Protected Designation of Origin in the Olive Growing Sector: Adoption Factors and Goodness of Practices in Andalusia, Spain

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Jel Classification: Q15, Q55, Q18

Abstract

In a context of increasing concentration and multinationalisation of olive oil supply, Protected Designation of Origin (PDO) represents an increasingly important strategy for competitiveness. Based on a survey of 400 olive growers in Andalusia, the leading olive producing region in the world, this paper investigates 1) the factors related to characteristics of olive farmers and farms, which have conditioned the adoption of PDO; and 2) the environmental, economic and agronomic goodness of PDO farming practices. A further diffusion of PDO would require highlighting PDO as a medium- to long-term quality strategy especially for non-highly productive farmers, promoting membership of agricultural associations and the use of external sources of information about innovations, and making growers aware of the importance of respect for the environment when producing. PDO farmers seem to be targeting quality whereas other attributes, such as respect for the environment, are neglected to some extent. Therefore, most practices could be improved. A further greening of PDO practices would represent added value in the eyes of local but also international consumers and would be in line with CAP 2014-2020 trends. The role of public administrations in promoting the adoption of PDO and training in the use of more sustainable farming practices should be further strengthened.

Keywords: *Olive production, Certified Quality Systems, quality, best practices, innovation adoption.*

Résumé

Dans un contexte de concentration croissante et de multinationalisation de l'approvisionnement de l'huile d'olive, l´Appellation d'Origine Protégée (AOP) représente une stratégie de plus en plus importante pour la compétitivité. À partir d´une enquête effectuée auprès de 400 oléiculteurs en Andalousie, la principale région productrice du monde, cette étude examine 1) les facteurs en relation aux caractéristiques des agriculteurs et de leurs exploitations qui déterminent l'adoption de l´AOP; 2) La qualité environnementale, économique et agronomique des pratiques agricoles AOP. La diffusion de l'AOP devra mettre en évidence que cette appellation est une stratégie de qualité à moyen et long terme, surtout pour les agriculteurs non très productifs, sur la promotion de l'adhésion aux associations agricoles, l'utilisation des sources d'informations externes sur les innovations, et la sensibilisation des oléiculteurs à l'environnement. Les agriculteurs qui adoptent l´AOP visent la qualité, alors que les autres attributs, tels que le respect de l'environnement, sont négligés. Par conséquent, la plupart des pratiques utilisées pourraient être améliorées. Une écologisation plus poussée des pratiques d'AOP représenterait une valeur ajoutée non seulement pour les consommateurs locaux mais aussi à l'échelle internationale, et serait en phase avec les tendances de la PAC 2014-2020. Le rôle des pouvoirs publics dans la promotion de l'AOP et la formation pour l'utilisation des pratiques agricoles les plus durables devrait être renforcé.

Mots-clés: Oléiculture, Systèmes de Qualité Certifiés, qualité, meilleure pratique, adoption de l'innovation.

1. Introduction

Olive growing plays an important socio-economic role in Andalusia, the most important olive growing region in the world, located in the south of Spain. Olive growing provided 27.7% of Andalusian fruit and vegetable production in 2010 (CAP, 2012); it generates around one third of agricultural employment, approx. 47.1% of which is family-based (CAP, 2009). Despite the technological improvements since the early 90s, especially in the mills, the sector currently faces a critical situation, especially in the first links of the agro-food chain. In this situation, two types of strategies emerge for olive growers to become more competitive, the first based on reducing production costs and the second on increasing the olive oil price through consumer value creation (Sanz Cañada and Macías Vázquez, 2005; Velasco Gámez *et al*., 2011). The first set of strategies is driven by the mechanization of harvesting and pruning, which reduces costs and increases the efficiency of crop production (Polelli *et al*., 2007). These strategies could be difficult to implement in a context of constantly increasing input costs (mainly fuel), and especially difficult for olive growers who are not highly productive. The second set of strategies directed at increasing the olive oil price is focused on quality, food safety, supply concentration and promotion. Among them, product differentiation based on the highest quality is one of the most powerful competitive strategies (Terlaak and King, 2006; Roselli *et al*., 2009; Sanz Cañada and Macías Vázquez, 2009). Quality and food safety are important attributes for consumers in highly developed countries and for the upper middle classes in developing countries (Mili and Rodríguez-Zúñiga, 2001; Sanz Cañada and Macías Vázquez, 2005).

Certification of quality through the adoption of a Certified Quality System (CQS) is becoming an increasingly important sales and marketing strategy for competitiveness in the agro-food sector. The CQS available in Europe include public and other private public norms (Hinojosa-Rodríguez *et al*., 2013). Protected Designation of Origin (PDO) is a public certification system in the framework of the EU quality policy. It guarantees that agricultural products and foodstuffs are produced, processed and prepared in a given geographical area using recognized know-how (EU Regulation 1151/2012 of the European Parliament

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and of the Council), all without prejudice to other rules relating to food security, quality, labelling, or other applicable measures (Ruiz Castillo, 2008). PDO aims to promote and protect the names of agricultural products and food quality, conceived in response to the growing consumer demand for quality certificates (Fotopoulos and Krystallis, 2001). PDO can be seen as a distinctive sign of quality which may generate competitive and marketing advantages for products under its protection (Fotopoulos and Krystallis, 2001; Espejel *et al*., 2007). Items such as the 'image' of the territory, the specific skills and cultures of the production process, the concerns of both the local population and institutions, all contribute in different ways to the perception of the value of a PDO product, embedding the services and the tradition into the product itself (Roselli *et al*., 2009). Olive oil certified under a PDO scheme must fulfil a set of production requirements in reference to the varieties planted, the physical, chemical and organoleptic characteristics of the oil, which in all cases must be of the highest grade ('extra-virgin'), the geographical area where the olive groves are located and certain specifications regarding cultivation practices, among other features. The cultivation practices implemented must be the traditional ones of the geographical area under PDO, with no additional requirements or restrictions, except for the harvest and transport practices. Olives must be collected and transported separately according to their quality, distinguishing olives collected from the ground and trees. A mixture of ground and tree olives would increase the acidity of the olive oil, thus reducing its quality.

PDO is the second most adopted CQS by Andalusian olive farmers, with an adoption rate of 16.1%, after integrated production, with 16.8% (Hinojosa-Rodríguez *et al*., 2013). Other certificates of origin, such as Protected Geographical Indication (PGI), are not implemented in Andalusian olive growing. PDO olive oil in Spain in 2010 represents 7.1% of the whole olive oil produced (MAGRAMA, 2010; AAO, 2011) and 18.0% of extra virgin olive oil (MAGRAMA, 2010, 2011). Only 22.1% (22,118 tonnes) of protected oil produced in 2010 (99,988 tonnes) was marketed as PDO (MAGRAMA, 2010); most of this olive oil was sold on the national market (83.8%) and the rest (16.2%) was exported to EU and third countries (9.7% and 6.5%, respectively) (MAGRAMA, 2010).

With this in mind, the objectives of this paper are: (1) To determine the adoption factors of PDO in the olive growing sector, in other words, the characteristics of the farmers and farms related to the adoption of PDO; and (2) To investigate the relationship between PDO adoption and the farming practices implemented by olive growers, and evaluate the goodness of PDO vs. non-PDO practices. This would help to design policies for a wider diffusion of PDO and an improvement of PDO sustainability and competitiveness.

2. Literature review

Despite the relative importance of PDO production in the Andalusian olive growing sector, the underlying mechanisms that have conditioned its adoption into the supply chain have not been sufficiently analysed. Moreover, the goodness of the farming practices associated with PDO olive growing vs. non-PDO practices has been analysed even less. Indeed, the international literature on PDO as a Certified Quality System in the olive agro-food system has dealt with diverse topics, but not those specifically analysed here, such as the demand/acceptance of PDO olive oil among consumers (Fotopoulos and Krystallis, 2001; van der Lans *et al*., 2001; Krystallis and Ness, 2005; Espejel *et al*., 2007; Navarro García *et al*., 2010; Erraach and Sayadi, 2011); and the marketing and sale of PDO olive oil (Ruiz Avilés *et al*., 2007; Ruiz Castillo, 2008; Martín Cerdeño, 2009). Previous studies in various producing countries indicate the very low penetration rate, even among rural populations, and highlight the low premium on the price of PDO olive oil, which is not enough to compensate the additional costs of joining a PDO scheme (Fotopoulos and Krystallis, 2001; van der Lans *et al*., 2001; Krystallis and Ness, 2005; Galluzzo, 2007; Roselli *et al.,* 2009). Externalities associated to Andalusian PDO olive oil have been analysed (Pérez-y-Pérez *et al*., 2013) being patent a dominance of economic vs. environmental and social externalities. The adoption of PDO has been analysed, with a different perspective from our work, as a quality differentiation strategy to improve the economic viability of olive agriculture in Italy (Polelli *et al*., 2007; Roselli *et al*., 2009), Portugal (Baptista and Biswas, 2010) and Spain, in particular in the regions of Castilla la Mancha (Marbán Flores, 2003, 2004, 2005) and Andalusia (Sanz Cañada and Macías Vázquez, 2005, 2008). The latter argue that there is a positive correlation between PDO adoption as an institutional innovation and the diffusion of technical innovations and good practices in the production process in the Andalusian olive agro-food chain. However, these studies are mostly qualitative and the level of detail in the practices and innovations analysed is not very high.

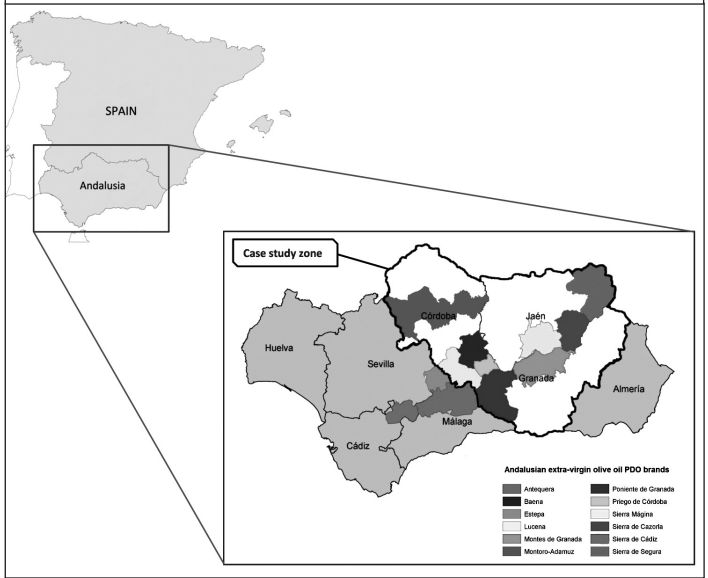
3. Materials and methods

The rationale of the research is that olive growers' characteristics, attitudes and opinions, and the structural characteristics of farms may affect the adoption of PDO and that the adoption of PDO may affect the farming practices implemented. The theoretical background behind this is the Diffusion of Innovations paradigm, in particular the most recent version of the Rogers theory (Rogers, 2003). This paradigm was formally conceived with the seminal work of Ryan and Gross (1943), and has been widely used to study the diffusion of innovations in agriculture. It proposes a model to explain the relationships between the characteristics and attitudes of individuals (or groups of individuals) and their behaviour with respect to the adoption of innova-

tions. Moreover, it highlights the importance of investigating the consequences of this adoption for adopters and other agents.

A survey of 400 farmers from the main olive growing provinces in Andalusia destined to olive oil production, namely Jaen, Cordoba and Granada (MAGRAMA, 2011), was carried out from May 2010 to February 2011. The survey was stratified proportionally to the number of olive farmers in homogeneous olive growing regions, which were previously delimited to include municipalities of similar importance for olive cultivation in terms of the average area of olive farms and density of farms over the total surface area. Since 239,323 farmers are the targeted population, for dichotomous variables at 95% confidence level the sampling error obtained is 2.94% for extreme proportions (p=0.9 y q=0.1) and 4.90% for intermediate proportions (p=q=0.5).The case study zone and the PDO areas are shown in Figure 1. The interviews were conducted face to face and followed a structured questionnaire.

Figure 1 - *Olive growing regions analysed and olive oil PDO areas in Andalusia.*



Source: Based on data from CAP website (http://www.cap.junta-andalcia.es/agriculturaypesca/portal).

The questionnaire, which is available to the interested parties upon request, included the following:

I. Characteristics, attitudes and opinions of the olive farmers. These include agricultural training, information sources on new practices and CQS, objectives when producing, objectives when innovating, difficulties in innovating, and priorities in R&D, among others.
II. Structural characteristics of the olive farms such as farm area distribution, yield, type of labour force, destination of the produce and slope of the land, among others.
III. Farming practices implemented such as planting, soil management, irrigation, fertilization, phytosanitary treatments, harvesting, transport, pruning and management of by-products.

The methods of analysis for each of the objectives are:

1) Adoption factors of PDO. First, variables that are individually related to the adoption of PDO are determined. A bivariate statistical analysis was conducted between the characteristics of olive farmers and farms and the adoption of PDO to detect characteristics significantly different between PDO and non-PDO. These differences can be related to and serve to explain, at least in part, the adoption of PDO. Bivariate statistical correlations are based on: (1) Corrected Yates χ^2 for contingent tables when degrees of freedom (d.f.) = 1; (2) Pearson χ^2 for contingent tables when d.f.> 1; (3) χ^2 for bivariate logit when proof for contingent tables is not statistically reliable. Additionally, we are interested in determining the main factors influencing PDO adoption, i.e. the minimum characteristics of farmers and farms, considering that the reasons and characteristics behind adoption may be interrelated. For this purpose, a multivariate binomial logit (logistic regression) model was adjusted. The dependent variable is 'adoption of PDO' (yes/no). The initial explanatory variables are those individually related to the adoption of PDO. These variables are subsequently selected by the backward stepwise Wald method, according to their significance and contribution to the explanation of the dependent variable.

2) Farming practices in PDO vs. non-PDO. Based on a bivariate statistical analysis between the agricultural practices implemented and the adoption of PDO, the aim is to identify those practices that are significantly different due to the implementation of this certification scheme. Bivariate statistical correlations are based on the same tests as for the previous topic. For each group of farmers we determine whether the practices are frequently used, i.e. implemented by 50.0% or more of growers, or infrequently used, i.e. implemented by less than 50.0%. This threshold was proposed in the diffusion of innovations theory to define different categories of adopters (Rogers, 2003): 50% segregates innovators, early adopters and early majority from late majority and laggards. It is also the common threshold used for majorities in voting processes and other decision making processes. The goodness from an environmental, economic and agronomic perspective of practices is determined on the basis of the olive Integrated Production norm in Andalusia, regulated by the Order of 15 April 2008 -BOJA N. 83. This norm regulates, based on scientific evidence, the agronomic practices required to achieve high quality production by means of an efficient use of production factors, taking into account sustainability criteria and environmental compliance (Parra-López and Calatrava-Requena, 2006; Orellana *et al*., 2011). Integrated practices demonstrated a high sustainability in the Andalusian olive groves (Parra-López *et al*., 2008; Hinojosa-Rodríguez *et al*., 2013) and could become the standard to receive public subsidies in a 'reinforced-compliance' context under the new CAP 2013 (Gómez Limón and Arriaza Balmón, 2011).

4. Results

4.1. Adoption factors of PDO

4.1.1. Characteristics, attitudes and opinions of olive farmers

The personal characteristics of PDO farmers are in general not very different from those of non-PDO farmers and thus do not constitute adoption factors of PDO (Table 1). Both groups are mainly middle-aged or older (46-65 years), male, married and with primary level or no education. However, women are significantly more common in PDO (15.8%) than in non-PDO (3.7%) olive growing, thus gender does constitute an adoption factor. Dedication to agriculture represents an important set of adoption factors. PDO farmers have been in agriculture longer than non-PDO ones: 50.0% of PDO vs. 33.4% of non-PDO have been devoted to agriculture for more than 30 years. It is probably for this reason that their agricultural training is significantly more based on experience (72.5% of PDO vs. 46.0% of non-PDO) and less on courses and lectures (23.2% of PDO vs. 48.2% of non-PDO). PDO farmers are more often tenants (9.3% of PDO vs. 2.2% of non-PDO) and less often employees (0.0% of PDO vs. 3.8% of non-PDO), although both groups are predominantly owners and active farmers (more than 90.0% in both cases). Both types of farmers, with no significant differences, depend either totally or partially on agriculture as their main source of income (more than 70.0% in both groups), and are involved in management and physical work (more than 78.0% in both cases).With regard to their membership of agricultural associations, PDO farmers belong more frequently than the rest to agricultural cooperatives (95.5% vs. 78.2%), associations of integrated farmers (28.2 vs. 10.0%), and Associations for Integrated Pest Management –ATRIA– (16.1% vs. 1.5%), and less frequently to agricultural unions (2.5% of PDO vs. 14.4% of non-PDO). The higher levels of ATRIA membership may be because many PDO brands belong to ATRIAs that provide technical advice for farmers. The greater membership of PDO farmers to associations of integrated farmers is logical, since they have more olive surface area devoted to integrated production, as we will see later. With respect to their prospects of staying in agriculture, both types of farmers intend in principle to continue until their retirement (more than 71.0% in both groups), but when prompted with the possibility of agricultural subsidies disappearing, a high percentage (more than 58.0% in both cases) think that they would probably give up agriculture.

Attitudes and opinions are in general significantly different for PDO farmers and the rest (Table 1). Some sources of information on new farming practices and CQS are used significantly more frequently by PDO farmers: other farmers (73.2% of PDO vs. 57.3% of non-PDO), agricultural associations (71.9% vs. 48.8%), and newspapers, radio and TV(42.9% vs. 27.1%). On the other hand, PDO farmers use the following sources less frequently than the rest: information from public research organisations (2.1% vs. 11.1%), suppliers (4.8% of PDO vs. 44.6% of non-PDO) and conferences, fairs and exhibitions (24.5% vs. 56.5%). Most farmers in both groups, without significant differences, use their personal experience and practice as a source of information on innovation (more than 54.0%). Internet is beginning to be used by both groups without significant differences: more than 12.0% in both groups. Other sources, such as customers, consultants, commercial laboratories and private R&D institutes, universities and higher education centres, technological centres, and scientific journals and publications are used by a minority of farmers: less than 7.0% in all cases and without differences between the two groups. These data highlight the importance of 'internal' sources which are close to the olive farmers for both groups, but especially for PDO olive growers. The use of 'external' sources by PDO growers is low - lower, in fact, than that of other farmers. Most of the information reaching PDO farmers seems to be channelled mainly through agricultural associations and contact with other farmers.

With respect to their priorities when producing, PDO farmers attribute relatively high importance to almost all the priorities analysed, although non-PDO farmers lend more importance to certain topics. For example, PDO farmers are slightly less concerned than others about taking minor risks when producing. This is logical as they are adopting an innovation and must take a risk. They also attach less importance to their personal prestige, and surprisingly to respecting the environment and obtaining healthy products. In any case, all these topics are either high or very high priority for the vast majority of farmers in both groups: e.g. more than 90.0% in both groups consider the environment to be a high or very high priority. Economic profit is the highest priority for both groups without significant differences, with more than 91.0% in both groups attaching very high importance to this aspect. The main objective of innovation and the research topics requested are significantly different for the two groups. The main objective of innovation for PDO farmers is more related to increasing production capacity (31.6% of PDO vs. 7.7% of non-PDO) and reducing labour costs (26.0% vs. 20.9%), and less to improving sale conditions (19.9% vs. 51.0%), which is the main objective of non-PDO growers. Improving olive and olive oil quality is also significantly more important for PDO olive farmers (11.4% of PDO vs. 3.5% of non-PDO). These objectives, mainly related to productive and economic factors, are consistent with the high concern for economic profit in both types of farmers. Environmental aspects or satisfying consumer requirements are scarcely targeted by either group when innovating. Following this rationale, the most important factors that hinder innovation for farmers are economic/financial, such as high costs and lack of on-farm funds, cited by more than 33.0% of farmers in both groups. Along the same lines, the research topics most in demand are related to technical and economic matters. However, there are some differences between the two

Table 1 - *Characteristics, attitudes and opinions of PDO and non-PDO olive farmers.*

	Absolute frequencies and percentages		Correlation statistics(+)	
	PDO	Non-PDO	χ^2 (d.f)	p (sign.)
CHARACTERISTICS OF FARMERS				
Age			9.400(5)	0.094(n.s.)
- 18-25	0(0.0)	4(1.1)		
- 26-35	6(9.5)	20(5.9)		
- 36-45	13(19.8)	41(12.2)		
- 46-55	22(33.9)	100(29.9)		
- 56-65	14(21.5)	127(37.8)		
- >65	10(15.3)	44(13.1)		
Sex			12.736(1)	0.000(**)
- Male	54(84.2)	323(96.3)		
- Female	10(15.8)	12(3.7)		
Civil state			3.210(4)	0.523(n.s.)
- Married	59(91.2)	289(86.3)		
- Single	4(6.8)	30(9.1)		
- Widower/widow	1(2.0)	8(2.3)		
- Separated	0(0.0)	6(1.9)		
- Others	0(0.0)	1(0.4)		
Level of education			3.315(5)	0.652(n.s.)
- Primary education	31(48.2)	171(51.1)		
- No education	13(20.2)	80(23.8)		
- Secondary education	6(9.3)	34(10.3)		
- Graduate	4(6.6)	22(6.6)		
- Postgraduate	6(10.0)	17(5.0)		
- Vocational training	4(5.7)	10(3.1)		
Legal status with respect to the farm			12.445(3)	0.006(**)
- Owner and active farmer	58(90.7)	308(92.4)		
- Tenant farmer	6(9.3)	7(2.2)		
- Employee	0(0.0)	13(3.8)		
- Other	0(0.0)	5(1.6)		
Dedication to agriculture (years)			9.692(3)	0.021(*)
- 0 – 10	10(14.9)	37(11.3)		
- 11 – 20	8(11.7)	86(26.0)		
- 21 – 30	15(23.4)	97(29.3)		
- >30	32(50.0)	110(33.4)		
Dependence on agriculture in final income			1.175(3)	0.759(n.s.)
- Total	27(42.1)	122(36.4)		
- Partial main	21(32.3)	123(36.8)		
- Partial secondary	15(22.6)	73(21.8)		
- Marginal	2(2.9)	17(5.0)		
Agricultural training			19.028(4)	0.001(**)
- Experience	47(72.5)	153(46.0)		
- Courses, lectures, etc.	15(23.2)	160(48.2)		
- Agricultural university education	3(4.3)	10(3.1)		
- Agricultural vocational training	0(0.0)	8(2.3)		
- Others	0(0.0)	1(0.4)		
Type of work on the farm			2.665(2)	0.264(n.s.)
- Management and physical work	54(83.6)	262(78.8)		
- Exclusively management	11(16.4)	57(17.1)		
- Exclusively physical work	0(0.0)	13(4.1)		
Membership of associations or agricultural collectives				
- Agricultural cooperative (y/n)	61(95.5)/3(4.5)	262(78.2)/73(21.8)	9.115(1)	0.003(**)
- Association of integrated farmers (y/n)	18(28.2)/46(71.8)	34(10.0)/302(90.0)	13.860(1)	0.000(**)
- Agricultural union (y/n)	2(2.5)/63(97.5)	48(14.4)/287(85.6)	5.314(1)	0.021(*)
- Association for Integrated Pest Management –ATRIA– (y/n)	10(16.1)/54(83.9)	5(1.5)/330(98.5)	25.885(1)	0.000(**)
- Agricultural Transformation Society (y/n)	0(0.0)/64(100.0)	2(0.6)/333(99.4)	0.000(1)	1.000(n.s.)
- Association of organic farmers (y/n)	0(0.0)/64(100.0)	2(0.1)/333(99.9)	0.000(1)	1.000(n.s.)
- Others (y/n)	0(0.0)/64(100.0)	0(0.0)/335(100.0)	0.000(1)	1.000(n.s.)
Prospects of continuing in agriculture			1.209(1)	0.271(n.s.)
- Continuing until retirement	45(71.0)	262(78.7)		
- Leaving before retirement	18(29.0)	71(21.3)		
If CAP subsidies disappear, how would it affect your prospects of continuing in agriculture?			1.135(1)	0.287(n.s.)
- I would probably leave	38(58.3)	222(66.2)		
- I would continue	27(41.7)	113(33.8)		
Future of the olive farm			7.559(3)	0.056(n.s.)
- Children will inherit it	56(88.8)	244(75.7)		
- Will rent it	1(2.4)	34(10.5)		
- Will sell it	4(6.4)	31(9.6)		
- Other	1(2.4)	14(4.2)		
ATTITUDES AND OPINIONS OF FARMERS				
Sources of information (on new olive farming practices and CQS)				
- Other farmers (y/n)	47(73.2)/17(26.8)	192(57.3)/143(42.7)	5.164(1)	0.023(*)
- Personal experience and practice (y/n)	35(54.6)/29(45.4)	182(54.2)/154(45.8)	0.000(1)	1.000(n.s.)
- Agricultural associations (y/n)	46(71.9)/18(28.1)	163(48.8)/172(51.2)	10.701(1)	0.001(**)
- Conferences, fairs, exhibitions, etc. (y/n)	16(24.5)/49(75.5)	189(56.5)/146(43.5)	20.783(1)	0.000(**)
- Suppliers (y/n)	3(4.8)/61(95.2)	149(44.6)/186(55.4)	34.408(1)	0.000(**)
- Newspapers, radio and TV (y/n)	28(42.9)/37(57.1)	91(27.1)/244(72.9)	5.856(1)	0.016(*)
- Internet (y/n)	10(14.9)/55(85.1)	43(12.9)/292(87.1)	0.126(1)	0.723(n.s.)
- Professional and sectorial associations (y/n)	7(10.6)/58(89.4)	38(11.4)/297(88.6)	0.000(1)	1.000(n.s.)
- Public research organisations (y/n)	1(2.1)/63(97.9)	37(11.1)/298(88.9)	5.561(1)	0.033(*)
- Scientific journals and publications (y/n)	5(7.1)/60(92.9)	16(4.6)/320(95.4)	0.444(1)	0.505(n.s.)

groups. PDO farmers request more research on consumer behaviour in international markets (27.7% of PDO vs. 11.4% of non-PDO) and using covers for the disinfection of soils (22.7% vs. 9.4%).

4.1.2. Structural characteristics of farms

PDO farms are significantly more often located in less favoured zones with steeply sloped land (42.4% of PDO vs. 17.8% of non-PDO)and are thus less productive: around 44.0% of PDO vs. 20.0% of non-PDO produce less than 4000 Kg olives per ha (Table 2). PDO farms include more surface area devoted to integrated production than other farms: 36.2% of PDO vs. 13.0% of non-PDO. Additionally, PDO farms depend more on exclusively family-based labour than non-PDO ones (40.8% vs. 29.7%) and less employee-based labour. The destination of olives to first-degree cooperative mills is more important for PDO farms (94.5% vs. 72.5%), in line with their previously mentioned greater membership of agricultural cooperatives. The two groups are similar in other features, such as the age of the plantation (around 50.0% are 10-50 years old), their traditional style of crop management (more than 84.0% in both groups), the destination of their produce to olive oil (almost 100.0%) and their main customer base being located within Andalusia (100.0% in both groups).

4.1.3. Main factors influencing PDO adoption

The specified logit model can be used to determine the main variables which could be targeted in certain policies aimed at boosting the diffusion of PDO (Table 3). Our focus is on short to medium term policies. In this case, it is assumed that only the farmers' characteristics, attitudes and opinions can be affected by such policies. The structural characteristics of farms are supposedly fixed.

Two types of farmers and farms have been defined due to their high relevance in analysing the effects of such policies (Table 4). Non-PDO farmer and farm with ex-ante extreme negative profile (type I) is defined by selecting the cate-

- Universities, higher education centres (y/n)	2(3.7)/62(96.3)	7(2.0)/328(98.0)	0.003(1)	0.959(n.s.)
- Customers (y/n)	1(1.6)/63(98.4)	7(2.2)/328(97.8)	0.000(1)	1.000(n.s.)
- Consultants, commercial laboratories, private R&D institutes (y/n)	0(0.0)/64(100.0)	1(0.4)/334(99.6)	0.000(1)	1.000(n.s.)
- Technological centres (y/n)	0(0.0)/64(100.0)	0(0.0)/335(100.0)	-	-
- Others (y/n)	2(2.5)/63(97.5)	9(2.6)/327(97.4)	0.000(1)	1.000(n.s.)
Priorities when producing				
- Economic profit (No/Low/Average/High/Very high)	0(0.0)/0(0.0)/2(2.5)/ 4(6.0)/59(91.4)	0(0.0)/1(0.4)/4(1.0)/ 10(3.1)/ 320(95.5)	2.472(3)	0.480(n.s.)
- Obtaining healthy products (No/Low/Average/High/Very high)	0(0.0)/0(0.0)/1(2.1)/ 35(54.8)/28(43.1)	0(0.1)/1(0.4)/18(5.3) /100(29.8)/216(64.4)	15.049(4)	0.005(**)
- Respect for the environment (No/Low/Average/High/Very high)	0(0.0)/0(0.0)/6(9.3)/ 38(58.7)/21(32.0)	0(0.0)/1(0.4)/21(6.2) /104(31.2)/208(62.2)	21.137(3)	0.000(**)
- Assuming a low risks (No/Low/Average/High/Very high)	0(0.0)/0(0.0)/9(13.7) /38(58.5)/18(27.2)	0(0.0)/4(1.3)/22(6.5) /124(37.0)/184(55.2)	19.634(4)	0.001(**)
- Personal prestige (No/Low/Average/High/Very high)	0(0.0)/4(5.7)/9(14.0) /36(55.6)/16(24.4)	1(0.2)/2(0.5)/24(7.3) /146(43.5)/163(48.5)	19.971(4)	0.001(**)
- Others (No/Low/Average/High/Very high)	0(0.0)/0(0.0)/0(0.0)/ 0(0.0)/2(100.0)	0(0.0)/0(0.0)/0(0.0)0 /(0.0)/4(100.0)	-	-
Main objective of innovation			48.172(9)	0.000(**)
- Improving sale conditions	13(19.9)	169(51.0)		
- Lower labour costs per unit of product	17(26.0)	69(20.9)		
- Greater production capacity	20(31.6)	26(7.7)		
- Higher olive and olive oil quality	7(11.4)	12(3.5)		
- Respect for the environment	3(4.9)	15(4.5)		
- Replacement of old processes	1(2.0)	16(4.9)		
- Achieving multifunctional agriculture	0(0.0)	15(4.4)		
- Improving working conditions	1(2.0)	5(1.7)		
- Complying with olive regulations	1(2.2)	2(0.7)		
- Improving IT capabilities	0(0.0)	3(0.8)		
- Satisfying customers' requirements	0(0.0)	0(0.0)		
- Increasing prestige	0(0.0)	0(0.0)		
- Others	0(0.0)	0(0.0)		
Factors that hinder innovation			8.519(8)	0.384(n.s.)
- Lack of on-farm funds	25(38.9)	140(41.6)		
- Costs are too high	26(40.3)	110(33.0)		
- Other cost factors	5(8.0)	35(10.5)		
- Lack of off-farm funds (outside financing)	3(4.7)	32(9.6)		
- Dominance of established enterprises	2(2.8)	9(2.7)		
- Lack of information on technology	2(3.2)	7(2.1)		
- Lack of qualified staff	1(2.0)	0(0.0)		
- Lack of information on markets	0(0.0)	1(0.4)		
- Difficulties in finding R&D partners	0(0.0)	0(0.0)		
- Other knowledge-related factors	0(0.0)	0(0.0)		
- Uncertainty about demand of innovative goods/services	0(0.0)	0(0.0)		
- No demand for innovation	0(0.0)	0(0.0)		
- Other market-related factors	0(0.0)	0(0.0)		
Requested research topics			28.602(8)	0.000(**)
- Olive genetic improvement: Resistance to Verticillium disease	8(13.0)	98(29.2)		
- Consumer behaviour in international markets	18(27.7)	38(11.4)		
- Using covers for disinfection of soils affected by Verticillium disease	15(22.7)	32(9.4)		
- Irrigation of olive grove, estimation of irrigation thresholds in critical periods. Control of alternate bearing	2(3.2)	17(5.1)		
- Potential demand for new products containing olive oil and demand for by-products	1(2.1)	14(4.1)		
- Other research topics related to innovation in production, sustainability and use of olive waste	1(2.0)	2(0.6)		
- Other research topics related to marketing, organisation, assets and territory	1(2.0)	1(0.4)		

(+) Corrected Yates χ^2 for contingent tables when degrees of freedom (d.f.) = 1; (2) Pearson χ^2 for contingent tables when d.f.> 1; (3) χ^2 for bivariate logit when proof for contingent tables is not statistically reliable. Significance (sign.): ** $p \leq 0.01$; * $0.01 < p \leq 0.05$; n.s. (not significant) $p>0.05$. y/n = yes/no.

gory that minimises the probability of PDO adoption for each variable of the model. For instance, not being a member of ATRIA minimises the probability of PDO adoption. Non-PDO farmer and farm with ex-ante modal profile (type II) is defined by the modal - i.e. the most frequent - category for each variable. For instance, not being a member of ATRIA is the most frequent condition of non-PDO farmers.

The proposed policies are targeted at shifting the characteristics, attitudes and opinions of farmers towards the categories that maximise the probability of PDO adoption. For instance, farmers of both types, I and II, are not members of ATRIAs (Table 4). The policies which serve to promote PDO should focus on changing this behaviour by making them become members of such agricultural associations.

The proposed measures are the same for both types of farmers (Table 4):

– Promote membership of Associations for Integrated Pest Management (ATRIA)

– Limit, or at least do not promote, the use of suppliers as sources of information on new farming practices and CQS

– Promote the use of newspapers, radio and TV as sources of information on agriculture

– Make growers aware of the high importance of respect for the environment when producing

– Highlight to farmers the importance of producing olives and olive oil of the highest quality when they consider innovating.

The joint effect of changing the targeted variables related to farmers' characteristics in the directions indicated would increase the probability of PDO being adopted. However, this effect is different for the two types. Type I (non-PDO farmers and farms with ex-ante extreme negative profile) would see an increase in probability from 0.000% to 83.812% (Table 4). Type II (non-PDO farmers and farms with ex-ante modal profile) would undergo an increase in probability from 1.283% to 99.635% (Table 5). These data reflect the high impact of the proposed measures to strengthen the diffusion of PDO olive growing in Andalusia.

4.2. Farming practices in PDO vs. non-PDO

The results summarised in Table 5 show that with regard to planting, although Picual is the main olive variety in both groups of growers, PDO farmers use this variety significantly less: 54.4% of PDO vs. 85.1% of non-PDO. PDO growers, however, use Hojiblanca more than non-PDO (25.0% of PDO vs. 5.9% of non-PDO) and also make greater use of Picudo (18.1% of PDO vs. 3.3% of non-PDO). The Hojiblanca and Picudo varieties have a milder flavour and some advantages associated with their lower diffusion in the region: less competition for labour during harvest, fewer fruit setting problems and less competition in the market. The milder flavour makes PDO olive oil more appropriate for sale in external and new markets where this flavour is more widely appreciated. Soil management is al-

Table 2 - *Structural characteristics of PDO and non-PDO olive farms.*

	Absolute frequencies and percentages		Correlation statistics(+)	
	PDO	Non-PDO	χ^2 (d.f)	p (sign.)
CHARACTERISTICS OF FARMS				
Total farm area (ha)			1.742(3)	0.628(n.s)
- [0-1]	0(0.0)	6(1.8)		
- (1-5]	24(37.5)	140(41.80)		
- (5-10]	20(31.2)	93(27.8)		
- (10-]	20(31.2)	96(28.7)		
Organic olive grove (y/n)	1(2.0)/63(98.0)	5(1.4)/330(98.6)	0.000(1)	1.000(n.s.)
Integrated olive grove (y/n)	23(36.2)/41(63.8)	44(13.0)/291(87.0)	18.399(1)	0.000(**)
Type of cultivation			1.286(2)	0.526(n.s.)
- Traditional	57(88.9)	269(84.3)		
- Intensive	7(11.1)	49(15.3)		
- Super-intensive	0(0.0)	1(0.4)		
Yield			22.005(4)	0.000(**)
- <2000 Kg olives ha^{-1}	8(12.1)	15(4.4)		
- 2000-4000 Kg olives ha^{-1}	21(32.1)	55(16.5)		
- 4000-6000 Kg olives ha^{-1}	32(49.5)	170(50.9)		
- 6000-8000 Kg olives ha^{-1}	4(5.5)	83(24.8)		
- >8000 Kg olives ha^{-1}	1(0.9)	11(3.4)		
Age of the olive plantation			1.977(3)	0.577(n.s.)
- <10 years	3(4.0)	28(8.5)		
- 10-50 years	32(49.2)	175(52.2)		
- 51-100 years	24(36.5)	101(30.0)		
- >100 years	7(10.3)	31(9.3)		
Labour			16.440(5)	0.006(**)
- Family and temporary employees	27(42.4)	154(46.2)		
- Exclusively family	26(40.8)	99(29.7)		
- Exclusively temporary employees	11(16.8)	42(12.6)		
- Temporary and permanent employees	0(0.0)	35(10.6)		
- Family, temporary and permanent employees	0(0.0)	2(0.6)		
- Exclusively permanent employees	0(0.0)	1(0.4)		
- Family and permanent employees	0(0.0)	0(0.0)		
Destination of the product (olives)			1.258(2)	0.533(n.s.)
- Olive oil	64(100.0)	332(98.9)		
- Table olives	0(0.0)	1(0.2)		
- Both	0(0.0)	3(0.9)		
Land slope			20.175(2)	0.000(**)
- Low	16(25.7)	141(42.3)		
- Medium	20(32.0)	133(39.9)		
- High	27(42.4)	59(17.8)		
Inserted cultivations (y/n)	0(0.0)/64(100.0)	4(1.2)/331(98.8)	0.038(1)	0.846(n.s.)
Livestock management (y/n)	0(0.0)/64(100.0)	1(0.2)/335(99.8)	0.000(1)	1.000(n.s.)
Main customer			12.409(1)	0.000(**)
- First-degree cooperative mills	61(94.5)	243(72.5)		
- Independent oil mills	4(5.5)	92(27.5)		
Main customer base location				
- Andalusia	62(100.0)	334(100.0)	-	-

(+) Corrected Yates $\chi 2$ for contingent tables when degrees of freedom (d.f.) = 1; (2) Pearson $\chi 2$ for contingent tables when d.f.> 1; (3) $\chi 2$ for bivariate logit when proof for contingent tables is not statistically reliable. Significance (sign.): ** $p \leq 0.01$; * $0.01 < p \leq 0.05$; n.s. (not significant) $p>0.05$. y/n = yes/no.

so significantly different for the two groups. PDO farmers make greater use of soil cover with spontaneous vegetation or cultivated plants than non-PDO: 35.2% vs. 23.7%, respectively. This is a recommended practice involving less soil erosion and is a mandatory requirement for olive growing in less favoured areas to receive CAP subsidies. Soil management is therefore better implemented by PDO farmers, although here there is room for improvement as the recommended practices are not widely diffused, i.e. they are implemented by less than 50.0% of growers.

Irrigation practices are very similar for both groups of farmers. Trickle irrigation is the recommended practice, as it saves a lot of water, and is widely implemented by both: more than 97.0% in both groups. Defining the time of irrigation following expert advice according to crop needs, and analysing the water quality before irrigation, both good practices, are not widely used by the two types of farmers. The fertilization practices for PDO and non-PDO farmers are not very different either. They make little use of fertirrigation, which is recommended as an irrigation practice: less than 6.0% in both groups. However, one important difference, due to its environmental consequences, is the soil or leaf analysis to determine whether it is necessary to fertilize. This good practice is surprisingly more frequently used by non-PDO olive growers, although it is not widely used in either case: 14.6% of PDO vs. 39.8% of non-PDO.

The practices used for the phytosanitary treatments are not significantly different in general for the two types of growers. Both of them widely use chemical substances and non-biological insecticides, very effective but with negative impacts on the environment and on the economic performance of the olive farm if not properly managed in terms of timing and precision of application. In this respect, the application of pesticide treatments directly on the source of infestation/infection, which is recommended rather than applying to the whole plantation, is significantly more widespread among PDO olive farmers: 6.1% of PDO vs. 0.6% of non-PDO (Table 5). On the other hand, the application of treatments only when the infestation/infection surpasses a specified threshold or following expert advice, which is considered good practice, is better implemented by non-PDO growers: 13.1% of PDO vs. 29.3% of non-PDO. Therefore, both groups do apply the recommended practices for phytosanitation to a certain degree.

With regard to harvesting, both groups with no significant differences widely determine the time to harvest according to a ripeness index, which is recommended: more than 67.0% in both groups. Other harvesting practices with a great impact on the quality of the olive oil obtained are significantly better applied in PDO olive growing, as required by the PDO scheme. Hence, the separation of ground and tree olives is carried out by 98.4% of PDO farmers vs. 60.7% of non-PDO farmers. Not collecting the fallen olives from the ground, which may serve to greatly increase the quality but entails renouncing additional sources of income, is scarcely implemented by either group, although significantly more by PDO growers: 6.8% of PDO vs. 3.5% of non-PDO.

The practices used to transport the olives, prune the olive trees and manage the by-products are very similar in PDO and non-PDO olive growing. Transportation in boxes is hardly ever adopted, by less than 1.0% of farmers in both cases, despite this being highly recommended to maintain the integrity of the olives and thus preserve their quality. Shredding and incorporating small pruning offcuts into the

Table 3 - *Multivariate binomial logit model for PDO adoption.*

Variable	Code	B	Std. error	Wald	d.f.	p(sign.)
Membership of associations or agricultural collectives: Association for Integrated Pest Management	ATRIA	3.726	.925	16.216	1	0.000(**)
Sources of information: Suppliers	INFOSUP	-2.097	.737	8.101	1	0.004(**)
Sources of information: Newspapers, radio and TV	INFONEW	1.243	.445	7.785	1	0.005(**)
Priorities when producing: Respect for the environment[a]:	PENV			8.102	2	0.017(*)
- No, low, average	PENV_NLA	0.079	0.810	0.010	1	0.922(n.s.)
- High	PENV_H	1.173	0.438	7.172	1	0.007(**)
Main objective of innovation[b]:	OBJ			35.504	7	0.000(**)
- Achieving multifunctional agriculture or respecting the environment	OBJ_MENV	4.038	1.824	4.899	1	0.027(*)
- Replacement of old processes or improving IT capabilities	OBJ_PRIT	3.292	2.029	2.632	1	0.105(n.s.)
- Improving sales conditions	OBJ_SALE	3.099	1.700	3.322	1	0.068(n.s.)
- Higher olive and olive oil quality	OBJ_QUAL	6.910	1.908	13.120	1	0.000(**)
- Complying with olive regulations	OBJ_REG	6.296	2.256	7.786	1	0.005(**)
- Greater production capacity	OBJ_PROD	5.892	1.758	11.230	1	0.001(**)
- Lower labour costs per unit of product	OBJ_COST	4.854	1.722	7.943	1	0.005(**)
Integrated olive grove	INTEG	1.773	0.481	13.568	1	0.000(**)
Yield[c]:	YIELD			12.928	4	0.012(*)
- <2000 Kg olives/ ha	YIELD_2	3.179	1.796	3.135	1	0.077(n.s.)
- 2000-4000 Kg olives/ ha	YIELD_2T4	2.705	1.736	2.428	1	0.119(n.s.)
- 4000-6000 Kg olives/ ha	YIELD_4T6	1.362	1.718	0.628	1	0.428(n.s.)
- 6000-8000 Kg olives/ ha	YIELD_6T8	1.029	1.792	0.330	1	0.566(n.s.)
Main customer[d]: Independent oil mills	CUST_IND	-2.604	0.793	10.784	1	0.001(**)
Constant	C	-8.804	2.581	11.632	1	0.001(**)

Omnibus test over model coefficients: $\chi 2 = 165.497$; d.f. (degrees of freedom) = 18; Significance = 0.000(**)

–2 log likelihood = 184.499; Nagelkerke $R^2 = 0.583$; Hosmer&Lemeshow significance = 0.552

Probability of Correct Classification = 91.4% (cut value = 0.5)

Dependent variable: Adoption of PDO (yes=1; no=0).

Reference categories: (a)Very high (PENV_VH); (b)Improving working conditions (OBJ_WORK); (c)>8000 Kg olives/ ha (YIELD_8); (d)First-degree cooperative mills (CUST_COOP).

Sign. (significance): ** $p \leq 0.01$; * $0.01 < p \leq 0.05$; n.s. (not significant) $p > 0.05$.

soil is a good practice for preventing soil erosion which is not widely implemented (by less than 30.0% in both groups).

Table 4 - *Typification of farmers and farms, and effects of the proposed policies.*

Variable	Code	Before policy intervention		After policy intervention	
		Non-PDO farmer and farm with ex-ante extreme negative profile (Type I)	Non-PDO farmer and farm with ex-ante modal profile (Type II)	Non-PDO farmer and farm with ex-ante extreme negative profile (Type I')	Non-PDO farmer and farm with ex-ante modal profile (Type II')
Membership of associations or agricultural collectives: Association for Integrated Pest Management (ATRIA)	ATRIA	No	No	Yes	Yes
Sources of information: Suppliers	INFOSUP	Yes	No	No	No
Sources of information: Newspapers, radio and TV	INFONEW	No	No	Yes	Yes
Priorities when producing: Respect for the environment	PENV	Very high	Very high	High	High
Main objective of innovation	OBJ	Improving work conditions	Improving sale conditions	Higher olive and olive oil quality	Higher olive and olive oil quality
Integrated olive grove	INTEG	No	No	No	No
Yield	YIELD	>8000 Kg olives/ ha	4000-6000 Kg olives/ ha	>8000 Kg olives/ ha	4000-6000 Kg olives/ ha
Main customer: Independent oil mills	CUST_IND	Yes	No	Yes	No
Probability of PDO adoption (%)		*0.000*	*1.283*	*83.812*	*99.635*

5. Policy implications and conclusions

Protected Designation of Origin (PDO) is a Certified Quality System (CQS) in the framework of the EU quality policy that constitutes a valuable strategy of differentiation, especially for non-highly productive olive growers who cannot compete on price with the large packing groups and retailer labels in these segments, which still make up the bulk of the market (Sanz Cañada and Macías Vázquez, 2005). This strategy mainly targets local markets close to the production areas where the quality of the product attached to its origin may be more widely appreciated (Sanjuán *et al*., 2006).

The results highlight that the adoption of PDO by Andalusian olive growers is mainly determined by a few explanatory variables (Table 3) referring to: 1) farmers' characteristics, attitudes and opinions, such as ATRIA membership, sources of information, priority of respect for the environment when producing, and main objective of innovation, and 2) farms' structural characteristics, such as growing integrated production olives, yield and main customer. Olive growers are very concerned with economic profit and financial issues, as is logical. They believe that innovations involve high costs they cannot afford. As mentioned before, previous studies indicate the very low penetration rate and premium on the price of PDO olive oil. However, PDO should be seen as a medium to long-term strategy. A quantitative expansion of the markets is expected and it will go hand-in-hand with a qualitative expansion, with an increasing demand for olive oils distinguished on the basis of product and process quality attributes (Anania and Pupo D'Andrea, 2008). Therefore, further sales and marketing developments are needed in the olive producing sector in a context of increasing concentration and multinationalisation of olive oil supply, with a very small number of bottling firms and large distribution enterprises controlling most of the market. In this sense, the olive growing sector in Spain, in general, and in Andalusia, in particular, displays a poor organizational structure. The small size of the farms and mills (Sanz Cañada and Macías Vázquez, 2005) implies a lack of ability to adapt to the requirements for the introduction and maintenance of a CQS and for innovation. In this situation, olive mills need to join together to be able to compete with other companies in the market

Table 5 - *Farming practices implemented by PDO and non-PDO olive farmers.*

	Absolute frequencies and percentages		Correlation statistics(+)	
	PDO	Non-PDO	χ^2 (d.f.)	p (sign.)
PLANTING				
Olive variety			41.159(5)	0.000(**)
- Picual	35(54.4)	285(85.1)		
- Hojiblanca	16(25.0)	20(5.9)		
- Picudo	12(18.1)	11(3.3)		
- Arbequina	0(0.0)	5(1.6)		
- Lechin de Sevilla	0(0.0)	2(0.6)		
- Lechin de Granada	0(0.0)	0(0.0)		
- Others	2(2.5)	12(3.7)		
SOIL MANAGEMENT				
Main soil management technique			16.874(3)	0.001(**)
- Bare soil, little tillage or shallow tillage, weed control with herbicides	32(50.1)	113(34.0)		
- Soil covered by spontaneous or cultivated plants	23(35.2)	79(23.7)		
- Bare soil, no tillage, weed control with herbicides	5(7.6)	80(24.0)		
- Bare soil, conventional farming (constant tillage)	5(7.2)	61(18.3)		
IRRIGATION				
Irrigation (y/n)	13(20.6)/51(79.4)	101(30.3)/234(69.7)	2.089(1)	0.148(n.s.)
Irrigation system			0.686(2)	0.710(n.s)
- Trickle irrigation	13(100.0)	97(97.3)		
- Flood irrigation	0(0.0)	2(2.1)		
- Sprinkler irrigation	0(0.0)	1(0.6)		
Timing of irrigation			3.257(1)	0.071(n.s.)
- Fixed calendar (not depending on crop needs)	12(87.4)	57(56.3)		
- Following expert advice (depending on crop needs)	2(12.7)	44(43.7)		
Analysis of water quality	4(30.8)/9(69.2)	32(31.7)/69(68.3)	2.089(1)	0.148(n.s)
FERTILIZATION				
Fertilization (y/n)	64(100.0)/0(0.00)	335(99.9)/0(0.1)	0.001(1)	1.000(n.s.)
Method for the application of fertilizers			5.308(2)	0.070(n.s.)
- Application by spray to the leaves	24(36.8)	175(52.5)		
- Direct application to the soil	37(57.2)	141(42.3)		
- Through irrigation water (fertirrigation)	4(6.0)	18(5.3)		
Fertilizers used			0.140(1)	0.708(n.s.)
- Inorganic fertilizers (NPK)	63(98.0)	330(98.6)		
- Organic fertilizers (pruning offcuts, compost, etc.)	2(2.0)	5(1.4)		
Analysis before fertilization			14.311(1)	0.000(**)
- None	55(85.4)	202(60.3)		
- Soil or leaf	9(14.6)	133(39.8)		
PHYTOSANITARY TREATMENTS				
Phytosanitary treatments (y/n)	64(100.0)/0(0.0)	332(99.1)/3(0.9)	0.001(1)	1.000(n.s.)
Treatment of olive fruit fly (Bractrocera oleae)			2.647(2)	0.266(n.s.)
- Non-biological insecticide	45(94.1)	199(98.3)		
- Mass trapping (one trap per tree = pheromones + glue + pyrethroids)	1(3.1)	1(0.5)		
- Biological control (Opius concolor)	1(2.7)	2(1.2)		
Treatment of olive moth (Prays oleae)			0.001(1)	1.000(n.s.)
- Chemical treatments	51(100.0)	297(99.1)		
- Biological control (Bacillus thuringiensis)	0(0.0)	3(0.9)		
Treatment of peacock spots, olive leaf blotch, olive leaf spot (Spilocaea oleagina= Cycloconium oleaginum)			0.001(1)	1.000(n.s.)
- Copper fungicides	61(97.9)	324(97.5)		
- Pruning to clear	1(2.1)	8(2.5)		
- Other chemical treatments	0(0.0)	0(0.0)		
Timing of phytosanitary treatments			6.573(1)	0.010(**)
- On a fixed calendar basis or with the first symptoms of infestation/infection	55(86.9)	230(70.7)		
- When the infestation/infection surpasses a threshold or following expert advice	8(13.1)	95(29.3)		
Localization of phytosanitary treatments			7.972(1)	0.005(**)
- The whole plantation	59(93.9)	324(99.5)		
- Only the source of infestation/infection	4(6.1)	2(0.6)		
HARVESTING				
- On a fixed calendar basis	21(32.7)	76(22.9)		
Method for collecting the fallen olives from ground			8.460(2)	0.015(*)
- By hand	45(70.3)	180(53.9)		
- Mechanical means	15(22.9)	142(42.5)		
- No collecting	4 (6.8)	12(3.5)		
Method for picking the olives from the trees			0.000(1)	0.991(n.s.)
- Branch or trunk vibrators	59(92.0)	313(93.3)		
- Hand–pole beating	5(8.0)	23(6.7)		
- Handpicking	0(0.0)	0(0.0)		
Separation of ground and tree olives (y/n)	63(98.4)/1(1.6)	202(60.7)/131(39.3)	32.837(1)	0.000(**)
TRANSPORT				
Ways of carrying the olives from the olive grove to the mill			3.598(2)	0.165(n.s)
- In a tractor or lorry trailer	64(100.0)	325(97.0)		
- Sacks	0(0.0)	8(2.5)		
- Boxes	0(0.0)	2(0.5)		
PRUNING				
Main pruning technique			0.844(1)	0.358(n.s.)
- Traditional, severe, every 1 or 2 years	46(72.0)	260(78.0)		
- Low intensity pruning, every 2 or 3 years	18(28.0)	73(22.0)		
MANAGEMENT OF BY-PRODUCTS				
Wood			1.675(1)	0.196(n.s.)
- Fuel	64(100.0)	321(95.9)		
- Furniture manufacture	0(0.0)	0(0.0)		
- Others	0(0.0)	14(4.1)		
Small pruning offcuts			1.605(3)	0.658(n.s.)
- Burning	43(67.2)	242(72.2)		
- Shredding and incorporation into the soil	20(30.8)	91(27.1)		
- Fuel	1(2.0)	2(0.6)		
- Animal food	0(0.0)	0(0.0)		
Leaves			8.856(2)	0.012(*)
- Fuel	1(11.3)	6(54.0)		
- Animal food	0(0.0)	1(11.9)		
- Therapeutic uses: hypertension, astringents, etc.	0(0.0)	0(0.0)		
- Others	12(88.7)	4(34.1)		

(+) Corrected Yates χ^2 for contingent tables when degrees of freedom (d.f.) = 1; (2) Pearson χ^2 for contingent tables when d.f.> 1; (3) χ^2 for bivariate logit when proof for contingent tables is not statistically reliable. Significance (sign.): ** $p \leq 0.01$; * $0.01 < p \leq 0.05$; n.s. (not significant) $p > 0.05$. y/n = yes/no.

(Montegut Salla *et al*., 2007). The ideal situation would be that all components of the olive producing sector worked together in unison. This collaboration could help to strengthen the organizational structure of the sector which may in turn lead to improvements in marketing (Montegut Salla *et al*., 2007; Sanz Cañada *et al*., 2011).

Otherwise, PDO farming practices are not very different, in general, from those used by non-PDO olive growers and the recommended techniques are infrequently used in both groups. It seems that PDO farmers are focusing especially on quality and the financial viability of their economic activity. Therefore, there is room for improvement in many farming practices implemented under PDO. In this sense, Spanish olive oil PDOs face a new emerging challenge: besides displaying differentiation in terms of organoleptic excellence and origin, they need to take on attributes of environmental friendliness and a greater degree of food safety and traceability to win over a significant share of the value chain at local level (Sanz Cañada and Macías Vázquez, 2005). Most PDO olive farms are located in less favoured areas of steep slopes and low productivity (CAP, 2002), depend, to a greater extent, on exclusively family-based labour, and are members of first-degree cooperative mills, as is confirmed by our results. PDO farms play an important multifunctional role as they help to improve the sustainability of rural areas through certain functions such as reducing erosion and protecting biodiversity and natural resources, combating the effects of climate change, and contributing to territorial cohesion (Ruiz Avilés *et al*., 2007). It is therefore desirable that besides promoting the idea of greater product quality being linked to a specific place as PDO scheme guarantees, PDO farmers also demonstrate a greater sustainability in the production process. It could be certified by the adoption of more sustainable and environmentally responsible farming practices, such as those associated with integrated production and organic agriculture. Although local certified-product systems are starting to incorporate quality attributes linked to the environment and sustainable development, much remains to be accomplished (Sanz Cañada and Macías Vázquez, 2005; Pérez-y-Pérez *et al*., 2013). This would be an added value in the eyes of not just local but also international consumers, which could increase their willingness to pay a premium on the price and serve to justify public support from a greener CAP. Olive farmers need to be aware of the environmental significance of agriculture and their role as producers of public goods (Sanz Cañada *et al*., 2011). In this context, PDO Regulatory Boards should play a more active role. They are institutions made up of farmers, cooperatives, industries, marketing companies and the public administration. They are responsible, among other things, for drawing up the reference standards or regulations for PDO and certifying and giving their seal of approval to

any products wishing to use the official label (Sanz Cañada and Macías Vázquez, 2005). Their support of farmers in adopting the most sustainable farming practices should be further strengthened.

In summary, PDO represents a small but increasing share of the olive oil produced in Andalusia. Attracting conventional farmers to PDO would entail providing them with information which highlights the economic attractiveness of PDO, as a medium to long-term strategy for competitiveness based on quality differentiation. Improvements should also be made in terms of palliating the short-term financial needs related to the implementation of PDO by facilitating access to credit. This is especially important since the main concerns of olive growers when producing and innovating are of an economic/financial nature. The importance of protecting the environment as an increasing demand from consumers and CAP should also be emphasised. The results indicate that there is room for improvement in many farming practices implemented under PDO especially from an environmental point of view. Farmers must also be aware of the need for further efforts to strengthen the organizational structure of the olive producing sector. This would benefit innovation in the sector in general and the adoption of Certified Quality Systems in particular. The design of public policies in support of PDO and sustainable agriculture should include training and information programs for farmers. The effective adoption of PDO, as for any complex adoption, is highly dependent on having an opportunity to carry out small-scale trials or at least to observe its implementation in near peers (Rogers, 2003). Given the high importance for farmers of internal and nearby sources of information, such as other farmers and agricultural cooperatives and associations, the strategy to bring relevant information closer to farmers could be twofold: 1) connect leading knowledge-generating external institutions, such as public research organisations, technological centres and universities, to the closer sources of information of farmers; this would entail great efforts to transfer knowledge from research to the sector; 2) incentivize farmers' direct use of external sources of information which are not widely diffused, such as internet and scientific journals and publications; this would require significant promotional efforts on the part of public research organisations to make these sources known to farmers. In addition to this, other sources which are relatively successful and regularly used by PDO farmers should also be promoted, such as newspapers, radio, television and membership of Associations for Integrated Pest Management (ATRIA), since the technicians of these associations indirectly encourage awareness and adoption of PDO in olive growing.

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