CAP subsidies matter for R&D? An evaluation of the farm R&D environmental objectives

Cristina Suárez*, Sonia Quiroga, Jesús Manuel Rodrigo
Universidad de Alcalá

Abstract:

The Common Agricultural Policy has evolved into a multifunctional instrument designed to satisfy a diverse portfolio of European Union policy objectives. In this context, research, innovation and knowledge transfer would be instruments to enhance competitiveness and improve sustainability in agriculture. The current paper combines a farm business dataset for Spain with CAP subsidies information to assess the impact over production different R&D environmental objectives. The results suggest that specific subsidies appear to generate a disincentive effect on production increase and environment protection R&D objectives and an incentive effect on cost efficiency goal, whilst in general, the decoupled subsidies are incentivizing all the R&D strategic purposes analyzed.

Keywords: European subsidies, environmental R&D, agriculture, farms, multivariate ordered probit

(*) Corresponding author:

E-mail: cristina.suarez@uah.es
1. Introduction

Structural evolution on Common Agricultural Policy (CAP) had successfully changed the focus of the policy from production to broader challenges (EC, 2010). A range of literature has focused on the analysis of the broad types of CAP policy instruments —direct payments, market measures, rural development, etc.— and their direct effects on agricultural productivity and efficiency (Quiroga et al, 2017; Rizov et al, 2013; Kumbhakar and Lien, 2010; Zhu and Oude-Lansink, 2010). However, other indirect effects through innovation have received less attention to date. Here we aim to analyze the impacts of the different types of CAP subsidies on the Research and Development (R&D) farms objectives.

Innovation is considered the heart of value creation for small and medium enterprises, and a key strategy to improve productivity, sustainable resource use, and a resilient tool for rural development (OECD, 2013). Agriculture sector is not on the sidelines of this statement, being around of 5% of all kinds of R&D investments dedicated to this sector (Pardey et al, 2016). In the recent years this sector has been experimenting a double changing in his trends. First, the private sector is increasing its share at the expense of public investments. Second, the middle-income countries are giving more funds whereas the richest countries are diminishing their contributions to agriculture R&D (Pardey et al, 2016), becoming a crucial aspect for understanding the long-term growth effects of public expenditure in the sector.

Some studies state that public subsidies could relax the R&D activity —substitution effect being dominant—, while others find that they stimulate and complement it —income effect being dominant (Zuñiga-Vicente et al, 2014). However, still not enough evidences in the agricultural sector. A more robust positive correlation exists between agricultural R&D spending and the total factor productivity in European Union (EU) agriculture (Wang et al, 2012, Latruffe, 2010; Gutierrez and Gutierrez, 2003). However, there are other aspects apart from productivity that investment and subsidies should also take care of. The kind of support used as agricultural subsidy may modify the biodiversity and so, nature protection objectives are affected (Gottschlack et al., 2007).

The new framework established by the political agreement "The CAP towards 2020" settles three challenges for the next years: economic, environmental and territorial challenges (EC, 2010). Research, innovation and knowledge transfer would be instruments to enhance competitiveness and improve sustainability in agriculture. So, which are the primary objectives of farms innovation processes, is an important issue to understand, especially considering that environmental objectives are of primary importance in the CAP ‘greening’ process. Greening measures, set by the European
Commission in order to protect the environment and face climate change challenges, consist on the incorporation of environmental concerns in the ideologies and practices of social systems (Burch et al., 2001). Some of those environmental oriented innovations include agroecology to solve the current unsustainability in agriculture (Sansilvestri et al, 2015; Koohafkan et al, 2012; Gliessman, 2007; Guzman and Alonso, 2007).

Compared with other EU members, Spain is in the fourth place in terms of agriculture production, only behind France, Germany and Italy (Eurostat, 2017), and being in the Southern Mediterranean region will be especially threatened by climate change extremes such as drought (Quiroga and Suarez, 2016; Iglesias et al., 2012a, 2012b; Ciscar et al., 2011), making innovation a particularly important issue in the region. In fact, the country has a comparative advantage in agriculture innovation, and has hugely increased in the last fifty years (Pardey et al., 2016), being the entry of the country in EU is a turning point in this evolution. Alongside with other actions, CAP instruments have promoted reforms to enhance market diversification and innovation in agricultural holdings (Agrosynergie, 2013).

Here we analyze the factors that may affect the R&D investment decisions regarding strategic objectives of innovation, especially what relates with the impact of CAP instruments on that decision in the Spanish micro-level activity of the farms.

The paper is organized as follows: section 2 shows the data and methodology used, such as the proposed framework, and the econometric model in order to identify these theoretical relationships; section 3 presents the main findings of the analysis, such as the estimated relationships and some simulations for different policy scenarios. Finally, we highlight the most important conclusions.

2. Methods

2.1 Developing a behavioural framework for R&D objectives

Figure 1 shows the proposed conceptual framework for the analysis in this paper. This framework focuses on identifying the drivers affecting the farm decision making process respect to R&D objectives. More specifically how they prioritize among production increase, cost efficiency and environment protection. Farms may decide between different strategic purposes in light of the R&D goals and these decisions may be influenced by the CAP subsidies. We consider the effect of some specific CAP instruments directly affecting one of the objectives —that is the case of production oriented subsidies affecting the priorities on production increase R&D objective; inputs
oriented subsidies affecting the priorities on cost efficiency R&D objective and environmental subsidies affecting the priorities on environmental protection R&D measures—and some general CAP subsidies as a transversal factor—that is the case of decoupled payments and less favored areas, that may affect all of the R&D objectives through an income effect.

The decision would also be affected and modulated by other market and environmental pressures. In this context, it is necessary to identify the drivers which are the underlying factors that affect the choice of R&D objective. It is understandable that not every factor concerning strategic purposes may have relevance in every of the three R&D aims. Then, we have some transversal determinants, affecting as a general factor to all the objectives and other specific drivers that only affect to the decision on prioritizing one of the objectives more specifically. Among the transversal drivers, we differentiate between

(i) Market drivers

Size. One of the main factors to measure the involvement in R&D objectives is farm size. There is evidence that larger farms are much better placed than smaller ones to invest in new technologies generated by R&D activities (Fernandez-Cornejo et al, 2002). One
of the major benefits is the positive correlation between size and financial access (MacDonald et al, 2013), this is a critical question for the new technologies that are costly, then unsubsidized farms must have scale and access to the funds to have greater potential to invest in them (Eastwood et al, 2010; Zimmermann and Britz, 2014).

**Experience.** Farm age is regarded as a proxy for the farming experience and knowledge-base. Younger farms are supposed to be more willing to use new production methods and management techniques than older ones and, in that sense, they may also have more exposure to innovations (Yu et al, 2014, Diederen et al, 2003).

**Internationalization.** Investment in knowledge is the key to value creation and new technologies can improve the quantity and quality of agricultural products with implications in market opportunities (Hirsch et al, 2014). Then it is important take into account the competitive advantages which could arise from the efforts made by farms toward innovation and internationalization (Triguero et al, 2013; Alarcón and Sánchez, 2016). The participation of agriculture firms into international markets through export activity allows them to grow.

**Differentiation.** In a market with a limited product range, differentiation is the way to reach a higher market share (Carter, 1997). In Europe, labels proclaiming Protected Designation of Origin (PDO) link products to their geographic origin, thereby promoting a specific taste or quality linked to a region (Regulation EU 1151/2012 of the European Parliament and of the Council), then this fact may reflect processes or conditions of production that impart value to the consumer. The European Commission encourages these producers to become more competitive through innovation, including modern techniques of production and management (EC, 2007).

(ii) Environmental pressures

Agricultural R&D has to target a potentially wide range of future climate outcomes. The most important factors that may modulate the R&D objectives could be the climate extremes, especially drought in the Mediterranean, and the pressures on nature, such as deforestation.

**Drought.** European climate leads to projected overall temperature increase from 2 to 4°C by the 2080s. The changes are likely to be more pronounced in southern Europe, with temperature increases reaching +5°C by the 2080s in some scenarios and an alarming increase of extreme temperature (hot and very hot days). Drought periods may increase throughout the Mediterranean region (Giorgi and Lionello, 2008; Christensen and Christensen, 2007) adding an important pressure over farm incomes (Quiroga and Suarez, 2016). In this context, R&D activities which seeks to improve yields and
resistance to stresses such as drought are focused at an efficient use of resources or the development of biotechnologies to enhance crop resilience (Ignaciuk, 2015). Also, optimal use of water resources for agricultural production has centered the efforts in R&D activities (George et al., 2000; Gu et al., 2017; Saccon, 2017).

Deforestation. The agriculture production depends on the amount of space available to farm and the agriculture activity seems to be the main cause of deforestation due to the forest clearing (Kasterine and Vanzetti, 2010). Byerlee et al. (2014) conclude in their literature review that at a global level, investment in R&D to improve agricultural productivity remains one of the best ways to reduce the pressure on increasingly scarce land resources and conserve natural ecosystems.

2.2 Data

Since our model considers the interrelation among R&D objectives and the impacts of different subsidy programs, it was necessary to combine several databases for the analysis. We have used a survey of innovating Spanish firms PITEC in the period 2008-2014 to achieve information about R&D objectives and market drivers. This data set is based on the Community Innovation Survey (CIS) framework, and it is built by the National Statistics Institute (INE) in collaboration with the Spanish Foundation for Science and Technology (FECYT), the Cotec Foundation for the Technological Innovation, and a group of university researchers. Following the context of this paper, we select an agricultural subsample (NACE-2009 code 0000) that includes companies which present information for some of the 7 years and provides information about farms R&D activities, management drivers, etc.

From this database come the three dependent variables which reflect the degree of importance in achieving objectives with technological innovation. These three objectives are related to production increase, cost efficiency and environmental protection. Other variables used from PITEC are related with market drivers, specifically, we introduce the size of the farm, the experience of the company and the percentage of exportations over total sales to measure internationalization.

Subsidies information for the period analyzed has been collected from FADN (Farm Accountancy Data Network, http://ec.europa.eu/agriculture/rica/database/database_en.cfm). The data in the network consists of physical and structural data, as well as economic and financial data, based on annual surveys carried out by the member states. The resulting data from the surveys present average farm statistics, which are calculated across years, EU NUTS2 regions,
economic size and type of farming. The subsample employed in this paper covers Spain regions (NUTS2) by six economic sizes in the FADN database over the period 2008-2014.

Farmers receive subsidies through different types of payments. We have distinguished between general CAP subsidies that are transversal to all objectives, like the Less Favoured Areas (LFA) subsidies or the decoupled payments; and the specific CAP subsidies, such that of production oriented (production increase), inputs oriented (cost efficiency) and environment oriented (environment protection). All of these variables are settled in euros per farm in real terms.

As one of the variables that measure differentiation, we also introduce the number of Protected Designation of Origin (PDO) which identifies products that are produced, processed and prepared in a specific geographical area, using the recognized know-how of local producers and ingredients from the region concerned. Ministry of Agriculture and Fisheries, Food and Environment (MAPAMA, 2017) provide a database including all the PDO by region.

To analyze the environmental pressures related with climatological aspects, we introduce the possibility there was a drought or not. We have taken the data about historical precipitations from AEMET (State Agency of Meteorology) and we have transformed the time series into a Standardize Precipitation Index (SPI, McKee et al., 1993). Broadly considered, this index is a representation of abnormal wetness and dryness based on precipitation series but is limited because it does not deal with the evapotranspiration side of the issue (Trenberth et al, 2014). It is calculated with the SPI program (http://drought.unl.edu/MonitoringTools/DownloadableSPIProgram.aspx). This approach has been used before in some previous analysis in Spain (Iglesias and Quiroga, 2007; Quiroga and Iglesias, 2009; Iglesias et al., 2010; Quiroga and Suárez, 2016).

Other environmental pressure variable is related with deforestation in Spain. This information is published by the MAPAMA (2017). This Ministry elaborates every year the Forest Statistics Yearbook (http://www.mapama.gob.es/3r/desarrollo-rural/estadisticas/forestal_anuarios.todos.aspx), from which we obtained information about forested and deforested regions in Spain.

Table 1 shows detailed information about the variables we used, the units and source of the data and main descriptive statistics.
## Table 1. Descriptive statistics of the variables (mean and standard deviation for the quantitative variables and frequency of qualitative variables).

<table>
<thead>
<tr>
<th>TYPE</th>
<th>NAME</th>
<th>DESCRIPTION</th>
<th>SOURCE</th>
<th>UNIT</th>
<th>DESCRIPTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependent variables</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production increase objectives</td>
<td>R&amp;D objectives</td>
<td>Degree of importance of having a greater productive or providing services capacity with technological innovation</td>
<td>PITEC</td>
<td></td>
<td>16.81</td>
</tr>
<tr>
<td>R&amp;D objectives</td>
<td>Cost efficiency</td>
<td>Degree of importance of having a lower need for materials per unit produced with technological innovation</td>
<td>PITEC</td>
<td></td>
<td>27.64</td>
</tr>
<tr>
<td>R&amp;D objectives</td>
<td>Environment protection</td>
<td>Degree of importance of having a lower environmental impact with technological innovation</td>
<td>PITEC</td>
<td></td>
<td>16.81</td>
</tr>
<tr>
<td>Independent variables</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Independent variables</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transversal variables</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size</td>
<td>Number of employees</td>
<td>PITEC</td>
<td>Number</td>
<td>95.66</td>
<td>(140.42)</td>
</tr>
<tr>
<td>Experience</td>
<td>Dummy variable for years since the firm was founded.</td>
<td>PITEC</td>
<td>1 = ≥ 10 years</td>
<td>94.02</td>
<td></td>
</tr>
<tr>
<td>Experience</td>
<td>Dummy variable for years since the firm was founded.</td>
<td>PITEC</td>
<td>0 = &lt; 10 years</td>
<td>5.08</td>
<td></td>
</tr>
<tr>
<td>Internationalization</td>
<td>Ratio between exportations and sales</td>
<td>PITEC</td>
<td>%</td>
<td>3.65</td>
<td>(11.21)</td>
</tr>
<tr>
<td>Differentiation</td>
<td>Number of products with Protected Designation of Origin (PDO)</td>
<td>MAPAMA</td>
<td>Number</td>
<td>29.85</td>
<td>(18.42)</td>
</tr>
<tr>
<td>Environmental pressures</td>
<td>Drought</td>
<td>Whether there was or not a drought according to the Standardized Precipitation Index (SPI)</td>
<td>AEMET</td>
<td>1 = Drought</td>
<td>76.07</td>
</tr>
<tr>
<td>Environmental pressures</td>
<td>Drought</td>
<td>Whether there was or not a drought according to the Standardized Precipitation Index (SPI)</td>
<td>AEMET</td>
<td>0 = Otherwise</td>
<td>23.93</td>
</tr>
<tr>
<td>Environmental pressures</td>
<td>Deforestation</td>
<td>Ratio between deforested area and total</td>
<td>MAPAMA</td>
<td>%</td>
<td>19.14</td>
</tr>
<tr>
<td>General CAP subsidies</td>
<td>Less Favoured Areas (LFAs)</td>
<td>Subsidies to areas where farming is handicapped by geography, topography or climate at constant prices (GDP prices deflator).</td>
<td>FADN</td>
<td>Euro</td>
<td>257.44</td>
</tr>
<tr>
<td>General CAP subsidies</td>
<td>Decoupled payments</td>
<td>Subsidies not linked to production at constant prices (GDP prices deflator).</td>
<td>FADN</td>
<td>Euro</td>
<td>4356.27</td>
</tr>
<tr>
<td>Specific variables</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specific variables</td>
<td>Production oriented subsidies</td>
<td>Subsidies on crops at constant prices (GDP prices deflator).</td>
<td>FADN</td>
<td>Euro</td>
<td>841.96</td>
</tr>
<tr>
<td>Specific variables</td>
<td>Inputs oriented subsidies</td>
<td>Subsidies on intermediate consumption at constant prices (GDP prices deflator).</td>
<td>FADN</td>
<td>Euro</td>
<td>50.63</td>
</tr>
<tr>
<td>Specific variables</td>
<td>Environment oriented subsidies</td>
<td>Subsidies on environmental at constant prices (GDP prices deflator).</td>
<td>FADN</td>
<td>Euro</td>
<td>367.59</td>
</tr>
</tbody>
</table>
2.3 Multivariate ordered probit model for R&D objectives estimates

The econometric model that summarizes the behavioral framework presented so far includes as independent variables \((Y_k)\) the R&D objectives for farms, where \(i = 1, \ldots, N\) are farms and \(k = 1, \ldots, K\) are different objectives for R&D activities, in our paper are production increase, cost efficiency and environment protection. The econometric procedure used to jointly estimate the interrelated equations is the multivariate ordered probit model (Greene and Hensher, 2010), this model was selected from the intuition that farmers are more likely to do R&D activities for a mix of reasons than for a single one. We consider two main sets of exogenous explanatory variables to evaluate the reasons for different objectives for R&D activities: transversal variables which are common to all the alternatives \((X)\) and specific variables, which are particulars for each concrete dependent variable \((W)\). The model is specified as follows:

\[
Y_{i1}^* = \beta_1' X_i + \gamma_1' W_{i1} + \epsilon_{i1}, \text{ where } Y_{i1} = j_1 \text{ if and only if } \mu_{j-1,1} < Y_{i1}^* < \mu_{j,1}
\]

\[
Y_{i2}^* = \beta_2' X_i + \gamma_2' W_{i2} + \epsilon_{i2}, \text{ where } Y_{i2} = j_2 \text{ if and only if } \mu_{j-1,2} < Y_{i2}^* < \mu_{j,2}
\] [1]

\[
Y_{i3}^* = \beta_3' X_i + \gamma_3' W_{i3} + \epsilon_{i3}, \text{ where } Y_{i3} = j_3 \text{ if and only if } \mu_{j-1,3} < Y_{i3}^* < \mu_{j,3}
\]

where \(\beta_k\) and \(\gamma_k\) are parameters to be estimated, \(\mu_{j,k}\) is the upper bound threshold for count level \(j\) of objective \(k\) \((\mu_{0,k} < \mu_{1,k} \ldots < \mu_{J,k}; \mu_{0,k} = -\infty, \mu_{J,k} = +\infty\) for each objective \(k\)). The threshold bounds define a range of the underlying latent continuous variable corresponding to each observed discrete outcome. The \(\epsilon_k\) a standard normal error term with:

\[
\begin{pmatrix}
\epsilon_{i1} \\
\epsilon_{i2} \\
\epsilon_{i3}
\end{pmatrix} \approx N\left(\begin{pmatrix}0 & 1 & \rho_{12} & \rho_{13} \\
0 & 1 & \rho_{21} & \rho_{23} \\
0 & \rho_{31} & 1 & 1\end{pmatrix}\right) \text{ or } N[0, \Sigma]
\]

The off-diagonal terms of \(\Sigma\) capture the error covariance across the underlying latent continuous variables of the different objectives; that is, they capture the effect of common unobserved factors influencing the propensity of choice for each objective for R&D activities. Then, if \(\rho_{12}\) is positive, it implies that farms with a higher than average propensity in their peer group to R&D activities in the first objective are also likely to have a higher than average propensity to R&D activities in the second objective. As is well known, if all the correlation parameters are zero, the model system in Equations [1] should be estimated as independent ordered response probit models for each objective providing consistent and asymptotically efficient estimators for all model parameters.
2.4 Simulated probabilities for change scenarios

In order to analyze the response of R&D objective selection from farmers responding to changes in the subsidies structure, we calculate simulations based on the marginal effects of the determinants estimated in the multivariate ordered probit model. The joint probability with ordered selection is then defined as:

\[ Pr(Y_1=j_1, Y_2=j_2, Y_3=j_3 \mid X, W) = \]

\[ \Phi(\omega_{j,1}, \omega_{j,2}, \omega_{j,3}, \Sigma) - \Phi(\omega_{j,1}, \omega_{j,2}, \omega_{j-1,3}, \Sigma) - \Phi(\omega_{j,1}, \omega_{j-1,2}, \omega_{j,3}, \Sigma) - \Phi(\omega_{j,1}, \omega_{j,2}, \omega_{j,3}, \Sigma) \]

\[ + \Phi(\omega_{j-1,1}, \omega_{j-1,2}, \omega_{j-1,3}, \Sigma) + \Phi(\omega_{j-1,1}, \omega_{j,2}, \omega_{j-1,3}, \Sigma) + \Phi(\omega_{j-1,1}, \omega_{j-1,2}, \omega_{j,3}, \Sigma) \]

\[ - \Phi(\omega_{j-1,1}, \omega_{j-1,2}, \omega_{j-1,3}, \Sigma) \]

where \( \Phi \) standard normal cumulative distribution function and \( \omega_{j,k} = \mu_{j,k} - \beta_k' X + \gamma_k' W_k \).

And then, marginal effects for multivariate ordered probit model are computed at the mean for continuous variables and median for dummy variables for each category following Mullahy (2017).

3. Results

3.1 Drivers for defining priorities among R&D objectives

The results of the multivariate ordered probit estimation are shown in Table 2. This table provides a general sense of the direction of impacts of specific factors when deciding among different R&D objectives (production increase, cost-efficiency and environment protection). As we can see in Table 2, all the three objectives are interrelated with each other. The positive and significant correlation coefficients support the use of a multivariate ordered probit model to analyze the data and indicate that a random increase in the outcome to one of the R&D objective tends to correspond to a random increase in the outcome of all the other objectives. Important differences can be observed on the estimation of transversal variables’ effects.
Table 2. Estimation results for R&D objectives

<table>
<thead>
<tr>
<th>Transversal variables</th>
<th>Production increase</th>
<th>Cost efficiency</th>
<th>Environment protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market drivers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log(size)</td>
<td>0.124** (0.054)</td>
<td>0.155*** (0.047)</td>
<td>0.063 (0.052)</td>
</tr>
<tr>
<td>Experience</td>
<td>-0.594* (0.337)</td>
<td>-0.141 (0.264)</td>
<td>0.364 (0.276)</td>
</tr>
<tr>
<td>Internationalization</td>
<td>0.013* (0.008)</td>
<td>0.010* (0.006)</td>
<td>0.001 (0.006)</td>
</tr>
<tr>
<td>Log(differentiation)</td>
<td>-0.202* (0.115)</td>
<td>-0.350*** (0.099)</td>
<td>0.206* (0.108)</td>
</tr>
<tr>
<td>Environmental pressures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drought</td>
<td>-0.115 (0.160)</td>
<td>-0.139 (0.146)</td>
<td>-0.202 (0.161)</td>
</tr>
<tr>
<td>Deforestation</td>
<td>0.035** (0.015)</td>
<td>0.049*** (0.014)</td>
<td>0.042*** (0.015)</td>
</tr>
<tr>
<td>General CAP subsidies</td>
<td>Log(LFA)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-0.061* (0.037)</td>
<td>0.001 (0.035)</td>
<td>-0.072** (0.036)</td>
</tr>
<tr>
<td></td>
<td>Log(decoupled)</td>
<td>0.168* (0.089)</td>
<td>0.160** (0.081)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.331*** (0.088)</td>
</tr>
<tr>
<td>Specific variables</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specific CAP subsidies</td>
<td>Log(prod_sub)</td>
<td>-0.060** (0.026)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Log(input_sub)</td>
<td>0.078*** (0.028)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Log(env_sub)</td>
<td></td>
<td>-0.066* (0.035)</td>
</tr>
<tr>
<td>( \rho_{12} )</td>
<td>0.733*** (0.044)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \rho_{13} )</td>
<td>0.593*** (0.061)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \rho_{23} )</td>
<td>0.599*** (0.056)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>351</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LR \chi^2(27)</td>
<td>102.84***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log likelihood</td>
<td>-836.88</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Standard errors are reported in parentheses. *p < 0.1; **p < 0.05; ***p < 0.01.

Figure 2 presents the marginal effects for these variables. These marginal effects represent the average change in the probability of a specific R&D objective outcome that corresponds to a one-unit change in a continuous independent variable and a change from zero to one in the dummy independent variable.
Figure 2. Marginal effects obtained from the regression

(a) Production increase as research objective

(b) Cost efficiency as research objective

(c) Environment protection as research objective

Note: *p < 0.1; **p < 0.05; ***p < 0.01
Size is relevant and the effect is positive (the bigger the size the higher the preference for this objective) when defining priorities towards production increase and cost-efficiency objectives. This result is consistent with the strategic approach of H2020 to EU agricultural research and innovation, which points as a weakness the size, and signals the small and medium-sized farms’ participation in research and innovation activities difficult for many reasons, including limited human, financial and infrastructure resources (EC, 2016). However, size seems not to be a determinant factor to prioritize investment on environmental oriented R&D in Spain.

Experience only makes differences affecting the production objective. Since the estimated coefficient is negative, this means that companies with more than 10 years of experience are less involved to apply R&D oriented to their production increase. This can be explained due to younger farms that are supposed to be more willing to use new production methods and management techniques than older ones, and so may also have more exposure to innovations, which has previously been found by Läpple et al. (2016).

Differentiation through PDO is relevant in the three cases, but exhibiting different effects. With respect to the production and cost objectives the effect is negative, but it affects positively for the environmental objective orientation. This could imply that firms with a higher number of PDO are not interested in increasing their production, conserving the exceptionality of their products; nor in improving their materials because of the unique procedure of production. The positive sign with the environmental objective may respond to the fact that, to conserve the quality of the PDO, it is necessary to ensure that the environment is not exhausted.

Internationalization is significant and has a positive effect in the two first objectives and it is not significant for the environment protection objective. Product or cost innovation is presumably directed towards the quality of products in some sense, which in turn is also likely to reflect the competitive conditions surrounding farms and then with export quality specialization (Bojnec and Fertő, 2017).

General subsidies. Decoupled direct payments are statistically significant, sharing for all objectives the positive sign. This means that, since decoupled subsidies do not constrain farmers’ choice and then granting subsidies with no production requirement is not indicative of wasted resources in terms of R&D objectives and the same as in many studies in other industries, this kind of subsidies show a dominant income effect on R&D in general. On the other hand, the subsidies given to less favored areas are only relevant for the increase of production and environment protection objectives, and show a
negative effect in the two cases. This may be explained because the objective of this subsidy is to ensure continued agricultural land use in order to contribute to the maintenance of a viable rural community.

We observe also some environmental pressures being relevant determining the R&D priorities: *Drought* is not significant for determining any of the objectives. This fact can be understood as a sign of low adaptive capacity building. Williges et al. (2017) studied several factors that could affect the capacity of European countries to face extreme droughts. They found that Central and Northern countries have more capacity to adapt in case of lack of water. Contrary, Southern countries, like Spain, have less capacity, but are more intensive in financial capital because of the insurance strategy. *Deforestation* is, however, positive and significant so that the increasing of non-forest land improves the investment in R&D objectives.

Finally, the three specific subsidy variables are significant in each specific objective as we would expect. Production increase and environmental protection objectives seems to be negatively affected by subsidies in production and environmental protection respectively, so in these two cases, the oriented subsidies would show a substitution effect. However, the opposite occurs for the cost-efficiency objective, which is clearly enhanced by the input-oriented subsidies, showing a dominant income effect in this case. This result may be policy relevant since it shows that R&D objectives in the EU policy strategy should be taken into account when redefining CAP instruments, which are in constant evolution.

### 3.2 Policy simulations for CAP influence on R&D structure

In order to analyze how the oriented CAP subsidies influence the attitude to R&D strategies, Figure 3 presents the predicted probabilities as a response to the expenditure per farm (perceived within the three specific CAP subsidies). Vertical lines represent the CAP subsidy mean values and we can observe that for mean values the predicted probability of high attitude to R&D linked with production increase is 65.58% (z=23.35***), for cost efficiency is 40.72% (z=14.32***) and for environment protection is 63.91% (z=21.98***).
Figure 3. Predicted probability of high R&D objective over specific CAP subsidies

Considering an average farm, the higher the CAP expenditure on specific oriented subsidies, the lower the probability of a farm orienting their R&D objectives to production increase or environment protection. The opposite occurs for cost efficiency objectives, which respond positively to specific subsidies with an input orientation. The graph shows that only the inputs oriented subsidies help Spanish agriculture firms to increase the relevance of applying R&D in their cost structure. Anyway, for the three cases, when the amount of the subsidy gets higher, the likelihood tends to be around the 60% and achieves convergence at this point. The three paths share that the probabilities are very sensitive to the existence of the subsidy, changing quickly as long as the funds separate from zero.

Figure 4 shows how the probability of a high R&D objective changes when modifying the decoupled payments. Vertical line represents the mean decoupled payment in euros per farm.
In the three R&D objectives, the coefficient of this variable is positive and significant (see Table 2), so the probability increases along with the amount of the funds. However, the three simulations present different paths. Taking the average subsidy as a reference, production and environment objectives has a higher probability of being enhanced. Even if production and environment objectives have a similar probability of being implemented at the average level of decoupled subsidies now, the direction of change of decoupling measures may be a turning point, where the more the decoupling the more the environmental protection R&D orientation. This may respond to the fact that decoupling may link farmers to territory and so favoring the conservation pathways for land use through more sustainable practices such as agroforestry.

4. Conclusions

At a time when the CAP is changing policy targets, it is important to assess whether the resulting reorientation of CAP instruments prepares farmers to improve their innovation processes. From the perspective of our specific research aims, specific subsidies appear to generate a disincentivating effect on production increase and environment protection R&D objectives, and an incentive on the cost-efficiency goal. This suggests a possible flaw in the production-oriented subsidies and environment-oriented subsidies if the policy aim is incentivize competitiveness and improve sustainability in agriculture.
On the other hand, decoupled subsidies, conceived to not constrain production requirement and to move towards a more market-oriented competitive model, are incentivizing all three R&D strategic purposes, this suggests a strength in their implementation and also that these direct payments show an income effect on R&D farmer goals.

The market drivers comprise also some relevant policy measures. Size and internationalization favored production increase and cost efficiency research objective and support the strategic approach of the reorientation of CAP instruments. In regard to the environmental pressures, deforestation shows a positive effect to farm R&D activities. Future European innovation programs need to develop future land use change scenarios stemming from the important role that farm and human activities play in environmental quality.

To further develop this research, additional work could explore the Spanish situation with the European one, trying to determine if the pattern is the same of the neighboring countries. Indeed, an additional extension of this analysis could link the farm survey data with remote sensing soil water information.

References


