Patents, research & development and technological cooperation in the Spanish agri-food industry

Silverio Alarcón* and Luis González Polonio*

Jel Classification: O32, L66

Résumé

Cette étude vise à contribuer à la connaissance des processus d'innovation dans l'industrie agroalimentaire espagnole et plus précisément les innovations que les entreprises protègent par l'enregistrement de brevets et qui génère, sans aucun doute, une plus grande valeur ajoutée. Un panel de 439 entreprises a été utilisé pendant la période 1998-2008 ainsi que des estimations économétriques grâce à des modèles de données de comptage en panel. Las variables explicatives sont groupées en actifs d'innovation tout comme les activités de R&D ou de coopération technologique, et en actifs complémentaires tels que les ressources technologiques, humaines, commerciales, financières et en matière d'organisation. Les résultats indiquent que les brevets sont déposés aussi bien par les PME que par les grandes entreprises. Dans le cas des PME, la R&D interne joue un rôle décisif alors que dans le cas des grandes entreprises, la relation est plus forte avec la R&D externe. De façon plus réduite, les entreprises agroalimentaires ont aussi recours à la coopération technologique. Les ressources humaines et commerciales sont aussi des actifs liés aux brevets des grandes entreprises.

***Mots clés**: innovation, industrie alimentaire, ressources technologiques, données de comptage en panel.*

Abstract

The aim of this study is to contribute to advancing knowledge on the current innovation processes in the Spanish agri-food industry. It specifically looks into that area of innovation which firms protect through patent registration and which arguably generates the greatest added value. A panel of 439 firms over the 1998-2008 period was used to that end, as well as econometric estimations with panel count data models. The explanatory variables are grouped into innovation assets, such as R&D activity and technological cooperation, and complementary assets such as technological, organizational, human, commercial and financial resources. The results show that both SMEs and large firms choose to register patents. Internal R&D plays a decisive role in the case of SMEs whereas large firms have a stronger relationship with external R&D. Agri-food businesses often resort to technological cooperation as well, though to a lesser extent. Human and commercial resources are further assets associated with patenting in the case of large firms.

Keywords: innovation,food industry, technological resources, count panel data.

1. Introduction

Innovation is seen as an essential factor when it comes to improving business competitiveness in the industrial sector. Therefore, this activity is included within the range of factors that work as economic growth engines. Although not all the innovations carried out by firms are protected by patents, studying them allows for the differentiation of those innovation areas which can be measured more objectively and which arguably generate greater added value.

The agri-food industry is one of the strategic Spanish sectors given that in 2011 it represented 18.3% of sales and 16.7% of employment in the Spanish industry as a whole (INE, 2012). The importance of this sector becomes even greater if we look into the contribution it makes to the support of the population in disadvantaged areas of rural Spain providing economic activity and therefore demand for labor, which in turn favors the development of these areas. It is therefore critical for agri-food companies to increase their competitiveness in order to keep contributing to and promoting economic growth.

Firms can resort to various alternatives for improving competitiveness through innovation: R&D activity, technological cooperation with other firms and/or public bodies and to other types of internal resources such as investment in equipment, skilled workforce, etc. Although the bulk of practical research shows that R&D (Gopinath and Vasavada, 1999; Cabral and Traill, 2001; Traill and Muelenber, 2002; Batternik *et al*., 2006) and investment in technology (Rama, 1996; García and Burns, 1999; Huiban and Bouhsina, 1998; Cabral and Traill, 2001) are the main factors in the agri-food industry, there are other variables and circumstances which also influence the success of innovations protected by patents.

In this context, the aim of this study is to determine which are the factors associated with business innovation in the Spanish agri-food industry taking the registration of patents as an indicator of innovation. In other words, we aim at providing empirical evidence to enable reflecting upon those strategies that Spanish agri-food businesses put in place in order to promote the kind of innovation which adds greater value and generates higher competitiveness, namely innovation protected by patents.

The contribution of this study to the empirical literature is the following: (1) different types of innovation inputs are dealt with together, that is various types of R&D (external and internal), various types of technological cooperation (with suppliers, customers, competitors, universities and technological centers) and various types of internal resources (technological, human, commercial and financial); (2) a differentiated analysis is carried out according to the type of company –SME or large firm– through a period of

* Department of Agricultural Economics, Polytechnic University of Madrid, Spain.

stable growth of the economy, 1998-2008 and (3) robust econometric models are used (fixed effect and random effect count panel data).

The study is structured in the following way. First, the most relevant theoretical and empirical literature is reviewed and the practical application hypotheses are proposed. Next, methodological aspects such as the data base used, the selected variables and the estimated econometric specifications are presented. Following that, the estimations are presented and results are commented on and discussed. Finally, the main implications of the study are set out.

2. Background and hypothesis

2.1. Theoretical framework

Solow's (1957) neoclassical model emphasizes that 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, with technological innovation offsetting diminishing returns on increases in capital and labor. However, there is a wide variety of factors that influence the dissemination and adoption of innovations.

The resource-based view (Penrose, 1959; Wernerfelt, 1984) examines how firms obtain competitive advantages through strategies which promote the development of resources and capacities. Among the various categories of resources considered, we obviously find those related to innovation and R&D spending, though they are not independent of other resources that firms may possess. Christensen (1995) presents an integrated vision of technological innovation, holding that it is determined by the conjunction and inter-relation between innovation assets and complementary assets (marketing, distribution, after sales service, etc.). Exclusive consideration of R&D resources can lead to undervaluing or neglecting a handsome part of the technological efforts made by businesses. Innovation assets include scientific research, process development (machinery, production systems, organization, logistics, quality, etc.) and products (product engineering, materials, components, etc.) as well as resources directed to aesthetic design (both product and packaging). Complementary assets are also critical for innovation success as shown by Teece (1986), through many examples of businesses which failed to capture the benefits of their innovations given that other imitator companies were strong in complementary assets for those innovations.

Technological innovation is better understood through this wider vision of combining innovation and complementary assets rather than resorting exclusively to R&D intensity. The interest of the empirical research would be singling out the assets' combinations to be addressed in the context of the innovation strategies of businesses in different areas and situations, while inertia can also be important by its decisive role in spreading innovation (Cannarella and Piccioni, 2007). Christensen (1995) discusses different profiles of industrial innovation and holds that in agri-food businesses innovation is more focused on the development of products and aesthetic design. However, there also exists the possibility of innovation in intensive scale production processes and also innovation based directly on scientific research through the use of biotechnology.

2.2. Empirical research

There is a vast empirical literature which looks into innovation determinants regardless of the production activity carried out by the businesses analyzed, which leads to a failure to detect the effects of the innovation (de Jong and Vermeulen, 2006). The specificity of each sector is important as each one approaches innovation at a different pace and through different technological sources (Pavitt, 1984) and also because the capacity to capture the innovation-generated income is a function of factors dependent on the productive structure, on the nature of the technology and on the protection regime (Teece, 1986). Studying in more depth the behavior patterns of each industry allows for improving innovation promotion policies and business competitiveness.

This section reviews the empirical literature of the last few years, more specifically the most relevant contributions which look into those business resources which characterize the innovation capacity of the agri-food industry. An interesting question, both in practical and theoretical terms, and one regarding the answer to which there is no consensus, is how to measure business innovation. In a good part of the agri-food literature reviewed, this is approached on the basis of dichotomous variables which look at whether companies innovate in products and/or processes (García and Burns, 1999; Huiban and Bouhsina, 1999; Röder *et al*., 2000; Cabral and Traill, 2001; Brewin *et al.* 2009). These variables are generally the answers given by businesses themselves to surveys on innovation strategies. This leads to counting certain aspects which do not involve a real change in technology and which do not confer a competitive advantage for the sectors' innovation. Another alternative for measuring innovation is the number of patents registered (Rama, 1996; Gopinath and Vasavada, 1999; Alfranca *et al*., 2004), an option which some authors view as too restrictive, especially so in the case of the agri-food industry given that new products are developed at high speed (Brewin *et al*. 2009). This study nonetheless adopts this approach as it constitutes a more objective measure and is the part of the innovation which contributes the most to competitiveness and the generation of added value and profitability for businesses.

Notable among the variables used to explain business innovation are technology investment inputs (Rama, 1996; García and Burns, 1999; Huiban and Bouhsina, 1998; Cabral and Traill, 2001), R&D spending (Gopinath and Vasavada, 1999; Cabral and Traill, 2001; Traill and Muelenber, 2002; Batternik *et al.,* 2006), technological cooperation (Cabral and Traill, 2001; Batternik *et al*., 2006; Karantininis *et al*., 2010; Baviera-Puig *et al*., 2012, 2013) and the quality of labor (Avermaete *et al*., 2004; Huiban and Bouhsina, 1998).

Many studies look into firm size (Alfranca *et al*., 2004; Cabral and Traill, 2001; Hartland Herrmann, 2006; Huiban and Bouhsina, 1998; Karantininis *et al*., 2010) and into factors related to the competitive position of the firm and the connections it has developed with suppliers, clients and competitors. Among these are studies which have measured the following variables: market orientation (Batternik *et al*., 2006; Cabral and Traill, 2001), market power of producers (Gopinath and Vasavada, 1999; Hartland Herrmann, 2006; Weiss and Wittkopp, 2005), market power of retailers (Weiss and Wittkopp, 2005), market size (Röder *et al*., 2000), pressure from competitors (Brewin *et al*., 2009), vertical integration (Karantininis *et al*., 2010), product diversification (Hartland Herrmann, 2006; Röder *et al*., 2000), marketing (Avermaete *et al*., 2004), exports (Karantininis *et al*., 2010), and financial resources (Batternik *et al*., 2006).

2.3. Hypotheses

Based on this theoretical and empirical review, hypotheses related to innovation assets and complementary assets have been proposed. The former include R&D activity (hypothesis 1) and technological cooperation (hypothesis 2) which have been broken down into different categories. A positive relationship between these variables and innovation by means of patents is expected.

Hypothesis 1A: external R&D bears a positive relationship to patent registration in the Spanish agri-food businesses.

Hypothesis 1B: internal R&D bears a positive relationship to patent registration in the Spanish agri-food businesses.

Hypothesis 2A: cooperation with suppliers bears a positive relationship to patent registration in the Spanish agri-food businesses.

Hypothesis 2B: cooperation with customers bears a positive relationship to patent registration in the Spanish agri-food businesses.

Hypothesis 2C: cooperation with competitors bears a negative relationship to patent registration in the Spanish agri-food businesses.

Hypothesis 2D: cooperation with universities and technology centers bears a positive relationship to patent registration in the Spanish agri-food businesses.

The review above shows how investment in capital goods can lead to innovation. Therefore, a positive contribution is expected:

Hypothesis 3A: investment in capital goods bears a positive relationship to patent registration in the Spanish agri-food industry.

Some authors claim that large firms can better improve the organization and financing of their resources and that this in turn can increase the chance of their carrying out innovation activities (Schumpeter, 1934). However, other authors argue the opposite, that is, that large firms tend to be more rigid than small ones, the latter being more capable of adapting to the environment where they operate. Therefore, a relationship between size and patenting capacity is to be expected. A plausible possibility would be to expect the existence of a certain optimum size and that the relationship would be positive up to that size and then negative once it is exceeded. Either way, the hypothesis is formulated in more general terms:

Hypothesis 3B: firm size bears a significant relationship to patent registration in the Spanish agri-food industry.

Furthermore, hypotheses for human, commercial and financial resources have been included and they are expected to bear a positive relationship to patenting capacity:

Hypothesis 3C: the quality of human resources bears a positive relationship to patent registration in the Spanish agri-food businesses.

Hypothesis 3D: the quality of commercial resources bears a positive relationship to patent registration in the Spanish agri-food businesses.

Hypothesis 3E: the quality of human resources bears a positive relationship to patent registration in the Spanish agri-food businesses.

3. Methodology

3.1. Data base

The data base used in this study is taken from the *Encuesta Sobre Estrategias Empresariales*, ESEE, [Survey of Business Strategies], http://www.fundacionsepi.es/esee/sp. The survey is carried out on a representative sample of firms from all sectors of industry. From this database an initial sample of 449 different agri-food businesses was extracted. It is an unbalanced panel with information for the period 1998-2008. This panel was divided in two, one formed by SMEs (200 or less employees) with 68.2% of observations and the other for large ones (more than 200 employees) with 31.8%.

3.2. Variables

The number of patents (PAT) registered both in Spain and abroad has been taken as the dependent variable. We consider patent registration as an output indicator measuring truly innovative activity. It is a count variable i.e. it corresponds to the answer to the survey question regarding the number of patents presented each year. The firms in the sample registered 348 patents between 1998 and 2008, of which 41.1% were registered by SMEs and 58.9% by large firms. In other figures that would be: in this sector the average patent rate per company and year is 0.1489 (Table 1) and large firms have average rates (0.2740) three times higher than SMEs (0.0899). Therefore, it is clear that large firms patent more both in absolute terms and by company. However, many SMEs also register patents and together they represent more than 40% of the sample total.

Figure 1 shows the change in the number of patents registered both in Spain and abroad over the period analyzed. In percentage terms and in the Spanish agri-food sector, the number of patents registered in Spain for the eleven-year period studied is 50% vs. 30% registered abroad. For the industry as a whole the registered patents average percentage in Spain is 41% vs. 59% registered abroad.

We estimated the technological resources based on the efforts made by firms to carry out R&D activity by means of R&D external expenditure (*exRDS*) and R&D internal expenditure (*in RDS*). The ratios included in the analysis are the values of these variables divided by volume of sales:

$$exRDS = \frac{R\&D\ external\ expenditure}{sales}$$

$$inRDS = \frac{R\&D\ internal\ expenditure}{sales}$$

Figure 2 shows there is a higher number of firms with R&D internal expenditure than firms with external expenditure. Thus, the average percentage of firms with R&D external expenditure is 18.8% vs. 25.5% with R&D internal expenditure. However, there are large differences depending on firm size: very few SMEs carry out R&D, only 12.4% buy external R&D and only 13.6% carry out internal R&D vs. 58.7% and 89.0% respectively in the case of large firms.

Technological cooperation is represented by means of dummy variables which represent firm activity in cooperation with suppliers (*Csup*), with customers (*Ccos*), with competitors (*Ccom*) and with universities and /or technology centers (*Cins*). The change in the number of firms following these different cooperation strategies is shown also in Figure 2. The option with the highest number of firms is cooperation with universities and technology centers, 21.1% (Table 1), followed by technological cooperation with suppliers, 16.4%. Technological cooperation with customers comes in at 6.6% and with competitors 1.5%. As is the case of R&D, technological cooperation is much less frequent in SMEs (13.8%) than in large firms (56.1%).

Physical resources have been measured through the capital goods investment ratio with respect to the total assets of each firm for each year of the period studied. The annual average investment is 4.9% of the assets (Table 1).

$$InvEA = \frac{capital\ goods\ investment}{Assets}$$

Firm size was estimated through the total average labor variable (*TAL*) and given its high level of variability we have used logarithms.

Human resources were estimated through labor cost over sales (*LCS*). The higher the value for this variable the higher the quality of the human resources used by the firm.

$$LCS = \frac{labor\ costs}{sales}$$

Commercial resources are quantified through the propensity to export of each firm for each year of the period studied; more specifically, we used the percentage represented by exports in the total sales of each firm (*PX*).The firms in the sample export an average 11.6% of their total sales (Table 1). Again, differences according to size are considerable as 41.1% of SME exports vs. 88.1% in the case of large firms, whereas export sales represent an average of 8.7% of the total sales of SMEs vs. 17.6% in the case of large firms.

Two ratios have used for financial resources. First, working capital ratio on sales i.e. a liquidity indicator. Then, the total debt of each firm was calculated as the product of its liabilities (external funds) and the net equity (capital base).

Fig. 1. *Numbers of patents in Spain and abroad.*

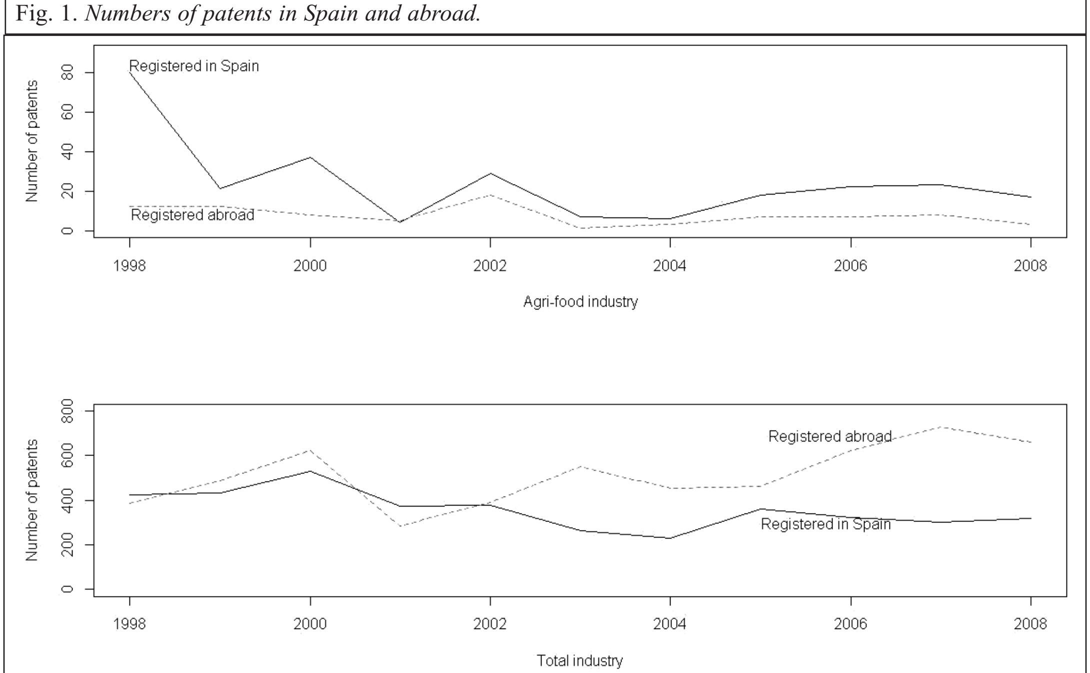


Table 1 - Summary statistics.

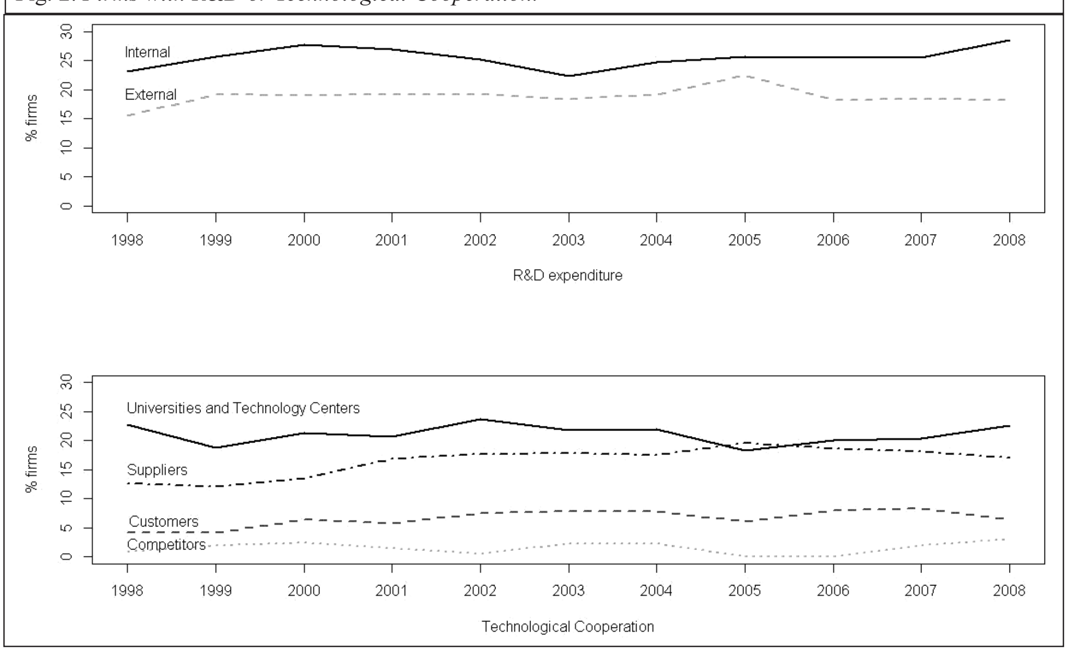
	Min	Mean	Median		Standard Deviation
PAT	0.00	0.15	0.00	32.00	1.18
exRDS	0.00	0.00	0.00	0.16	0.01
inRDS	0.00	0.00	0.00	0.08	0.00
Csup	0.00	0.16	0.00	1.00	0.37
Ccos	0.00	0.07	0.00	1.00	0.25
Ccom	0.00	0.02	0.00	1.00	0.12
Cins	0.00	0.21	0.00	1.00	0.41
InvEA	0.00	0.05	0.03	0.52	0.07
TAL	3.00	229.90	49.00	5291.00	433.66
LCS	0.70	20.24	15.70	83.10	14.00
PX	0.00	11.55	0.80	100.00	20.57
WCS	-2.65	0.14	0.08	14.21	0.45
Debt	0.00	4.49	1.23	1033.82	27.83

PAT (number of patents), exRDS (expenditures on external R&D divided by total sales), inRDS (expenditures on internal R&D divided by total sales), Csup, Ccos, Ccom, Cins (technological cooperation with suppliers, customers, competitors and institutions, respectively), InvEA (investment on equipment divided by total assets), TAL (total average labor), LCS (labor cost to sales), PX (percentage of exports over sales), WCS (working capital to sales), Debts (total debts to total equity).

$$WCS = \frac{current\ assets - short\ term\ external\ funds}{sales}$$

$$DEBT = \frac{liablilities}{net\ equity}$$

Fig. 2. *Firms with R&D or Technological Cooperation.*



3.3. Econometric model

The variable to explain the number of patents in Spain and abroad is a count variable which takes non-negative integer values. Therefore, rather than using ordinary least squares (OLS), it is better to use a model which takes into account that the dependent variable has been generated using a Poisson distribution expressing the probability of an event occurring in a specified time interval (Greene, 2008).

The specification used to carry out the empirical application is the following:

$$log\ (PAT_{it})$$
$$= \beta_0 + \beta_{1A} exRDS_{it} + \beta_{1B} inRDS_{it} + \beta_{2A} Csup_{it} + \beta_{2B} Ccos_{it} + \beta_{2C} Ccom_{it}$$
$$+ \beta_{2D} Cins_{it} + \beta_{3A} InvEA_{it} + \beta_{3B} \log TAL_{it} + \beta_{3C} LCS_{it} + \beta_{3D} PX_{it} + \beta_{3E} WCS_{it}$$
$$+ \beta_{3E*} DEBT_{it} + FIRM_i + YEAR_t \quad (1)$$

The sub-index$i$denotes firm ($i = 1,...,N$) and the sub-index t indicates year ($i = 1998,...,2008$). The coefficients β_{1A} and β_{1B} correspond to the Hypotheses H1 related to expenditure in R&D, β_{2A}, β_{2B}, β_{2C} and β_{1D} contrast the Hypotheses H2 on technological cooperation, and β_{3A}, β_{3B}, β_{3C}, β_{3D}, β_{3E}, y β_{3E*} establish the role of other complementary assets (Hypothesis H3).

Poisson regression models assume their mean and their variance are the same, and in the bulk of practical econometrics cases the variance is higher than the mean (overdispersion). This study uses robust overdispersion procedures. Moreover, the data structure of the panel permits improved results to be obtained by means of an estimation conditioned to the effects of each firm ($FIRM_i$) and of each year ($YEAR_t$). Both fixed effects and random effects models are estimated here and results are compared.

One other point to bear in mind is the possibility of including lagged regressors given that it seems logical that the effects of R&D and technological cooperation will become apparent years after they are carried out. However, Hall*et al*. (1986) show that R&D contemporary variables best explain patenting capacity.

4. Results

A first look at the correlations between PAT and explanatory variables (Table 2) shows that the bulk of them are positive except for human resources and working capital. There is also a positive correlation between R&D technological cooperation variables, the highest value being found between *i*n RDS and *Csup*, which reaches 0.673. More generally, 87.1% of patents are registered by firms which have at some point carried out some forms of R&D. In terms of technological cooperation, the percentage is 86.2%. Only 11.7%

Table 2 - *Spearman coefficients of correlation.*

	PAT	exRDS	inRDS	Csup	Ccos	Ccom	Cins	InvEA	TAL	LCS	PX	WCS	Debt
PAT	1.00												
exRDS	0.19	1.00											
inRDS	0.17	0.54	1.00										
Csup	0.18	0.53	0.67	1.00									
Ccos	0.17	0.37	0.42	0.52	1.00								
Ccom	0.11	0.20	0.18	0.24	0.35	1.00							
Cins	0.15	0.52	0.48	0.45	0.37	0.21	1.00						
InvEA	0.05	0.05	0.05	0.06	0.04	-0.03	0.04	1.00					
TAL	0.11	0.35	0.49	0.45	0.25	0.15	0.39	0.15	1.00				
LCS	-0.06	-0.21	-0.16	-0.17	-0.09	-0.04	-0.22	0.02	-0.28	1.00			
PX	0.09	0.28	0.36	0.29	0.17	0.09	0.27	-0.02	0.44	-0.42	1.00		
WCS	-0.03	0.02	0.06	0.04	0.01	0.06	0.01	-0.20	-0.06	0.03	0.04	1.00	
Debt	0.02	-0.04	-0.05	-0.06	-0.05	-0.03	-0.05	0.01	-0.01	-0.08	0.13	-0.50	1.00

Table 3 - *Estimates of the quasipoisson fixed effects regressions Dependent variable: number of patents.*

	SMEs			Large		
	Coefficient	SD		Coefficient	SD	
(Intercept)	-1.06	13740.00		-53.20	15330.00	
R&D activities						
exRDS	69.54	86.39		260.50	65.81	***
inRDS	54.79	25.28	**	24.34	18.58	
Technological cooperation						
Csup	-3.24	1.69	*	-0.15	0.43	
Ccos	-0.87	0.96		0.90	0.47	*
Ccom	1.96	0.74	***	1.97	0.80	**
Cins	-1.01	0.39	***	0.03	0.49	
Complementary assets						
InvEA	-3.32	2.29		-4.76	2.70	*
log(TAL)	-4.45	1.20	***	3.44	1.04	***
LCS	-0.04	0.06		0.17	0.09	*
PX	-0.02	0.03		0.08	0.03	**
WCS	0.54	0.41		1.55	1.51	
Debt	0.19	0.07	***	0.39	0.24	

Asterisks indicate significance at 10% (*), 5% (**) and 1% (***)

Table 4 - *Estimates of the quasipoisson random effects regressions Dependent variable: number of patents.*

	SMEs			Large		
	Coefficient	SD		Coefficient	SD	
(Int	-5.76	3.85		-23.95	4.67	***
R&D activities						
exRDS	7.87	79.05		111.50	37.89	***
inRDS	57.18	27.58	**	5.70	15.38	
Technological cooperation						
Csup	-1.59	1.20		0.11	0.38	
Ccos	-0.11	1.01		1.14	0.41	***
Ccom	1.80	0.93	*	0.61	0.61	
Cins	-0.52	0.45		0.23	0.42	
Complementary assets						
InvEA	-0.29	2.77		-3.53	2.42	
log(TAL)	-0.45	0.95		2.15	0.71	***
LCS	-0.10	0.06		0.04	0.07	
PX	0.01	0.03		0.06	0.02	**
WCS	0.17	0.48		1.52	1.09	

Asterisks indicate significance at 10% (*), 5% (**) and 1% (***)

of the patents were registered by firms which had never joined in R&D or technological cooperation activities. In spite of this correlation, the multicollinearity analysis of regressors (calculation of variance inflation factors for generalized linear models) shows that the recommended values (Neter *et al*., 1989) for R&D, technological cooperation and other complementary assets are not exceeded.

Tables 3 and 4 show the model results (1) estimated by fixed and random effects quassipoisson regression, respectively.

In relation to Hypothesis H1, both the fixed and random effects models show that external R&D in large firms and internal R&D in SMEs are positive and significant, even after controlling for the intrinsic factors of each firm. These results seem to be fairly robust and are in line with other studies on patents (Hall*et al*., 1986; Cincera, 1997). In the sector studied here, Gopinath and Vasavada (1999) for a panel of 32 American agri-food industries over the period 1970-1985 conclude that their results show a positive association between patenting and R&D and they also measure the spillover effects of R&D of the industry as a whole. Cabral and Traill (2001) in a sample of 242 Brazilian firms (1994-1996) also found that the probability of carrying out non-protected innovations is positively associated with R&D expenditure. However, Batterink *et al*. (2006) used 328 Dutch agri-food firms in 2001 but did not find any relationship with R&D expenditure. For Spanish agri-food firms, Triguero *et al*.(2013) show that R&D increase product innovation probability but to a lesser extent than for other manufacturing industries. The contribution of this study is the fact that it differentiates external and internal R&D as well as firm size. This allows us to underscore the role of internal R&D in the innovation processes of Spanish agri-food SMEs as opposed to other studies which highlight the higher level of innovation capacity of the European agri-food large firms (Huiban and Bouhsina, 1998; Traill and Muelenber, 2002). Our results are more in line with Alfranca *et al*. (2004) who, studying a group of multinational food and beverage companies, find that the companies which tend to register the most patents are not the largest ones but rather those with persistence in innovation.

In terms of technological cooperation, the cooperation with suppliers hypothesis is rejected (H2A); cooperation with customers (H2B) in large firms is accepted; cooperation with competitors (H2C) is accepted in SMEs (both fixed and random effects estimations are positive and significant) and likewise in large firms though to a lesser extent. The positive relationship of agri-food patents with cooperation with universities and technology centers (H2D) is rejected. Although these types of cooperation are carried out always with the aim of improving the innovating position of a firm, the results obtained are not always clear, as shown by Batterink *et al.* (2006), who examined these four kinds of technological cooperation and failed to find associations.

Although the propensity to vertical cooperation with suppliers and customers should be higher when exploitation goals prevail over exploration goals (Santamaría and Surroca, 2010), this study does not show effects as clear on innovation as those found by Karantininis *et al*. (2010) in their study of Danish agri-food industry. But R&D collaborations with customers appear to affect positively protected innovations, at least for large firms, which seems in accordance with the fact that the agri-food industry is a consumer-oriented sector.

Horizontal cooperation is more frequent in high-tech sectors (Arranz and Fdez de Arroyabe, 2008); however, the fact that this study finds a positive effect of cooperation with competitors in agri-food SMEs has great value as it confirms that public policies (E2I, 2010) to favor this kind of action are having positive effects.

As to complementary effects, only the (negative) effect of size (H3B) and the positive relationship with debt (H3E) in the estimation conditioned to fixed effects are accepted in SMEs, even though the random effects model does not show any significant coefficient. In large firms positive relationships with size (H3B) and commercial resources (H3D) are observed, likewise but to a lesser extent with human resources (H3C). These results would indicate that large firms have more access to the commercial and human resources necessary to cope with the risks and costs related to innovation (Karantininis *et al*., 2010).These findings could be pointingto the limited capacity of SME firms to attract qualified workers. They also give support to the recommendations of international organizations (i.e, OECD, 2010)in the sense that governmentsshould ensure education for forming human capitaland labour policies aimed at encouraging innovation.

Contrary to what Rama (1996) found for the period 1969-1988 on the role played by equipment suppliers in agri-food industry innovation, this study has not found evidence in that direction and HypothesisH3A is rejected.Other studies highlight the importance of this factor in non-protected product innovations (García and Burns, 1999) or even for firms results (Alarcón and Sánchez, 2013) but today capital goods investment does not seem to be a sufficient condition in itself for agri-food firms to increase their protected innovations.

5. Conclusions

Public and private innovation actions are essential for overcoming the economic crisis. Innovation involves more than R&D, and policy makersplay a crucial role by regulating frameworks, markets, institutions and networks that improve environment for innovation (OECD, 2010).In this context, the protection and management of intellectual property is the part of the innovation which contributes the mostto create value. This study confirms that R&D activity is the most important and direct way to register patents in the Spanish agri-food industry. Estimations show that R&D expenditure bears a clearly positive and significant relationship to patented innovation. Internal R&D shows greater effectiveness in SMEs whereas external R&D is more effective in large firms. Given that a high percentage of firms (approximately 50%) still fail to carry out R&D activity, this could be a possibility for many firms to establish competitive advantages. Arguably, not all firms will have this opportunity given that R&D activities tend to be costly, but our analysis reveals that it should not be restricted to large firms: SMEs also register patents and their internal R&D contributes to patenting.

Relationships between technological cooperation and patents are not as strong as is the case with R&D. Evidence in that regard is weaker but still should not be discarded. Results show the role played by vertical cooperation on the part of large agri-food firms, which reflects the efforts made to develop new products adapting the technical possibilities of firms to the needs of consumers. The development of new products frequently leads to patent registration.

Horizontal integration with competitors has proved to be positive and significant in SMEs and large firms once other factors have been controlled for. This type of technological cooperation, which is the least used by firms but constitutes nonetheless a way of promoting participation in R&D projects they would be unable to carry out on their own and appears as an additional or alternative way of patenting and gaining competitiveness for firms. Moreover, the main role of cooperation is not to save on costs, rather its capacity tobroaden the scale of a project orcomplement firms' competencies (OECD, 2010). Consequentlyit enables access to new ideas and procedures, and in turn contributes to developnew products or services. Taking into account that technological cooperation is not frequent within the agri-food industry (see Table 1), there is much room to promote these activities (partnerships, alliances, jointventures, networks, etc.)as a means to boosta culture of innovation.

The results confirm that universities and technological centers are underutilized as collaborators, and consequently policies aimed at promotingthe mobility of researchers between these institutionsandmanufacturing firms would strengthen the technological connection between the scientific community and the industry (Santamaría and Surroca, 2010). Also communications campaigns should be launchedto divulgetheir capabilities for technologicaltransfer.On the other hand, as supported by García Álvarez-Coque *et al*. (2013) the innovation in agri-food systems can be improved by providing access to training services and technological institutes.

In terms of complementary assets, no influence on propensity for patenting has been found in SMEs, but human and commercial resources do contribute to patenting in the case of large firms. Therefore, firm size seems to be an important factor which encourages businesses to organize their complementary resources in a more efficient way so that they can be used in partnership with innovation assets to register patents.

Acknowledgments

The authors express their gratitude for the funding received from Project AGL2012-39793-C03-01of the Ministerio de Economía y Competitividad of Spain. The first author thanks Ana Sánchez for her assistance.

References

Alarcón S. and Sánchez M., 2013. External and internal R&D, capital investment and business performance in the Spanish agri-food industry. *Journal of Agricultural Economics*, 64(3): 654-675.

Alfranca O., Rama R. and von Tunzelmann N., 2004. Innovation spells in the multinational agri-food sector. *Technovation,* 24(8): 599-614.

Arranz N. and Fdez de Arroyabe J. C., 2008. The choice of partners in R&D cooperation: An empirical analysis of Spanish firms. *Technovation*, 28(1), 88-100.

Avermaete T., Viaene J. and Morgan E.J., 2004. Determinants of product and process innovation in small food manufacturing firms. *Trends in Food Science & Technology,* 15(2004): 474-483.

Batterink M.H., Wubben E.F.M. and Omta S.W.F., 2006. Factors related to innovative output in the Dutch agrifood industry. *Journal of Chain and Network Science*, 6(1): 31-44.

Baviera-Puig A. Buitrago-Vera J. and Mas-Verdú F., 2012. Trade areas and knowledge-intensive services: the case of a technology centre. *Management Decision*, 50 (8): 1412–1424.

Baviera-Puig A., Roig-Tierno N.,Buitrago-Vera J. and Mas-Verdú F., 2013. Comparing trade areas of technology centres using 'Geographical Information Systems'. *The Service Industries Journal*, 33(7-8): 789-801.

Brewin D.G., Monchuk D.C. and Partridge M.D., 2009. Examining the adoption of product and process innovations in the Canadian food processing. *Canadian Journal of Agricultural Economics*, 57(1): 1744-7976.

Cabral J.E.O. and Traill W.B., 2001. Determinants of a firm's likelihood to innovate and intensity of innovation in the Brazilian food industry.*Journal on Chain and Network Science*, 1(1): 33-48.

Cannarella C. andPiccioni V., 2007. Barriers to innovation in rural enterprises: the strategy of "doing nothing". *New Medit*, 6(4): 54.

Christensen J.F., 1995. Asset profiles for technological innovation. *Research Policy*, 24(5): 727–745.

Cincera M., 1997. Patents, R&D, and technological spillovers at the firm level: some evidence from econometric count models for panel data. *Journal of Applied Econometrics*, 12(3): 265-280.

E2I, 2010. *Spanish innovation strategy*. Ministerio de Ciencia e Innovación, Gobierno de España. http://www.idi.mineco.gob.es/stfls/MICINN/Innovacion/FICHEROS/Spanish_Innovation_Strategy.pdf

García M. and J. Burns, 1999. Sources of technological development in the Spanish food & drink industry. A 'Supplier-dominated' industry. *Agribusiness,* 15(4): 431-448.

García Alvarez-Coque J.M., López-García Usach T. and Sánchez García M., 2013. Territory and innovation behaviour in agri-food firms:does rurality matter? *New Medit*, 12(3): 2-10

Gopinath, M. and Vasadava, U., 1999. Patents, R&D, and market structure in the U.S. food processing industr. *Journal of Agricultural and Resource Economics*, 24(1): 127-139.

Greene, W., 2008. *Econometric Analysis*. 7th ed. New Jersey: Prentice Hall.

Hartl J. and Herrmann R., 2006. The role of business expectations for new product introductions: a panel analysis for the German food industry. *Journal of Food Distribution Research*, 37(2): 12-22.

Hall B., Griliches Z. and Hausman J., 1986. Patents and R&D: Is there a lag? *International Economic Review*, 27 (2): 265–283.

Huiban J.P. and Bouhsina Z., 1998. Innovation and the quality of labour factor: An empirical investigation in the French food industry. *Small Business Economics*, 10(4): 389-400.

Karantininis K., Sauer J. and Furtan W.H., 2011. Innovation and integration in the agri-food industry. *Food Policy*, 35(2): 112-120.

INE, 2012. *Encuesta Industrial de Empresas 2011*. http://www.ine.es/prensa/np755.pdf

de Jong J.P.J. and Vermeulen P.A., 2006. Determinants of product innovations in small firms. A comparison across industries. *International Small Business Journal*, 24(6): 587-609.

Neter J., Wasserman W. and Kutner, M. H. (1989). *Applied linear regression models*. Homewood, IL: Irwin.

OECD, 2010. *Ministerial Report on the OECD innovation strategy, innovation to strengthen growth and address global and social challenges - key findings*. Paris: OECD. www.oecd.org/innovation/strategy.

Pavitt K., 1984. Sectoral pattern of technological change: towards a taxonomy and theory. *Research Theory*, 13(6): 343-373.

Penrose E. T., 1959. *The theory of the growth of the firm*. New York: John Wiley.

Rama R., 1996. Empirical study on sources of innovation in international food and beverages industry. *Agribusiness*, 12(2):123–134.

Röder C., Herrmann R. and Connor J. M., 2000. Determinants of new product introductions in the US food industry: A panel-model approach. *Applied Economics Letters*, 7(11): 743–748.

Schumpeter J.A., 1934. *The theory of economic development*. Cambridge, MA: Harvard University Press.

Solow R.M., 1957. Technical change and the aggregate production function. *Review of Economics and Statistics*, 39(3): 312-20.

Santamaria L. and Surroca J., 2011. Matching the goals and impacts of R&D collaboration. *European Management Review*, 8(2), 95-109.

Teece D.J., 1986. Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. *Research Policy*, 15(6): 285-305.

Traill W.B. and Meulenberg M., 2002. Innovation in the food industry. *Agribusiness*, 18(1): 1-21.

Triguero Á., Córcoles, D. and Cuerva M. C., 2013. Differences in innovation between food and manufacturing firms: an analysis of persistence.*Agribusiness,* 29 (3): 273-292.

Weiss C. R. and Wittkopp A., 2005. Retailer concentration and product innovation in food manufacturing. *European Review of Agricultural Economics*, 32(2): 219-244.

Wernerfelt B.,1984. The resource-based view of the firm. *Strategic Management Journal*, 5(2): 171-180.