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PAPER

Economic sustainability of organic dairy sheep systems in Central Spain

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Abstract

Sheep production systems in regions with a Mediterranean climate are important in social, economic and environmental terms. Modeling these systems allows, among others, evaluation of the costs efficiencies which in turn permits assessing the expected effects of changes in production variables. This paper presents a prototype analysis of the economic sustainability of ecological dairy sheep systems of Castilla-La Mancha, Central Spain evaluated through the estimation of costs efficiencies. Costs functions were developed using data from 31 farms. Rate of supplementary feeding, labour use, and flock size were used to measure the cost efficiency. On average, cost efficiency was $61.7 \pm 15.5\%$, with significant differences among typological groups. High efficiency was found in only 29% of the farms. The economic analyses performed suggest that the continued existence of economically unsustainably farms is explained by the available subsidies, lack of amortization of fixed assets leading to progressive decapitalization, and subsistence incomes by family groups (gross family income).

Introduction

Sheep production systems of regions with a Mediterranean climate like Italy, Spain, Greece and Chile have received special attention because they are located in less favoured areas with few alternative economic activities. Their continued existence potentially also allows protection of natural resources, preservation of life styles and prevention of rural exodus. Nevertheless, and despite existing support policies, their relative importance continues to

decrease as exemplified by Chile's regions with a Mediterranean climate, where the number of sheep farms decreased by 17% in the last 10 years (Toro-Mujica *et al.*, 2013), probably in association with incipient new and more profitable activities. These trends forced them to compete using strategies based on product differentiation and quality such as denomination of origin, ecological or organic labels, certification of sustainability, food safety, and healthier fat profiles (Luna *et al.*, 2005, 2008; Mele *et al.*, 2011; Vera *et al.*, 2013; Vargas-Bello *et al.*, 2013), in order to increase their economic sustainability. Economic sustainability can be defined as the result of applying strategies that optimize resources use over the long term. Economic sustainability has been evaluated using a variety of parameters, such as net average yield per head and per hectare (Darwish *et al.*, 2001; Barham and Weber, 2012), net present value and internal rate of return (Solís and Bravo-Ureta, 2005), and productivity in the MESMIS framework in addition to net marginal returns, cost-benefit ratio, initial investment, labour profitability and profitability per animal (Ripoll-Bosch *et al.*, 2012; Merlín-Urbe *et al.*, 2013). The values of these variables are dependent upon output yields. The resulting output yields associated with changes in resource allocation can be estimated by various procedures, including the use of numerous indexes and econometric approaches. The primal approach based on the production function is an example that allows relating the use of technology to the level of production, although it does not use economic information and therefore does not allow cost minimization. This approach would lead to efficient use of inputs but may fail to minimize costs given that the price of inputs is not optimized. On the other hand, the cost function estimates the minimum cost of a given combination of outputs conditioned by factor prices, thereby providing information on alternative technological options for the enterprise (Coelli *et al.*, 2005). Various methodologies have been used to determine the cost function, including the classical Cobb-Douglas function (Toro-Mujica *et al.*, 2011), the constant elasticity of substitution function (CES), and others that include more flexible functional forms such as the transcendental logarithm (TL; Christensen *et al.*, 1973; Binswanger, 1974; Kumbhakar and Tsionas, 2005), the generalized Leontief function (GL; Diewert, 1973) and the symmetric generalized McFadden (SGM; Diewert and Wales, 1987). There is a paucity of research that use the cost function in farming as an estimator of farm economic sustainability, the exception being

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Pierani and Rizzi (2003) that evaluated the cost efficiency of dairy cattle systems in the plains of the Po river. As indicated above, organic sheep production in less favoured areas is defined as a system based on the harmonious relationship between land, plants and livestock, respect for the physiological and behavioral needs of livestock, and the use of organically grown feedstuffs or natural resources as fodders (IFOAM, 2002). This type of system constitutes a possible alternative for extant systems since its adoption and compliance with the European norms (European Commission, 2007) would confer it a competitive advantage through the differentiation of its products. Properly managed organic production is related to low input farming systems, that seek to optimize the management and use of internal production inputs (i.e. on-farm resources) and to minimize the use of purchased inputs, such as fertilizers and pesticides, to lower production costs, to avoid pollution of surface and groundwater, to reduce pesticide residues in food, to reduce a farmer's overall risk, and to increase both short- and long-term farm profitability (Parr *et al.*, 1990). Thus, Guesmi *et al.* (2012) showed that the production of ecological grapes in Cataluña although less productive, had higher technical efficiency and

were more economically viable than conventional systems. Mendoza (2002) describes how ecological rice farms are more feasible and are four times more efficient in terms of energy consumption than conventional farms. Regarding milk production, Nemes (2009) found that milk yield per cow in ecological systems was similar to that of conventional systems. Ronchi and Nardone (2003) suggested the dependence between the profitability of small ruminant farms and the existence of national and regional support policy to the development of production, processing and labeling of organic foods, emphasizing the importance of conversion subsidies, given the critical financial viability of this period. The dairy sheep sector of Castilla-La Mancha, in Central Spain, is taken as an exemplary case given its large social, economic and environmental importance that arises from the need to preserve and retain rural populations, and the existence of livestock sectors that use grasslands located in areas with limited access and scarce natural resources. The use of these resources allows the valorization of the territory and contributes to preserve environmental equilibrium (Lobley *et al.*, 2009). Nevertheless, the dairy sheep sector exhibits a number of weaknesses, including its complete dependence upon climatic unstable climate, low rate of animal genetic improvement, the need for a herder which in turn is limited by very low generational change, deficient marketing strategies, and low input use efficiency (Caballero and Fernández-Santos, 2009). The gradual adaptation of dairy sheep systems to the requirements of organic production has resulted in three production subsystems identified by Toro-Mujica *et al.*, (2012), which differ from traditional systems in the costs of the inputs used (Ronchi and Nardone, 2003), as well as prices of outputs. Feed and labour costs in these ecological systems are higher, whereas those due to veterinarian services and drugs are lower. Prices of outputs of organic systems have increased 25-30% for intermediaries and business firms, and up to 90% for end consumers (Nemes, 2009). These increases lead to a re-examination of the production system and the allocation of resources in order to adjust milk production to the available farm resources, to reduce dependence on external inputs, and minimize costs. Thus organic systems move away from the objective of traditional production, oriented to the maximization of outputs and the intensification of the system (Wiswall, 2009). On the contrary and according to Van't Hooft *et al.* (2012), organic systems or smallholder

mixed farming maintain bio-diversity, and minimize dependence on external inputs (Altieri and Toledo, 2011; Viglizzo *et al.*, 2011). The adoption of organic production in the sheep systems of Castilla-La Mancha requires knowledge and management of the costs structure to evaluate the economic sustainability of eventual technical changes such as the appropriate use of supplements (Aguilar *et al.*, 2006), to take advantage of public policies. The present work analyzes variables associated with cost inefficiencies in ecological dairy sheep systems of Castilla-La Mancha in view of their importance in determining farm economic sustainability. The analysis is applied to each of the sub-systems defined by Toro-Mujica *et al.* (2012), with the main purpose of seeking ways to improve the use of inputs and increase farm economic sustainability. The analysis of system's sustainability must rely on a holistic approach; nevertheless the emphasis of this study is on economic sustainability given the low observed profitability of sheep production systems in less favoured areas, based on the analysis of the efficiency of costs structures in dairy sheep farms that decided to differentiate their product by pursuing organic or ecological principles. The transcendental logarithm methodology was used for the analysis, given its flexibility and that it avoids imposing restrictions based on the elasticities of substitution among inputs or economies of yield scale, thus allowing the minimization of costs in relation to flock sizes.

Materials and methods

Study area and data collection

Thirty one dairy sheep farms were selected within the Castilla-La Mancha area, including all 10 farms certified as ecological plus 21 (85% of all in existence) that were evolving to organic production in order to comply with 80% of the requirements established by the European norms [Council Regulation EC N° 834/2007 (European Commission, 2007), Commission Regulation EC N° 223/2003 (European Commission, 2003a), Council Regulation EC N° 1452/2003 (European Commission, 2003b)]. Farms in transition were randomly selected according to size and geographical location. The design of the survey described by García *et al.* (2008), Dohoo *et al.* (2010) and Valerio *et al.* (2009) was used to collect information on total costs, flock size, milk production, and the costs of the factors of production. The economic characterization of the ecological sheep dairy systems sampled was performed using the *accounts of earnings and*

losses calculated for the 2007-2008 period (Perea *et al.*, 2008; Nemes, 2009).

Determination of efficiency of costs

The econometric analysis of the performance of organic dairy sheep farms was carried out through a sequence of steps to arrive to an estimate of their economic efficiency. Initially, an average cost function without random component was estimated as follows:

$$Y_i = f(X_i; B, \text{constant}) \quad (\text{eq. 1})$$

where Y_i is the observed cost of the i th farm, X_i are the levels of inputs used by farms, and B is the vector of parameters to be estimated. The cost frontier function is the minimum cost of producing a given amount of output. Subsequently, the difference between the estimated costs based on the above function and the costs observed for each farm are calculated. The largest negative residue is added to the model constant, in order to obtain the frontier cost function (Álvarez, 2001). The cost efficiency is calculated then as the ratio between the estimated by the cost frontier function and the observed farm costs using the following formula:

$$\text{Efficiency index} = \frac{\text{estimated cost}}{\text{observed cost}} * 100 \quad (\text{eq. 2})$$

The efficiency index value is 0 when the system is totally inefficient and 100 in the opposite case. Once the farms were characterized in terms of cost efficiency, they were classified according to the sample average (Pérez *et al.*, 2007) in order to assess the relationship of efficiency of costs with technical and economic indicators. Farms were classified into low, medium, and high groups based on the deviation of $\pm 1/2$ standard deviation from the overall mean.

Modeling of costs function

The average function of costs for the dairy sheep systems of Castilla-La Mancha was modeled following the methodology of Christensen *et al.*, (1973) which is based on a transcendental logarithm function (translog). The translog cost function is a flexible function, which is obtained by a second-order approximation (Christensen *et al.*, 1973). It consists of a set of simultaneous equations, where the first one represents the costs and the remaining equations indicate the proportion of the total costs incurred by each of the production factors (Kumbhakar and Tsionas, 2005; Sidhu and Baanante, 1981). The translog function and the equations specifying the

inputs were tested by applying asymmetry and elasticities of substitution according to Zellner (1962) *seemingly unrelated regressions (SUR)* model. The estimation of the cost function simultaneously with the share equations of the production factors in total costs increase the degrees of freedom, leads to a better causal model, and increases the efficiency of estimation.

The cost share equations of the i -th factor were obtained by derivation of the cost function over the price of each of the inputs, using the formula:

$$\frac{\partial \ln C}{\partial \ln W_i} = \frac{W_i X_i}{C} = S_i = \phi_i + \sum_{j=1}^n \phi_{ij} \ln W_j + \phi_{Yi} \ln Y \quad (\text{eq. 3})$$

where C is the total cost, W is the input price, X is the amount of input, S_i is the equation, ϕ is the estimated parameters, Y is the total production, and i, j are the inputs.

The above method is based on the premise that farms use fixed, or quasi fixed production factors that are difficult to modify when faced with changes in factor prices and therefore, the difference between actual and estimated costs is indicative of the potential for decreasing farm costs, and thus, farm efficiency. The

relation between actual and estimated costs is indicative of the potential to decrease costs in each farm and therefore their economic efficiency.

To estimate the average cost function, farm data were fitted to a model composed of three equations (4,5,6), where the first one represents the short-term total cost associated with milk production and lamb sales, and the remaining two equations correspond to the cost shares of labour (l) and feeding (f) respectively:

$$\begin{aligned} \ln C = & \alpha_0 + \alpha_Q \ln Q + \frac{1}{2} \beta_{QQ} (\ln Q)^2 + \alpha_l \ln P_l \\ & + \alpha_f \ln P_f + \alpha_R \ln R + \frac{1}{2} \beta_{ll} \ln P_l \ln P_l + \frac{1}{2} \\ & \beta_{ff} \ln P_f \ln P_f + \frac{1}{2} \beta_{ll} (\ln P_l)^2 + \frac{1}{2} \beta_{ff} (\ln P_f)^2 + \\ & \frac{1}{2} \beta_{Rl} \ln R \ln P_l + \frac{1}{2} \beta_{Rf} \ln R \ln P_f + \frac{1}{2} \beta_{RR} \ln R \ln R \end{aligned} \quad (\text{eq. 4})$$

$$S_l = \alpha_l + \beta_{ll} \ln P_l + \beta_{Rl} \ln R + \beta_{lll} \ln P_l + \beta_{Qll} \ln Q \quad (\text{eq. 5})$$

$$S_f = \alpha_f + \beta_{ff} \ln P_f + \beta_{Rf} \ln R + \beta_{fff} \ln P_f + \beta_{Qff} \ln Q \quad (\text{eq. 6})$$

where, $\ln C$ is natural log of the total cost, α , β are coefficients, Q is daily amount of milk sold, P_l , P_f are costs of labour and supplementary feeds and R is number of ewes per farm.

The sum of the set of share equations is equal to one and to avoid singularity in the

covariance matrix, one of the equations is deleted when the model is run. The model can be restricted to satisfy homotheticity, such that the cost share of each input remains constant regardless of the level of production. Similarly, the model can be made homogeneous such that for a given production level the total cost is increased when prices increase proportionally. The above two restrictions, together with the requirement that elasticities of substitution add up to one, lead to a total of five additional models, as follows: Model 1, unrestricted; Model 2, homothetic ($\beta_{Yi}=0$); Model 3, homothetic and homogeneous ($\beta_{Yi}=0$ and $\beta_{Yj}=0$); Model 4, elasticities of substitution add up to 1 ($\beta_{ij}=0$); Model 5, homothetic and elasticities of substitution add up to 1 ($\beta_{Yi}=0$ and $\beta_{ij}=0$); Model 6, homothetic, homogeneous and elasticities of substitution add up to 1 ($\beta_{Yi}=0$, $\beta_{Yj}=0$, and $\beta_{ij}=0$).

The model was fitted using the iterative SUR procedure included in the Eview 5.1[®] software (Pulido and Perez, 2001) that yields parameters that converge to maximum likelihood. The Wald test was applied to the estimated coefficients, to ensure compliance with the restrictions imposed.

Table 1. Mean values and statistical significance of technical variables of the typological groups defined by Toro-Mujica *et al.* (2012).

Technical variables	Group		
	I	II	III
Flock size, UGM	24.9 ^{a***}	138.7 ^c	72.6 ^b
Sheep stocking rate, UGM•ha ⁻¹	0.12 ^{c***}	0.69 ^a	0.39 ^b
Pasture area per ewe, ha•ewe ⁻¹	1.6 ^{a***}	0.16 ^b	0.62 ^b
Work unit per animal, AWU 100 ewes ⁻¹	0.71 ^{a***}	0.53 ^{ab}	0.27 ^b
Work unit per area, AWU 100 ha ⁻¹	0.65 ^{b*}	2.5 ^a	0.62 ^b
Milk production, Tonn year ⁻¹	11.186 ^{c***}	88.911 ^a	47.301 ^b
Milk productivity, L•ewe ⁻¹ •year ⁻¹	75.5 ^{b**}	103.5 ^a	108.3 ^a
Supplementary feed, kg•ewe ⁻¹ •year ⁻¹	226 ^{b***}	386 ^a	229 ^b
Supplementary feed, kg•L ⁻¹	3.6 ^{ab**}	4.1 ^a	2.2 ^b
Land in ownership, %	1.7 ^{b**}	50.5 ^a	20.2 ^b
Familiar labour, %	100 ^{a***}	51.9 ^b	93.4 ^a

AWU, annual work unit [it corresponds to a worker devoted full-time during a year to the agricultural/livestock activity (European Commission, 2012)]. UGM refers to bulls, cows and other cattle that are older than two years and equines of more than six months (European Commission, 2006). ^{a-c}Different letters in the same row denote significant differences among variables. * $P \leq 0.05$; ** $P \leq 0.01$; *** $P \leq 0.001$.

Table 2. Descriptive statistics for the ecological dairy sheep systems of Castilla-La Mancha.

Variable	Mean	Max	Min	Standard deviation	Coefficient of variation, %
Daily milk production, L	97.3	182.6	47.2	31.0	31.9
Labour cost, €/AWU	14,014	30,560	4,240	4,554	32.5
Cost of supplement, €/kg	0.27	0.42	0.12	0.07	26.4
Selling price of milk, €/L	1.04	1.20	0.84	0.10	9.4
Selling price of lamb, €/lamb	41.9	49.6	36.0	2.7	6.5
Flock size	508	1300	99	393	78.6

AWU, annual work unit [it corresponds to a worker devoted full-time during a year to the agricultural/livestock activity (European Commission, 2012)]. * $P \leq 0.05$, indicating that the parameter should be included in the model.

Analysis of the economic sustainability in relation to typology

Using the survey data for the 31 farms, Toro-Mujica *et al.* (2012) classified ecological dairy sheep production into three groups that were used to estimate relationships between economic sustainability and typology. The mean values of the technical variables that characterize them are shown in Table 1.

Group I: subsistence systems that maintain long term tradition by employing family labour only, small flocks and low stocking rates. Feeding is based on supervised grazing and high rates of supplementary feeding in relation to production level. Average milk production was 76 kg ewe⁻¹ year⁻¹.

Group II: intensive commercial systems, where sheep are fed indoor most of the year. Feeding is based on conserved forages and concentrates. Hired labour accounts for 49% of the total labour input, but physical productivity is low. Given high investment costs and poor feed management, these systems tend to have low productivity. Average milk production was 104 kg ewe⁻¹ year⁻¹.

Group III: commercial systems that rely

mostly on family and qualified labour, including medium-sized flocks, and semi-extensive management. In general they tend to be physically and economically efficient. Feed inputs per liter of milk are lower than for the other groups due to the use of large surface areas of grasslands. Average milk production was 108 kg ewe⁻¹ year⁻¹.

Due to the variability between different typological groups, the effects of economic and technical variables on the economic sustainability were analyzed using an incomplete 3 x 3 factorial analysis including 3 levels of efficiency and the 3 typological groups (Freund *et al.*, 2010). Finally, Pearson correlations (*r*) were obtained among the efficiency of costs and its associated variables.

Results and discussion

Characterization of variables

The total mean cost per liter of milk was of 1.9 €, including feed, labour and amortization costs that accounted for 37, 33 and 12% respectively of the total cost. The costs derived

from independent professional services were just 2%, while other costs (including repairs, supplies, leases, insurance, taxes and financial costs) amounted to 16%. Concentrate supplements accounted for 75% of the feed cost per liter of milk, with a range of 47-100% associated with variability in the inclusion of straw and hay in the diet. Amortization costs and flock size were positively correlated (*r*=0.86, *P*<0.01) as were flock size and other costs (*r*=0.45, *P*<0.01).

Only 16% of the farms were able to produce milk at costs below the payment received of 1.04 € L⁻¹, demonstrating the importance of other sources of income including subsidies, lamb and wool sales, and other byproducts. These results coincide with those of Tzouramani *et al.* (2011) in Greece, who found that the probability of negative net returns was 57.3% in a scenario without subsidies, and decreased to 0.2% with government support. Table 2 shows statistical descriptors for each of the relevant variables for the estimation of the cost efficiency.

Average costs function

Production costs are shown in Table 3. Only

Table 3. Parameter values and their statistical significance for each of the six models fitted to the data.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
α_0	10.33	17.49	1.38	3.24	17.34	2.44
P	0.24*	0.02	0.01	0.65	0.001	0.001
α_Q	-1.09	-0.83	0.15	1.52	-2.79	0.05
P	0.71	0.58	0.27	0.46	0.02	0.74
β_{QQ}	0.42	0.10	-	-0.29	0.28	
P	0.23	0.51	-	0.33	0.01	
α_I	0.44	-0.80	-0.72	1.29	0.47	0.47
P	0.64	0.36	0.41	0.001	0.001	0.001
α_f	-2.18	1.80	1.72	-0.29	0.53	0.53
P	0.48	0.04	0.05	0.37	0.001	0.001
α_R	-0.76	-0.63	-1.24	-3.79	0.60	0.71
P	0.81	0.62	0.21	0.06	0.001	0.001
β_{If}	-0.09	-0.02	-0.03			
P	0.36	0.80	0.76			
β_{IR}	0.02	-0.12	-0.12			
P	0.85	0.01	0.01			
β_{II}	0.12	0.20	0.19			
P	0.24	0.04	0.05			
β_{Rf}	-1.98	-0.11	-0.08			
P	0.01	0.52	0.61			
β_{If}	-0.27	0.37	0.38			
P	0.76	0.58	0.56			
β_{RR}	0.96	0.37	0.48			
P	0.24	0.09	0.00			
β_{Qf}	1.45			0.07		
P	0.02			0.07		
β_{QR}	-0.71			0.42		
P	0.34			0.03		
β_{QI}	-0.13			-0.08		
P	0.14			0.01		
R ² fitted	0.85	0.84	0.84	0.83	0.85	0.83

two statistically significant parameters ($P \leq 0.05$) were included in Model 1. Given that only one of the β_{Y_i} was significant, it is assumed that the model was homothetic. Similarly, the β_{Y_Y} was not significant, and the homogeneity of the model was accepted. If homotheticity and homogeneity are assumed for Model 3, then only two out of eleven substitution coefficients were significant. Model 6 incorporated all three restrictions ($\beta \downarrow Y_i = 0$, $\beta \downarrow Y_Y = 0$, and $\beta \downarrow i_j = 0$) and did not appear to be suitable, since the parameter was not significant. Model 5 does not imply homogeneity but includes homotheticity, and appeared to be the most adequate of all alternatives since all the parameters were significant in addition to yielding a high adjusted R^2 .

The Wald test of the estimated parameters confirmed that the restrictions applied to the model were satisfied. Thus, the function that relates cost of production to inputs (Model 5) is as follows:

$$\ln C = 17.341 - 2.794 \ln Q + 0.142 (\ln Q)^2 + 0.467 \ln P_l + 0.533 \ln P_f + 0.599 \ln R \quad (\text{eq. 7})$$

Model 5 shows the importance of labour and supplementary feeding in determining costs, two variables that in the short term could be modified by management. The equation also shows the effect of milk output and flock size on the cost of production. The logarithm of cost increases linearly with increases in flock size, but that is not the case for total milk output (Q), given that the equation is not homogeneous for the price of factors.

Efficiency of costs

The frontier function of cost was as follows:

$$\ln C = 16.772 - 2.794 \ln Q + 0.142 (\ln Q)^2 + 0.467 \ln P_l + 0.533 \ln P_f + 0.599 \ln R \quad (\text{eq. 8})$$

Figure 1 shows the response surface represented by this equation. The x and y axis show the natural relationship between total yearly costs and flock size, whereas z and y show the effect of the efficiency in the use of labour and feeding on the production costs, demonstrating that an increase in milk output is feasible without a concomitant increase in total costs.

The above equation estimates the costs incurred by the 31 farms studied, and allowed calculating their efficiency index. The mean efficiency index was $61.7 \pm 15.5\%$, with minimum and maximum values of 33.5 and 93.9% respectively. Farms were subsequently grouped into three levels of efficiency (low, medium, high) (Table 4).

Comparison of groups according to levels of efficiency through an analysis of variance identified the variables responsible for differences in cost efficiencies (Table 4).

The cost efficiency was not generally related to flock size or size of the farm, and in general few statistically significant differences associated with technical variables were found, although some trends are evident. Lower efficiency tends to be associated with low labour productivity [0.6 annual work unit (AWU) 100 ewes⁻¹], since total AWU (1.88 AWU) was lower in farms presenting higher

efficiency (2 AWU) ($P < 0.05$). Similarly, the less efficient farms used higher supplementation rates per animal (357.9 kg ewe⁻¹ year⁻¹) ($P < 0.01$) and tended to have higher stocking rates (0.53 Animal Units ha⁻¹). With regard to economic variables, there were significant differences in the average cost (€ ewe⁻¹), and net income (total €, € ewe⁻¹ and € L⁻¹) with or without the inclusion of subsidies. Thus, farms with low efficiency showed negative profitability, with and without subsidies (-55.7 and -78.8 € ewe⁻¹ respectively). The variables associated with profitability confirm the dependence of the majority of these organic systems on subsidies and family labour. Positive returns are observed in the three profitability variables (net margin without subsidies, net margin including subsidies and gross family income respectively) only in high efficiency farms. On the other hand, medium efficiency farms depend on subsidies, in coincidence with results reported by Gaspar et al. (2009) for extensive Dehesa systems, and for Ripollesa sheep systems by Milán et al. (2003). Farms with the lowest efficiency depended on family labour, in addition to subsidies (Table 4).

Pearson correlations between the efficiency of costs and the technical and economic variables studied confirmed the importance of total labour (AWU) and supplementary feeding in the economic sustainability of these farms. A negative correlation ($P < 0.01$) was found between average cost (€ ewe⁻¹) and the cost efficiency, and the latter is considered an adequate indicator of farm economic sustainability.

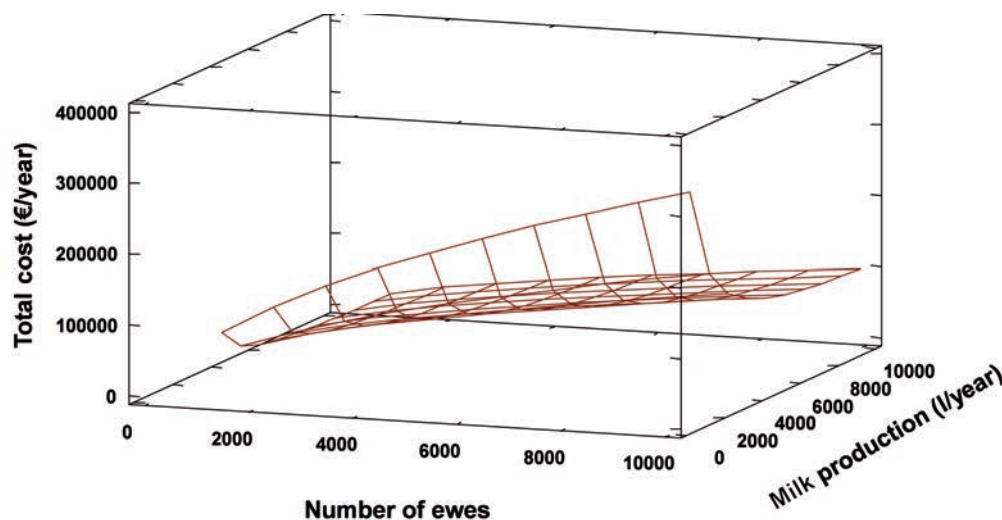


Figure 1. Response surface as a function of costs frontiers.

Efficiency of costs and farm typology

Farm groups I-III were compared in terms of efficiency of costs, and their statistical descriptors are shown in Table 5. Group II significantly differed from the other two groups ($P < 0.01$) having the lowest efficiency both on average (49.2%), and in absolute terms (minimum of 33.5%) (Tables 5 and 6). Although groups I and III did not differ from each other, higher percentages of farms showing medium (46.1%) and high efficiency (38.5%) levels were found in Group III (Table 6). The corresponding chi-square test did not show a significant dependence ($P > 0.05$) between efficiency and typology, but the size of some of the adjusted residues are indicative of the relationship both variables. Improvement of economic sustainability in group I farms would require an increase in labour productivity. However, these family farms possess a social function that is not adequately valued by a purely economic perspective, and it is justified in view of today's labour conditions and

employment rates in the region. The intensive management group (Group II) proved to be the least efficient (49.2%), but on the other hand, there were both similarities and differences between groups that should be carefully considered before attempting to improve their performance. The improvement of the economic sustainability is associated with congruence amongst the size of the flock, stocking rate, milk production and the supplementation requirements. The size of Group III farms (± 138) is compatible with family labour but shows high costs per sheep as consequence of the imbalance between the cost of supplementary feeding and the marginal milk returns to supplementation.

The analysis of the data using an incomplete factorial design allowed new insights into farm performance. Total milk production, flock size, and total costs and income were significantly lower in the least efficient farms, compared to those of medium efficiency. Thus, farm typology offered insights into farm efficiency that would

otherwise have gone unnoticed. Low and high efficiency farms were similar in terms of size, but higher feed supplementary levels associated with higher stocking rates and lower farm sizes, led to lower marginal incomes in the less efficient farms. Aggelopoulos *et al.* (2009), mentioned the size of the holding as one of the two factors that have a major impact on the profitability of sheep and goat farms, noting that in Greece the majority of sheep farms function under increasing performances of scale, similar to the situation observed in the study farms.

Farms of medium efficiency had larger flocks and employed lower rates of supplementation than those of low levels of efficiency. Farms of medium efficiency were similar to those of high efficiency, although there were non-significant differences in labour use and supplementation, which are probably responsible for their lower classification (Table 4).

When the effect of typology was removed, the economic results (Table 4) confirmed the high

Table 4. Comparisons between groups in terms of technical and economic parameters.

Variable	Efficiency			
	Total	High	Medium	Low
Mean efficiency	61.7	82.4 ^a	61.1 ^b	44.1 ^c
Farms, n	31 (100)	8 (26)	14 (45)	9 (29)
Milk production, Tonn•year ⁻¹	48,897	33,529	60,528	44,464
Number of ewes	510.8	350.8	619.3	475.2
Farm size, ha	359.2	347.5	410.5	289.6
Pasture area, ha	227.4	235.0	271.0	152.8
Supplementary feed, Tonn•year ⁻¹	138.13	66.08	149.95	183.78
AWU total	1.88	1.13 ^a	2.23 ^b	2.0 ^{ab}
AWU 100 ewes ⁻¹	0.47	0.39	0.44	0.60
Milk per ewe, L	97.4	90.2	100.4	98.9
Stocking rate, animal units•ha ⁻¹	0.38	0.21	0.39	0.53
Supplementary feed per ewe, kg•ewe ⁻¹ •year ⁻¹	242.7	155.4 ^a	218.5 ^a	357.9 ^b
Supplementary feed per liter of milk, kg•L ⁻¹	2.6	2.3 ^a	2.9 ^{ab}	4.2 ^b
Family labour, %	83.3	94.0	77.3	83.3
Mean cost per liter of milk, €•L ⁻¹	1.9	1.7	1.78	2.3
Mean cost per ewe, €•ewe ⁻¹	190.0	154.6 ^a	183.1 ^a	232.4 ^b
Total cost, €	90,138	52,595	108,909	94,310
Total income, €	91,577	68,980	109,871	83,206
Profit per farm without subsidies, €	-10,930	7161 ^b	-13,867 ^{ab}	-22,441 ^a
Profit per farm with subsidies, €	1439	16,385 ^b	961 ^{ab}	-11,104 ^a
Profit per liter, without subsidies, €•L ⁻¹	-0.46	-0.135 ^b	-0.34 ^{ab}	-0.95 ^a
Profit per liter, with subsidies, €•L ⁻¹	-0.182	0.186 ^b	-0.065 ^{ab}	-0.692 ^a
Profit per ewe without subsidies, €•ewe ⁻¹	-31.5	6.3 ^b	-22.6 ^b	-78.8 ^a
Profit per ewe with subsidies, €	-7.2	31.6 ^b	1.8 ^b	-55.7 ^a
Gross family income, €	16,614	27,427	15,697	8,427

AWU, annual work unit [it corresponds to a worker devoted full-time during a year to the agricultural/livestock activity (European Commission, 2012)]. ^{a,c}Different letters in the same row denote significant differences with $P \leq 0.05$. Values in brackets are expressed as percentage.

Table 5. Cost efficiency according to typological group.

Group	Mean, %	Standard deviation, %	Coefficient of variation, %	Min, %	Max, %
I	65.3 ^b	14.9	22.8	44.4	86.1
II	49.2 ^a	11.6	23.5	33.5	63.8
III	67.7 ^b	14.0	20.6	47.5	93.9

^{a,b}Different letters denote significant differences with $P \leq 0.01$.

Table 6. Contingency table of the relationship between efficiency costs and typological groups.

Efficiency	Group		
	I	II	III
High	33.3%	0.0%	38.5%
Adjusted residues	0.61	-2.1	1.37
Medium	44.4%	44.4%	46.1%
Adjusted residues	-0.05	-0.05	0.09
Low	22.2%	55.6%	15.4%
Adjusted residues	-0.53	2.08	-1.42

Adjusted residues are calculated as the difference between observed and expected frequency. Values greater than ± 2 indicate that the proportion of farms in the category (level of efficiency cost) differ from expected values.

dependency on subsidies. Nevertheless, highly efficient farms were economically viable in the absence of subsidies if amortization of the infrastructure (17% of the costs) is ignored. Systems of medium efficiency could be viable in absence of subsidies if amortization costs are absent and if part of the retribution to family labour (33% of the costs) is reduced. Finally, farms showing low levels of efficiency were not viable in any scenario. Three main reasons explain their continued existence in the market: the presence of subsidies, the lack of amortization of the fixed assets, and the realization of positive gross family incomes that are independent of the AWU assigned to the activity (Table 4).

Improvement of the efficiency is associated with levels of supplementation that are adjusted to the physiological condition and productive potential of ewes and, more generally, it points to the need to more closely adjusting farm outputs to the available system resources while minimizing external inputs, as indicated by Toro-Mujica *et al.* (2011).

Within group correlations between the efficiency of costs and the observed variables identifies variables associated with higher efficiency. Total labour use (total AWU) was closely and inversely associated with efficiency within Group I (subsistence systems), a characteristic that is reflected in the total mean and mean/sheep costs. Thus, improvement in the economic sustainability of this group is associated with an increase in farm size and reduction of labour costs. Nevertheless, given that they use exclusively family labour and have low investment capacity, one feasible strategy would be their vertical integration aimed at

producing higher added-value products as shown for model family farms in China (Huang, 2011).

Groups II and III showed the negative influence of feeding strategy on efficiency. Farms in these groups are commercially oriented and the response to supplementation falls in the area of decreasing performance and increasing costs. In Group II, positive correlations between the efficiency, sheep stocking rate, milk production and flock size were observed, suggesting the existence of economies of scale.

Conclusions

The homothetic transcendental log function with unit elasticity adequately represented the cost function of organic dairy sheep systems in Central Spain. Cost efficiency constitutes an appropriate indicator of farm economic sustainability since it integrates information on resource allocation and their corresponding prices. The values of cost efficiency obtained revealed the significant influence of labour and supplementary feeding costs, flock size and milk output on the economic sustainability of the farms studied. The average cost efficiency was 61.7% with a wide range of values (60.4 units). Only 26% of the farms showed high efficiency, suggesting the existence of considerable room for improvement of economic sustainability. Farms of low to medium efficiency had higher stocking rates and used high levels of supplementation associated with higher costs and low economic

sustainability.

Lastly, other aspects related to economic sustainability of organic systems such as the political environment, the existence of environmental policies and of markets willing to pay increased values for organic products, and others, should be considered. Nevertheless, farms that have positive results in terms of cost efficiency reduce uncertainty and show higher levels of security in circumstances of contextual changes that can alter their competitive advantages. The above two aspects support the validity of the costs analyses since they allowed estimation of the impact of public policies on these farms within a sustainability context.

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