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The public funding of innovation in agri-food businesses

Silverio Alarcón and Pedro Arias

Universidad Politécnica de Madrid, Dept. Agricultural Economics, Statistics and Business Management. Ciudad Universitaria s/n, 28040 Madrid, Spain.

Abstract

Public administrations have in recent years developed programs of public funding for innovation to boost the competitiveness of business. The study of how companies have used these funding sources generates knowledge to improve the design of support for private innovation and to provide advice for innovative companies. This paper investigates these issues in the agri-food sector which is of particular interest as it is comprised mainly of small and medium enterprises with a wide regional presence and interaction with their local environment. A survey on technological innovation was used to estimate panel logit models with random effects, taking as dependent variables three types of funding: regional, state and European Union. The results generally show a positive relationship between innovation efforts and access to public funding, but also significant differences between types of funding and between sectors. Food companies that obtain public funding tend to have a more innovative profile than Agriculture ones. Both types of firm present higher probabilities than others companies when it comes to gaining access to regional funding, though the opposite often occurs in the case of state funding. Firm size is not significant for regional funding and no overlap was detected between regional and state funding. The financial crisis has adversely affected regional and national aid, which experienced a significant decrease in the period from 2008 to 2013.

Additional keywords: innovation policy; subsidies; random panel logit.

Abbreviations used: Ci (capital intensity); CNAE (National Classification of Economic Activities); coopera (technological cooperation); EU (European Union); EUpf (EU public funding of innovation); exRD (external R&D); inRD (internal R&D); logit RE (logit random effects); PITEC (Community Innovation Survey on Spanish Firms); R&D (research and development expenditures); Rpf (regional public funding of innovation); SME (small and medium enterprise); Spf (state public funding of innovation).

Authors´ contributions: Conception and design: SA. Data search, quantitative analysis and writing: SA and PA. Both authors read and approved the final manuscript.

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Correspondence should be addressed to Silverio Alarcón: silverio.alarcon@upm.es

Introduction

In recent years public administrations have sought to become involved in promoting innovation by private firms. This opens ways to strengthen those parts of the economy based on knowledge, quality employment and greater capacity for internationalization. The Spanish Strategy for Science and Technology and Innovation 2013-2020 (MEC, 2012) is the current framework in Spain for strengthening these elements and to coordinate all relevant actors so that economic and social returns are maximized.

As a result of these activities, companies have access to comprehensive and varied programs to support private innovation (Fernández-Ribas, 2009). Empirical research on the different sources of public funding for innovation are key aspects that can improve the design of private innovation. Given the heterogeneity of the production processes of the various industries some authors (Pavitt, 1984; Blanes & Busom, 2004; De Jong & Vermeulen, 2006) have recommended studies for each sector on innovation and its funding.

Thus, other empirical studies have shown the greatest social impact of studying innovation in the agri-food sector as a result of its territorial implantation (Garcia Alvarez-Coque *et al.*, 2013) and interaction with the environment (De Noronha *et al.*, 2006). In addition, the fact that small- and medium-sized firms predominate leads to the importance of knowledge networks and public programs to access innovation (Garcia Alvarez-

Coque *et al.*, 2015). Moreover, innovation in this industry has increased in recent years due to increased demand for quality, organic and functional products (Traill & Meulenberg, 2002; Filippaios *et al.*, 2009).

Public funding for innovation in the agri-food sector has not been a widely discussed topic in the empirical literature, the exception being work related to the increasing role of public-private partnerships as a mechanism to involve different agents, share risks, disseminate results and increase funding (Alston & Gray, 2013; Fuglie & Toole, 2014; Garcia Alvarez-Coque *et al.*, 2015; FAO, 2015; Moreddu, 2016). However, there are few studies comparing different types of public funding of innovation in the agri-food sector. We therefore consider it of interest to fill this gap, and try to answer the following questions: What kind of innovative agri-food companies have access to public funding of innovation? How important are the characteristics of each firm in making the decision to apply for this funding? Are there differences between agri-food companies and those involved in other activities in their access to the various programs? Are there territorial differences? Is there overlapping between various public programs or are they aimed at different groups? Has the financial crisis negatively affected the availability of public subsidies for innovation?

The Community Innovation Survey on Spanish firms (PITEC) has been used to answer these questions as it provides information on innovation by firms in different sectors of economic activity. The main contributions of this study are: (1) three data panels have been extracted from PITEC data in the period 2008-2013 (agricultural companies, food and other sectors) and these were studied separately in order to allow for differences and similarities in innovative behaviour according to production activities to appear, (2) in each of them three dependent variables are used covering public funding of innovation from the regional, state and European Union (EU) levels, and this makes it possible to compare alternative sources of funding; and (3) logit regression panel models with random effects, of which little use has been made for analyzing financial innovation, are employed here as they significantly improve the modelling of the intrinsic factors of each company.

Material and methods

Background and hypothesis

The various levels of government focus their programs on promoting private innovation with diverse objectives (Blanes & Busom, 2004). These include: reducing failures in the capital market, promoting large national projects, and fostering technological development in traditional or declining sectors that are considered to be of strategic importance. Each region has its own social, economic and productive characteristics leading it to promote policies that address these characteristics and mobilize the agents and resources to produce positive effects in the generation of knowledge, innovation and value (García-Quevedo & Afcha, 2009). Currently the administrative powers regarding innovation are shared between the regions and the central government. The role of regional governments is important because in addition to developing their own policies, they manage EU projects and thus they are sometimes also responsible for carrying out state actions (Altuzarra, 2010).

Moreover, the principle of subsidiarity in the EU means that it must act when lower levels of government are unwilling or unable to. In this regard, the innovation policies of the EU would be justified in relation to the promotion of economies of scale and cross-border effects (Busom & Fernández-Ribas, 2007). This leads to its various programs benefiting companies with different characteristics and problems, and therefore it makes sense to estimate a model of participation for each level of administration.

Empirical studies often compare different levels of aid, the national and the regional in some cases (Blanes & Busom; 2004; García-Quevedo & Afcha, 2009); others include the EU (Busom & Fernández-Ribas, 2007; Altuzarra, 2010; Guisado-González *et al.*, 2013). Most of these studies look at the companies involved as a whole, and some use dummy variables to analyse different types of industries (Blanes & Busom, 2004). However, innovation is itself a very different activity depending on the productive sector being considered and therefore the needs for technological resources and funding can vary greatly (Pavitt, 1984). Hence the recommendation to look more deeply at the behaviour of each sector arises as a study that does not distinguish between productive activities can mask what is happening in each of them (De Jong & Vermeulen, 2006). These authors stress the need for studies to identify distinct characteristics and sectorial strategies in relation to research and development expenditures R&D.

The explanatory variables most frequently used are related to innovation inputs such as R&D (Blanes & Busom, 2004; Busom & Fernández-Ribas, 2007; Fernández-Ribas, 2009; Garcia-Quevedo & Afcha, 2009; Altuzarra, 2010; Guisado-González *et al.*, 2013) and technological cooperation (García-Quevedo & Afcha, 2009; Altuzarra, 2010; Guisado-González *et al.*, 2013), although some studies also consider innovation outputs and product innovation (Garcia Quevedo &

Afcha, 2009; Altuzarra, 2010; Guisado-González *et al.*, 2013) or processes (Altuzarra, 2010; Guisado-González *et al.*, 2013), patents (Busom & Fernández-Ribas, 2007; Fernández-Ribas, 2009; Garcia-Quevedo & Afcha, 2009; Altuzarra, 2010; Guisado-González *et al.*, 2013) or incremental or radical innovation (Fernández-Ribas, 2009; Guisado-González *et al.*, 2013). In this paper we have considered it more appropriate to use innovation efforts by companies and not the results obtained as explanatory variables given that public funding is used to obtain resources with which to conduct R&D and technology cooperation.

Other variables used as regressors are size, foreign capital in the business (Blanes & Busom, 2004; Busom & Fernández-Ribas, 2007; Fernández-Ribas, 2009; Garcia-Quevedo & Afcha, 2009; Altuzarra, 2010; Guisado-González *et al.*, 2013), internationalization (Busom & Fernández-Ribas, 2007, Guisado-González *et al.*, 2013), geographical location (García-Quevedo & Afcha, 2009), obstacles to innovation (Fernández-Ribas, 2009; Guisado-González *et al.*, 2013) and other sources of public funding (García-Quevedo & Afcha, 2009).

From the background above and taking into account the objectives of this study, six hypotheses have been formulated. The first four seek to capture the relations between the innovation efforts made by companies and their access to public funding for innovation. The final two look at, respectively, whether there are differences by region and overlaps between different levels of government.

H1: There is a positive relationship between capital investment and public funding of innovation.

H2: Firms that spend on internal R&D obtain more public funding than those firms that do not.

H3: Firms that spend on external R&D obtain more public funding than those firms that do not.

H4: Companies that cooperate technologically with other companies or institutions obtain more public funding than those that do not.

H5: The location of firms influences (positively or negatively) their probability of obtaining public funding.

H6: There are overlaps between different types of public funding of innovation.

These hypotheses were set up for three kinds of firms: Agriculture, food and others, and for three types of public funding of innovation: regional, state and EU. This will allow for them to be tested in each case and to compare the kind of funding for each firm.

Data and variables

The PITEC database (http://icono.fecyt.es/PITEC) provides statistical information on the technological innovation activities of Spanish companies. PITEC mainly includes companies that perform some kind of R&D. Therefore, PITEC is not representative of the general population of companies and conclusions drawn from it cannot be generalized to the rest of the economy. However, it is very useful for studying the most innovative companies in each sector, *e.g.*, their problems and their consequences in relation to their technological activities.

Three samples have been taken from this database, which we call Agriculture, Food and Others. Agriculture includes agriculture, livestock, forestry and fisheries' companies (CNAE-2009 codes 01, 02 and 03). Food contains information on food, beverages and tobacco companies (CNAE-2009 codes 10, 11 and 12). Others includes companies engaged in other activities except oil firms which have been left out because they are few in number and very large in size and hence might distort the results. Accordingly, this latter group is used as a reference to analyse whether there are major differences between Agriculture and Food innovative companies and innovative companies engaged in other area of productive activity. Three incomplete panels of companies in the period 2008-2013 and for the three types of firms are used: in Agriculture there are 499 observations grouped in 136 companies; in Food 2679 observations in 659 companies and in Others 33394 observations in 8375 companies. The fact that there are only 136 companies in the Agriculture sample shows that PITEC is not representative of the agricultural sector (and more generally of any other sector) because only companies with R&D activities are included in it.

Three public funding of innovation variables have been used: Regional (which includes local and Autonomous Community levels) (Rpf), State (Spf) and EU (EUpf). All three are dichotomous variables that take the value 1 if the company gains access to the corresponding type of public funding of innovation, and 0 otherwise. Table 1 shows the proportions of the variables in the three groups of companies. Less than a fifth of Others access regional (17.45%) or state funding (16%), and only a very small number (4.69%). accede to EU funding. The comparable percentages in the case of Agriculture are 22.72%, 16.35% and 5.62%, respectively, while those of Food come in at a lower level 17.21%, 13.30%, 2.19%, respectively. Overlaps between different sources of funding are of the following order: 9.2% of companies in Others firms receive funding from two of the levels and 2.4% to three. In the other two categories these percentages are lower: in Agriculture 8.9% and 0.9 % and in Food 5.7% and 0.5%. This also indicates that over 70% of PITEC companies, that is they perform some activity of technological innovation, do not get any public funding.

Table 1. Descriptive statistics.

	Agriculture	Food	Others
Rpf (proportion)	0.23	0.17	0.17
Spf (proportion)	0.16	0.13	0.16
EUpf (proportion)	0.06	0.02	0.05
Ci (average)	0.01	0.01	0.01
inRD (proportion)	0.47	0.45	0.43
exRD (proportion)	0.30	0.24	0.20
coopera (proportion)	0.35	0.28	0.26
Size (average)	35	63	49
capitalex (proportion)	0.09	0.08	0.13
ex (proportion)	0.54	0.76	0.59

However, these three funding levels vary over time (Fig. 1). Thus, regional funding decreases considerably during the period considered. In the Others category 20% had access to it in 2008, a figure that had declined to 11% by 2013. In the case of Agriculture the comparable figures are 28% and 9% respectively and in the case of Food 19% and 7% respectively. The decline in state funding is less marked and in the case of Agriculture it even increases. EU funding increases slightly in the three groups and perhaps more markedly in Agriculture, from 5.6% in 2008 to 7% en 2013.

The explanatory variables have been grouped into four blocks:

(1) Innnovation inputs. Innovation has been represented by measures of innovation inputs. The relevance of internal and external R&D and other forms of innovation has been highlighted by several authors (Cassiman & Veugelers, 2006; Lokshin *et al.*, 2008; among others). The choice of various innovation options depends generally speaking on the technological intensity of each company, on the activities it carries out and its size (Audretsch *et al.*, 1996; Cassiman & Veugelers, 2006; Lazzarotti *et al.*, 2011). These are the variables of interest that try to answer the main hypotheses (H1 to H4). Positive signs for all these variables are expected because a greater effort in innovation or modernization involves searching for and obtaining funding, including public funding.

− Capital intensity (Ci): is the ratio of annual investment in tangible assets and sales, and measures the degree of capitalization of the company. It also includes information on the heterogeneity of the companies in their production processes. Table 1 shows that Agriculture and Food companies spend annually around 1% of their sales on such investment, higher than the figure for Others, 0.5%.

− Internal R&D (inRD). This has been measured as a binary variable that takes the value 1 if the company carries out internal expenditure on R&D, and 0 otherwise. The proportion of companies that perform this activity is in the range 40-50%, with Agricultural having the highest value.

− External R&D (exRD). This has been measured as a binary variable that takes the value 1 if the company carries out internal expenditure on R&D, and 0 otherwise. In this case the proportion of companies

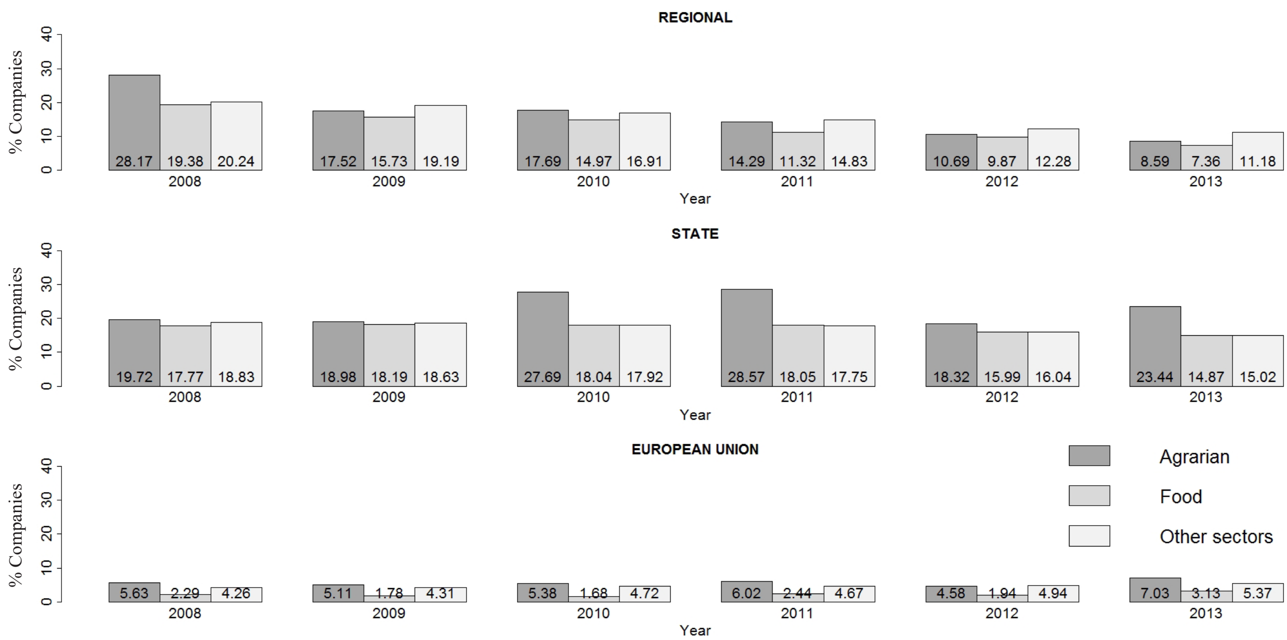

Figure 1. Percentage of companies accessing each type of funding.

that perform this activity is much lower and once more Agriculture leads the way at 20% followed by Food at 24% and others at 20%.

− Technological cooperation (coopera): This variable takes the value 1 if the company carries out technological cooperation with other firms (suppliers, competitors or clients) or institutions (universities, research and technology centers) and 0 otherwise. The same pattern as in the previous variables is repeated here with Agriculture at 35% being far higher than the other two groups. Everything seems to indicate that the agricultural firms on the PITEC database have a very innovative profile, more so than firms in other areas. These companies are therefore not representative of the agriculture and livestock sector but rather of innovative companies in that sector.

(2) Geographic area variables (Region). The existing literature reveals a varying relationship between inputs and outputs of innovation across countries and regions (Ghazalian & Fakih, 2017). PITEC database includes four category variables that divide the Spanish territory into four zones (Madrid, Catalonia, Andalusia and the rest of Spain). These variables are used to test hypothesis H5. In the regression analysis Madrid is taken as the reference.

(3) Other sources of public funding. In each estimation the other two types of funding are included as explanatory variables. The aim is to establish the degree of relatedness between the various forms of public funding available for innovation and to test hypothesis H5.

(4) Control variables. Other variables which might have a significant connection with the dependent variables are included:

− Small size can be a limiting factor for innovation and consequently for obtaining access to public funding. The size of firms has been identified through the number of their employees. Table 1 shows that there is a large number of SMEs (small and medium enterprises) in all three groups with the smallest being in Agriculture. Since it is a variable with a very high range of variation it is taken in logarithms (size) to avoid scalability problems. The possibility of nonlinear relationships between funding and size has also been considered and a squared term (size2) introduced.

− Foreign capital (capitalex). This has been measured as a binary variable and takes the value 1 if the proportion of foreign capital exceeds 50% and 0 if it does not. This variable seeks to capture any effect of public administrations discriminating in favour of national capital. A negative sign is therefore expected. The proportion of firms with foreign capital in Others (13%) is higher than that of Agriculture and Food (8-9%).

− Internationalisation (ex). The degree of openness of a firm to foreign markets may interact with its innovative character and thus it is appropriate to take this factor into account when analysing public funding of innovation. The ex variable takes a value of 1 if the firm exports and 0 if it does not. The differences between the three groups are considerable as in Agriculture only 53.8% export while 76.3% of those in Food do.

Econometric model

The funding of innovation can be accomplished by the usual means for any business activity: self-funding, shareholder contributions, public funding and external funding through banks or individuals. They all have their advantages and disadvantages. Public funding is an option without financial costs but it is not without drawbacks as it involves conditions, obligations and great bureaucratic effort. Not all companies will be willing or able to assume these non-financial costs, so that the decision to go down this route will depend on whether the expected net return is higher than what would be expected if this funding was not accessed. The empirical analysis here seeks to identify and quantify through a binary choice model the factors explaining the probability that a company will use public funding for innovation. Specifically, it was considered appropriate to use a logit panel with random effects which includes explanatory variables of enterprises and also allows to model non-observed random effects taking advantage of the panel data structure. Given our lack of interest in any specific company effect but in the whole population of innovative companies, we have chosen a logit panel with random effects (Faraway, 2005):

$$log\left(\frac{p_{it}}{1-p_{it}}\right) = \alpha + \theta f_{it} + \beta I_{it} + \rho R_{it} + \gamma Z_{it} + \epsilon_{it} \quad (1)$$

$$\alpha = \alpha_0 + U_i \quad (2)$$

The *i* and *t* subscripts respectively indicate company and year. The dependent variable p_{it} is the probability of obtaining public funding for innovation and the three levels for obtaining it are considered, *Rpf, Spf* and *EUpf*. For each estimation, the two other avenues for funding, *f*, are included. For example, in the estimation of regional funding, state and EU funding are included as regressors. The variables of interest are innovation inputs (*I*): *Ci, inRD, exRD* and *coopera*. Also included are regional dummies, *R*, and control variables *Z* (*size, size2, capitalex, ex*) and time dummies. Equation (1) represents a logit regression that does not take into account the structure of the panel data: by adding the equation (2), the independent term α is broken down into a fixed part, α_0, which is common to all businesses, and another random one, U_i, which captures the specific, time-invariant and unobserved characteristics of each company. The estimate is made using the restricted maximum likelihood method (Bates, 2010).

To evaluate the goodness of fit, $R^2_{\text{Nagelkerke}}$ is estimated (Nagelkerke, 1991), which is a generalization of the coefficient of determination R^2 to multilevel linear models (Faraway, 2005). The maximum precision value is obtained by analysing the curves characteristic of the operation (Swets, 1988) and comparing the observed probabilities with the estimated ones. This statistic varies between 0 and 1 so that the closer it is to 1 the greater the ability of the regression to correctly classify the observation based on the values of explanatory variables.

Regression models were used to predict probabilities of access to public funding in the various situations, primarily to establish probabilities depending on the intensity of innovation activities. Geographic location and evolution over time were also considered. To do this, the values of the variables of interest in each case were changed, and at the same time average values were taken for the rest of the variables and a zero value was assigned to the individual residue value of each company (U_i=0) (Steele, 2008).

Results

Regressions

Tables 2, 3 and 4 show the results of models for regional, state and EU funding, respectively. Each table shows the logit and logit random effects (logit RE) estimations for the Agriculture, Food and Others sectors.

The goodness of fit measures indicate that estimates are acceptable. Thus, for the three types of

Table 2. Logit models. Dependent variables: Regional public funding.

	Agriculture		**Food**		**Others**	
	logit	**logit RE**	**logit**	**logit RE**	**logit**	**logit RE**
(Intercept)	**-2.88** (0.79)***	-2.44 (1.48)	**-5.34** (0.58)***	**-6.18** (0.92)***	**-4.39** (0.09)***	**-4.92** (0.15)***
Innovation inputs						
Ci	-0.00 (0.10)	-0.00 (0.20)	**0.47** (0.20)*	**0.60** (0.27)*	-0.00 (0.00)	-0.00 (0.00)
inRD	**1.54** (0.32)***	**1.64** (0.48)***	**1.22** (0.13)***	**1.39** (0.18)***	**1.68** (0.04)***	**1.74** (0.06)***
exRD	0.24 (0.25)	-0.00 (0.38)	**0.66** (0.12)***	**0.66** (0.16)***	**0.64** (0.03)***	**0.71** (0.05)***
coopera	**0.66** (0.25)**	0.63 (0.37)	**0.75** (0.12)***	**0.72** (0.16)***	**0.86** (0.03)***	**0.86** (0.05)***
Region (Madrid)						
Barcelona	**-1.77** (0.74)*	-1.65 (1.25)	**0.93** (0.44)*	1.01 (0.65)	0.10 (0.06)	0.06 (0.10)
Andalusia	-0.20 (0.53)	0.03 (1.10)	**1.46** (0.47)**	**1.47** (0.70)*	**0.98** (0.07)***	**1.07** (0.14)***
Other regions	0.50 (0.44)	0.63 (0.90)	**2.11** (0.43)***	**2.24** (0.62)***	**1.75** (0.05)***	**1.83** (0.09)***
Other sources of public funding						
Spf	0.31 (0.24)	0.11 (0.38)	0.16 (0.12)	0.07 (0.17)	**0.78** (0.03)***	**0.64** (0.05)***
EUpf	0.03 (0.40)	0.31 (0.61)	0.10 (0.26)	0.36 (0.34)	**1.15** (0.05)***	**1.10** (0.08)***
Control variables						
size	0.17 (0.34)	-0.19 (0.66)	0.28 (0.18)	0.42 (0.33)	0.05 (0.03)	**0.13** (0.06)*
size2	-0.02 (0.05)	0.04 (0.09)	-0.03 (0.02)	-0.05 (0.04)	**-0.01** (0.00)***	**-0.02** (0.01)**
capitalex	0.10 (0.35)	0.57 (0.75)	**-0.55** (0.24)*	-0.33 (0.35)	0.02 (0.04)	0.01 (0.08)
ex	-0.15 (0.23)	-0.23 (0.40)	**0.38** (0.14)**	**0.50** (0.22)*	**0.15** (0.03)***	**0.26** (0.05)***
AIC	599.61	520.77	2666.23	2389.01	32906.75	29061.94
Log Likelihood	-280.80	-240.39	-1314.12	-1174.50	-16434.38	-14510.97
R^2_{McFaden}	0.21	0.33	0.20	0.29	0.33	0.41
$R^2_{\text{Nagelkerke}}$	0.29	0.43	0.27	0.37	0.43	0.52
Maximum precision value	0.84	0.93	0.87	0.93	0.87	0.93
Number of observations	801	801	4195	4195	56108	56108
Number of groups		164		781		10517
Variance: (Intercept)		4.56		3.18		3.49

Standard errors in parentheses. *,**,***: significance at 5%, 1% and 0.1%, respectively. Figures in bold: significance lower than 5%.

Table 3. Logit models. Dependent variables: State public funding.

	Agriculture		Food		Others	
	logit	logit RE	logit	logit RE	logit	logit RE
(Intercept)	**-5.34** (0.82)***	**-6.90** (1.48)***	**-5.73** (0.52)***	**-6.48** (0.83)***	**-4.37** (0.09)***	**-4.95** (0.16)***
Innovation inputs						
Ci	-0.14 (0.32)	-0.34 (0.42)	-0.38 (0.38)	-0.25 (0.46)	-0.00 (0.00)	-0.00 (0.00)
inRD	**2.18** (0.30)***	**2.47** (0.42)***	**1.67** (0.14)***	**1.68** (0.18)***	**2.07** (0.04)***	**2.20** (0.06)***
exRD	**0.90** (0.22)***	0.60 (0.32)	**1.06** (0.11)***	**1.10** (0.14)***	**0.67** (0.03)***	**0.75** (0.05)***
coopera	0.19 (0.23)	0.50 (0.32)	**1.03** (0.11)***	**1.01** (0.15)***	**0.91** (0.03)***	**0.94** (0.05)***
Region (Madrid)						
Barcelona	0.26 (0.50)	-0.20 (0.98)	**0.56** (0.25)*	0.70 (0.43)	**-0.25** (0.04)***	**-0.28** (0.09)**
Andalusia	0.51 (0.46)	0.28 (0.95)	-0.21 (0.31)	-0.07 (0.52)	**-0.40** (0.07)***	**-0.38** (0.14)**
Other regions	0.41 (0.39)	0.12 (0.80)	**0.49** (0.24)*	0.59 (0.41)	**-0.49** (0.04)***	**-0.42** (0.08)***
Other sources of public funding						
Spf	0.24 (0.24)	0.25 (0.37)	0.16 (0.12)	0.07 (0.16)	**0.79** (0.03)***	**0.61** (0.05)***
EUpf	0.01 (0.38)	0.05 (0.54)	**0.85** (0.25)***	**0.90** (0.32)**	**1.43** (0.05)***	**1.22** (0.08)***
Control variables						
size	0.63 (0.34)	**1.42** (0.66)*	**0.40** (0.20)*	0.52 (0.33)	**0.25** (0.03)***	**0.30** (0.07)***
size2	-0.06 (0.05)	-0.17 (0.09)	-0.02 (0.02)	-0.02 (0.04)	**-0.02** (0.00)***	**-0.02** (0.01)**
capitalex	0.32 (0.33)	0.58 (0.65)	**-0.66** (0.19)***	**-0.68** (0.30)*	**-0.31** (0.04)***	**-0.21** (0.08)**
ex	-0.07 (0.22)	-0.02 (0.36)	**0.44** (0.15)**	**0.47** (0.22)*	**0.35** (0.03)***	**0.39** (0.06)***
AIC	665.15	597.86	2698.91	2472.59	34340.46	29718.13
Log Likelihood	-313.58	-278.93	-1330.46	-1216.29	-17151.23	-14839.07
R^2_{McFaden}	0.27	0.35	0.31	0.37	0.34	0.43
$R^2_{\text{Nagelkerke}}$	0.38	0.48	0.41	0.48	0.45	0.54
Maximum precision value	0.82	0.91	0.86	0.92	0.86	0.93
Number of observations.	801	801	4195	4195	56108	56108
Number of groups		164		781		10517
Variance: (Intercept)		3.47		2.33		3.90

Standard errors in parentheses. *,**,***: significance at 5%, 1% and 0.1%, respectively. Figures in bold: significance lower than 5%.

funding and the logit RE models the $R^2_{\text{Nagelkerke}}$ statistic has in almost all cases values between 0.30 and 0.50 and probabilities correctly classified close to or above 90%. Both the $R^2_{\text{Nagelkerke}}$ statistic and the maximum precision value show considerable differences between the logit and logit random effects estimates, proving that there is a great intrinsic variability in each company regarding their decisions to apply for public funding for innovation. The proportion of residual variation that is due to unobserved firm characteristics is in all cases very high; indeed tests confirmed in all cases that the random effects are very significant.

With regard to innovation input variables, in general terms there is a positive and significant relationship between these dependent variables. Therefore, the companies that make the greatest efforts in innovation are also those that make the most use of funding.

Ci is only positive and significant for the regional public funding in Food (H1 is not rejected only in this case, one of the nine logit RE models) and not for any type of funding for the Agriculture and Others sectors. One possible explanation could be that process innovation is common in Food (Archibugi & Pianta, 1996; Alarcón *et al.*, 2014), which is usually associated with increased capital investment.

Internal expenditure on R&D, *inRD*, is always positive and significant in the regional and state public funding for Agriculture and Food companies, but not with regard to EU funding. In any case, the H2 hypothesis is the one failed to be rejected in the most number of cases (seven out of nine logit RE models). In the case of regional funding, the coefficients of internal expenditure on R&D are lower in Agricultural and Food than in Others. The state funding coefficient for Agriculture is higher than that for the other two groups with Food being lower than Others. In the case of EU funding, *inRD* is significant only for Others and for neither Agriculture nor Food. In short, regional and state funding are common routes of access to resources for companies in the Agriculture and Food sectors that

Table 4. Logit models. Dependent variables: EU public funding.

	Agriculture		Food		Others	
	logit	logit RE	logit	logit RE	logit	logit RE
(Intercept)	-18.78 (865.51)	-20.78 (2366.57)	**-6.02** (1.05)***	**-5.98** (1.45)***	**-4.92** (0.14)***	**-6.31** (0.28)***
Innovation inputs						
Ci	-0.01 (0.17)	0.00 (0.17)	0.57 (0.37)	0.76 (0.40)	-0.00 (0.00)	-0.00 (0.00)
inRD	0.40 (0.51)	-0.03 (0.71)	**0.83** (0.35)*	0.76 (0.41)	**1.02** (0.08)***	**1.12** (0.12)***
exRD	**1.14** (0.42)**	**1.11** (0.54)*	0.43 (0.26)	0.33 (0.31)	**0.19** (0.05)***	**0.37** (0.09)***
coopera	**1.11** (0.43)**	0.85 (0.58)	**1.28** (0.29)***	**1.03** (0.33)**	**1.16** (0.06)***	**1.06** (0.09)***
Region (Madrid)						
Barcelona	15.33 (865.51)	16.85 (2366.57)	-0.47 (0.54)	-0.51 (0.81)	**-0.46** (0.07)***	**-0.51** (0.17)**
Andalusia	16.26 (865.51)	17.33 (2366.57)	0.38 (0.60)	0.23 (0.90)	0.01 (0.10)	0.08 (0.25)
Other regions	16.01 (865.51)	17.20 (2366.57)	0.03 (0.51)	-0.04 (0.75)	**-0.54** (0.06)***	**-0.34** (0.15)*
Other sources of public funding						
Spf	0.09 (0.39)	0.45 (0.55)	0.00 (0.26)	0.25 (0.33)	**1.18** (0.05)***	**0.97** (0.09)***
EUpf	0.07 (0.38)	-0.12 (0.53)	**0.80** (0.25)**	**0.84** (0.31)**	**1.43** (0.05)***	**1.03** (0.09)***
Control variables						
size	-0.70 (0.39)	-0.64 (0.72)	0.19 (0.40)	-0.02 (0.57)	**-0.28** (0.05)***	-0.13 (0.11)
size2	0.08 (0.05)	0.10 (0.10)	-0.02 (0.04)	0.01 (0.06)	**0.03** (0.01)***	0.02 (0.01)
capitalex	-0.18 (0.58)	0.03 (0.90)	-0.16 (0.43)	-0.66 (0.67)	**0.43** (0.06)***	0.25 (0.14)
ex	-0.25 (0.36)	-0.20 (0.56)	0.11 (0.33)	0.22 (0.43)	0.09 (0.05)	**0.32** (0.10)**
AIC	326.89	298.47	786.81	722.48	14919.61	11499.95
Log Likelihood	-144.44	-129.23	-374.40	-341.24	-7440.80	-5729.97
R^2_{McFaden}	0.17	0.25	0.15	0.23	0.30	0.46
$R^2_{\text{Nagelkerke}}$	0.20	0.30	0.17	0.25	0.34	0.51
Maximum precision value	0.95	0.97	0.98	0.98	0.95	0.98
Number of observations	801	801	4195	4195	56108	56108
Number of groups		164		781		10517
Variance: (Intercept)		4.14		3.38		8.14

Standard errors in parentheses. *,**,***: significance at 5%, 1% and 0.1%, respectively. Figures in bold: significance lower than 5%.

spend money on internal R&D. However EU funding is not as common as for Others.

As for external expenditure on R&D, *exRD*, it is not significant in the logit RE models for Agriculture for state and regional funding but it is for EU funding. It is also positive and significant for Food, and for Others for state and regional funding. H3 is not rejected for six of the nine logit RE models. However, like the previous variable, the state funding coefficient is greater than for regional funding in the case of Food. In terms of EU funding, it is less common in Food when compared to other sectors.

The technological cooperation variable is not significant in the logit RE models for Agriculture. However it is positive and significant in Food and Others for the three types of funding. H4 is not rejected in six of the nine cases. Once again the state funding coefficient for Food is greater than that for Others, while in the case of regional funding and the EU the reverse is true.

As for the influence of geographical location when accessing public funding for innovation (considering only the logit RE models), H5 is not rejected for Others companies for the three levels of funding. H5 is rejected for Agriculture for the three levels and for Food in the case of state and EU funding. Therefore, for Agriculture and Food companies the location of their headquarters is not of great relevance as a decisive factor for accessing public funding for innovation.

With regard to the question of whether there are overlaps between the various levels of funding, H6 is rejected for Agriculture while for Food a correlation is found with both state and EU funding but nor for regional funding with these two sectors. As for Others, H6 is not rejected for the three types of funding.

Finally, the control variables generally show more significance in regressions for Others than for Agriculture and Food. Size proved to be both positive and significant for regional and state funding for Others, but lacks these in the case of Agriculture and Food. The foreign capital variable is negative and significant for regional and state funding of Food which suggests that these administrations favour locally owned companies and especially those engaged in activities related to food. Export-oriented nature is positive and significant for Food and Others for regional and state funding but not for Agriculture. Time dummies (not reported in the tables) show a decrease in regional state aid for innovation in the period considered, while state funding decreased to a lesser extent for Food and Others sectors and increased for Agriculture. EU funding slightly improved over time for all groups but remains the least accessible route to funding.

Probabilities

The logit RE models estimated have been used to predict the average probability of accessing public funding in various situations: (1) intensity of innovation activities, (2) geographical location and (3) evolution over time.

Thus, Table 5 shows the probability of carrying out R&D and/or cooperation activities in various situations. In general we can say that the chances of obtaining state funding are usually somewhat higher than for regional funding, and both are much higher than for innovation funding from the EU. It is also safe to state that in general terms as innovation activities of enterprises intensifies so does the likelihood of obtaining funding. Thus companies that perform two types of innovation activities (*i.e. coopera* + *inRD*, *coopera* + *exRD*, *inRD* + *exRD*) have higher chances of obtaining funding than companies that perform only one of them and those companies that combine the three types of innovation inputs do better still. At the lowest level, with very little chance of obtaining funding are those companies that carry out no innovation activity.

When companies that carry out one innovation input activity only are compared it can be seen that those who carry out internal R&D activity have a higher probability of obtaining regional or state funding than those that carry out technological cooperation or external R&D. Specifically, for an Agriculture company, the probability of it obtaining regional funding is 13.6% if it carries out *inRD*, 6.3% if it carries out technological cooperation and 2.2% if it contracts *exRD*. The probabilities of obtaining state funding are 25.3%, 4.2% and 6.3% while those of obtaining EU funding are much lower at 1.2%, 3.4% and 4%. However, this source of funding is more associated with firms carrying out technological cooperation and external R&D.

Both with regard to regional and state funding the Agriculture companies that carry out technological cooperation and internal R&D (*coopera* + *inRD*) have a higher probability of obtaining it than those with other combinations of innovation inputs (*coopera* + *exRD* or *inRD* + *exRD*). In the Food category internal and external (*inRD* + *exRD*) offers slightly better possibilities than technological cooperation and internal R&D (*coopera* + *inRD*) and much better than those of *coopera* + *exRD*. However, with regard to EU funding, the best combination is technological cooperation and external R&D, especially for Agriculture firms.

The firms that combine the three types of innovation input (*coopera* + *inRD* + *exRD*) have a probability of 24.6% (47.1%) of obtaining regional funding (state funding) if they are Agriculture ones, whereas 28% (52.2%) in case of Food ones. It is clear from these findings that state financing is more focused on firms with a greater intensity of innovation activities. Furthermore, access to EU funding remains difficult, since in the same conditions, these three innovation inputs are present, the probability for Agriculture is 9.4% and 2.9% in Food.

Table 6 provides the probabilities based on the location of the firms and Table 7 based on the year. The

Table 5. Probability of obtaining public funding for R&D and cooperation.

		Without innovation inputs	***coopera***	***inRD***	***coopera+ inRD***	***exRD***	***coopera+ exRD***	***inRD+ exRD***	***coopera+inRD +exRD***
Regional	Agriculture	0.04	0.06	0.14	0.26	0.02	0.07	0.18	0.25
	Food	0.03	0.05	0.10	0.17	0.06	0.10	0.18	0.28
	Others	0.03	0.06	0.12	0.23	0.06	0.11	0.21	0.38
State	Agriculture	0.03	0.04	0.25	0.36	0.06	0.08	0.37	0.47
	Food	0.02	0.05	0.11	0.25	0.06	0.16	0.26	0.52
	Others	0.02	0.04	0.13	0.27	0.04	0.08	0.24	0.45
EU	Agriculture	0.01	0.03	0.01	0.03	0.04	0.09	0.03	0.09
	Food	0.00	0.01	0.01	0.02	0.01	0.012	0.01	0.03
	Others	0.00	0.01	0.01	0.02	0.00	0.01	0.01	0.03

Table 6. Probability of obtaining public funding.

		Madrid	Barcelona	Andalusia	Other regions
Regional	Agriculture	0.10	0.02	0.10	0.15
	Food	0.02	0.05	0.05	0.13
	Others	0.04	0.04	0.09	0.18
State	Agriculture	0.26	0.12	0.27	0.19
	Food	0.12	0.18	0.07	0.14
	Others	0.14	0.13	0.10	0.12
EU	Agriculture	0.00	0.02	0.05	0.04
	Food	0.01	0.01	0.01	0.01
	Others	0.01	0.01	0.01	0.01

Table 7. Probability of obtaining public funding by year.

		2008	2009	2010	2011	2012	2013
Regional	Agriculture	0.28	0.12	0.11	0.09	0.05	0.041
	Food	0.16	0.12	0.11	0.08	0.06	0.041
	Others	0.16	0.15	0.12	0.10	0.07	0.061
State	Agriculture	0.17	0.15	0.24	0.26	0.14	0.22
	Food	0.15	0.15	0.15	0.15	0.13	0.12
	Others	0.14	0.14	0.13	0.13	0.11	0.10
EU	Agriculture	0.03	0.03	0.03	0.04	0.03	0.05
	Food	0.01	0.01	0.01	0.01	0.01	0.02
	Others	0.01	0.01	0.01	0.01	0.011	0.02

first shows that in regions like Andalusia and Madrid Agriculture companies have a higher probability of obtaining regional or state funding than Food ones, while in Barcelona it is Food firms that have the best chance. In the second the decline in regional funding over time is confirmed. So the probability for Agricultural was 28.5% in 2008 and only 4.2% in 2013, Food went from 16.3% to 4.2% and Others 16.6% to 6% in the same period. In the case of state funding this fall in access is lower, as is the case of Food from 15.2% in 2008 to 11.6% in 2013 and in that of Others from 13.9% to 9.6% in the same period. In the case of Agriculture there was even an increase from 16.9% in 2008 to 21.8% in 2013. With regard to EU funding the probability increases with the passage of time in the three groups of companies.

Discussion

Many empirical studies have detected a correlation between innovation efforts and access to public funding but differentiated by type of business and finance (Blanes & Busom, 2004; Garcia-Quevedo & Afcha, 2009; Altuzarra, 2010, among others). This present study updates this literature and provides some detail in certain sectors. Thus, Agricultural companies conducting internal R&D most frequently access regional and state funding while in Food there are also companies that usually spend on external R&D and technological cooperation. These latter have greater diversity in their innovation efforts, probably because they have developed more complex structures and are more related to other agents involved in innovation. In other words, Food companies that obtain public funding tend to have a more innovative profile than Agriculture ones (Alarcon & Sanchez, 2016). Among the former there are clear connections with conducting internal and external expenditure on R&D and/or with technological cooperation with other companies or institutions, while among the latter only companies with internal spending on R&D obtain access to funding. In addition, logit models with random effects have identified in all cases the great importance of the factors intrinsic to the companies when it comes to assessing public funding for innovation.

Regional and state funding are common routes to access resources for Agriculture and Food though to a greater extent in the case of regional funding. There are other studies that show that state funding is focused on either large national companies (Altuzarra, 2010; Guisado-González *et al.*, 2013), which are not common in the food industry where there are many SMEs, or on sectors like pharmaceuticals, information technologies and communication equipment (Blanes & Busom, 2004).

As for regional funding, not all regions manage their innovation resources and policies (Heijs & Buesa, 2016) with equal efficiency. But in general, according to Ortega *et al.* (2015), the innovation systems of the Spanish regions function well (Catalonia, Navarra, Madrid, Aragon, Basque Country and Asturias being the most efficient) and are tending towards improvement over time. In addition to this information, this paper finds empirical evidence that Food businesses increase their chance to access regional funding if they are located in Andalusia or in other regions, compared to Madrid. In addition to this, Table 5 shows that Agriculture and Food obtained higher probabilities than Others when it comes to gaining access to regional funding, though the opposite often occurs in the case of state funding. These results are consistent with the idea that certain Autonomous Communities direct their actions to industries with specific weight in their regions and with a need to strengthen company innovation. Examples of support from regional governments to this sector include, among others: in Andalusia, the Campus of International Excellence in Agri-Food (ceiA3), which combines the research efforts of five universities (Córdoba, Almería, Cádiz, Huelva and Jaén), two research centers (IFAPA and the CSIC) and numerous companies in order to do research and transfer knowledge to the food sector; in Murcia, Arcas *et al.* (2014) describe and analyze the Agri-food Science, Technology and Innovation System in this this region, which drives innovation through collaboration of agri-food companies with research institutions; and in Navarra several public-private initiatives such as the agro-food city of Tudela and the Research Institute on Innovation & Sustainable Development in Food Chain (IS-FOOD) of the Public University of Navarra also exist.

Moreover, firm size is not significant for regional funding of Food and Agriculture firms, which suggests that Autonomous Community governments do not prioritize it and instead look towards innovation to maximise regional development (Altuzarra, 2010), and as part of this strategy innovation is encouraged in firms closely linked to the rural environment like agri-food ones or which, due to their size, have more barriers in the way of engaging in technological activities (Fernández-Ribas, 2009; García-Quevedo & Afcha, 2009). In their studies (Almus & Czarnitzki, 2003; Blanes & Busom, 2004) indicate the size of the company as a key element to increasing the likelihood of access to public funding, which is explained by the need for a certain volume of activity and organizational capacity to address research projects. In this study this was confirmed for Others but not for Agriculture and Food in regional funding.

No overlap between regional and state funding was detected, at least in terms of Agriculture and Food companies, which corroborates the results of previous research (García-Quevedo & Afcha, 2009; Altuzarra, 2010). Significant correlation was detected between State and EU funding in Food, pointing to some level of overlap between these two levels of government. Although this is likely to benefit certain businesses it prevents these actions reaching a broader set of innovative initiatives. As noted by Fernández-Ribas (2009), among others, it is necessary to coordinate and articulate the various programs of public aid to private innovation so as not to exclude newly-formed or less competitive companies.

The financial crisis has adversely affected regional and national aid, which experienced a significant decrease in the period from 2008 to 2013. This means that companies have fewer resources to invest in R&D and technological cooperation (Zouaghi & Sanchez, 2016). However, EU funding has increased slightly over time in the three groups of companies. While this funding source remains the least accessible, the idea was confirmed that many Agriculture and Food firms have begun to involve themselves in European projects and to R&D access services tailored to their specific characteristics (Baviera-Puig *et al.*, 2012; Garcia Alvarez-Coque *et al.*, 2015).

Following this study future research should seek to quantify to what degree the various sources of public funding are actually increasing innovation (product or process), the issuing of patents and the sales of innovative products. This being a sector made up of SMEs with obstacles in the way of their doing research or innovation, this hypothesis seems more plausible than the contrary one, that is, that public funds are financing projects that would in any case funds from other firms, banks or savers.

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