in the domain of the dependent variable.

It was found that the ROA variable is persistent over time and once a certain level of profitability is reached, it produces a permanent effect the following year. An interesting avenue for future research would be to analyze the factors leading to this persistence of profitability.

Statistical evidence was found that the external spending on R&D positively affects profitability, not immediately but with a lag of up to two years. In large companies external R&D, lagged a year or two, always has a positive and significant impact, although this decreases with increasing profitability. In the case of SMEs, external R&D is significant in the middle and upper part of the conditional distribution of ROA. It therefore seems necessary to have some level of profitability or be a large business for the external R&D to have an impact on results. The practical implication of this conclusion would be to indicate that the necessity to encourage, promote and encourage external R&D spending in the agri-food industry is especially critical as it has a positive impact in the medium term, but this must be done from a baseline of profitability higher than the industry average or from a firm size of greater than 200 employees. Doing R&D in the business itself is expensive and most businesses do not have the capacity to carry it out. For this reason many firms choose to outsource this task. The empirical results of this study support this idea, and show a greater effectiveness of outsourced R&D. This idea can be complemented by noting the increase in interest in the agri-food sector for other innovation options like open innovation (Lazzarotti et al., 2011, García et al., 2012 and Bayona et al., 2012) in businesses of all sizes. This may be explained by the changes that can be detected in some agri-food businesses that have stopped being dominated in terms of innovation by their suppliers and have come to be strongly influenced by science.

As in the case of other studies (Christensen, Rama, Von Tulzeman, 1996; Rama, 1996; Pavitt, 1984) that found the food industry relies more on innovation in other sectors in technological innovation than on its own efforts, no evidence was found of a direct effect of internal R&D. However, an indirect effect through investment in equipment cannot be discounted. In very few of the regressions performed was it found that both the internal and external R&D variable were significant. This may be due to the high level of competitiveness of research and development in biotechnology and process engineering. Nor were there indications found that profitability causes R&D. The idea was therefore rejected that greater profitably leads firms to invest more in internal or external R&D.

Investments in capital goods improves business performance; the impact on SMEs increases with increasing profitability while in large firms this effect is more significant and bigger in size, but declining. Therefore, the modernization of production processes remains an important way to increase competitiveness. This would explain the low proportion of firms undertaking R&D; firms perceive that they still have a long way to go in terms of acquisitions of capital which have a more direct impact on profitability, as well as being cheaper and more secure.

Finally, at the operational level it has been shown that the use of quantile regressions and the differentiated treatment of internal and external R&D allows for the obtaining of more robust estimations as well as providing a broader vision of the complex relations which exist between R&D, profitability and capital investment.

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