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Economic weights of fertility, prolificacy, milk yield and longevity in dairy sheep

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Economic weights have been estimated in two breeds (Latxa and Manchega) using economic and technical data collected in 41 Latxa and 12 Manchega dairy sheep flocks. The traits considered were fertility (lambing per year), prolificacy (number of lambs), milk yield (litres) and longevity (as productive life, in years). A linear function was used, relating these traits to the different costs in the flock. The variable costs involved in the profit function were feed and labour. From this function, economic weights were obtained. Labour is considered in the Latxa breed to be a constraint. Moreover, farm profits are unusually high, which probably means that some costs were not included according to the economic theory. For that reason, a rescaling procedure was applied constraining total labour time at the farm. Genetic gains were estimated with the resulting economic weights to test if they give any practical difference. Milk yield only as selection criterion was also considered. The medians of the estimated economic weights for fertility, prolificacy, milk yield and longevity were 138.60 € per lambing, 40.00 € per lamb, 1.18 € per l, 1.66 € per year, and 137.66 € per lambing, 34.17 € per lamb, 0.73 € per l, 2.16 € per year under the linear approach in the Latxa and Manchega breeds respectively. Most differences between breeds can be related to differences in production systems. As for the genetic gains, they were very similar for all economic weights, except when only milk yield was considered, where a correlated decrease in fertility led to a strong decrease in profit. It is concluded that the estimates are robust for practical purposes and that breeding programmes should consider inclusion of fertility. More research is needed to include other traits such as somatic cell score, milk composition and udder traits.

Keywords: breeding objectives, dairy ewes, profits, rescaling, selection index.

Introduction

Economic weights are key in the definition of breeding objectives and criteria for livestock improvement programmes (Groen *et al.*, 1997). The methods have largely been discussed (see Goddard (1998) for references and a general discussion) and economic weights for many species and management systems have been calculated. However, to our knowledge, very few attempts have been made to estimate economic weights in dairy sheep. Kominakis *et al.* (1997) compared several selection schemes based on economic weights from previous research; unfortunately, details on the calculus of economic weights remain unpublished. Moreover, they did not include any functional trait in their work. Barillet *et al.* (1997) presented a general discussion of the subject, but with an emphasis on theoretical approaches and possible outcomes of the selection schemes; they did not use any economic data. Gabiña *et al.* (2000) estimated the relationship between profit and some characteristics at the farm level, such as milk production or fertility, although their work is not a formal research on economic weights.

Most dairy sheep selection programmes have started with an aim towards increasing milk yield, as a trait *a priori* economically relevant and easy to measure and improve (Barillet, 1997). Later, breeding objectives and criteria (the merit index) have been explicitly extended towards milk composition (Barillet, 1997; Asociación Nacional de Criadores de Ganado Ovino Selecto de Raza Churra (ANCHE), 2005), udder and body type traits (ANCHE, 2005) or somatic cell score (Rupp *et al.*, 2002). Other traits such as milkability or longevity are under consideration. To our knowledge, the weights given to these traits on the selection criterion or merit index have been assigned on a desired-gains basis. There is no information about the economic aspects of each trait and the future outcome of the different selection criteria. It has been long pointed out, though, that a set of weights in a merit index is equivalent to a set of arbitrary 'pseudo-economic weights' and can yield economically sub-optimal gains (Gibson and Kennedy, 1990). It is also true, as commented by Groen *et al.* (1997), that it might be very hard to know all economic and technical data required to estimate economic weights.

The purpose of this paper is two-fold: first, to calculate the economic weights for a set of productive and functional traits (milk yield, fertility, prolificacy, and longevity), for two different dairy sheep breeds (Latxa and Manchega) used in very different environments, and considering several farms. Second, we want to compare the obtained economic weights within and across breeds regarding its practical relevance (i.e. genetic gains). A final aim is to prepare a coherent framework to take decisions in the Latxa and Manchega breeding schemes.

Milk composition (somatic cell count, fat and protein contents) is important for milk price and cheese yield. Somatic cell count is also related to the health of the flock. However, the lack of economic and technical data concerning these traits in this study does not allow the estimation of economic weights. Besides, these traits have non-linear profit functions (Barillet, 1997) that are worth their own treatment. A companion paper (Legarra *et al*., 2007) describes economic weights for somatic cell score in dairy sheep.

Material and methods

Description of the breeds

Latxa and Manchega breeds are located in two different regions of Spain. The Latxa breed is located in the Basque Country and Navarre, a humid and mountainous area, whereas the Manchega breed is located in the Castilla-La Mancha region in an arid environment with a low rainfall and high temperatures. Management systems are therefore quite different.

(a) Manchega flocks include about 600 to 1000 productive ewes, whereas size of Latxa flocks ranges from 200 to 400 ewes.
(b) The Latxa farmers make more use of grasslands and mountain pastures, whereas Manchega farmers, situated in an agricultural region (vineyards and grain crops) make use of their own crops (grain) and crop residues (straw, stubble). To fulfil flock needs they also make use of purchased forages and concentrates.
(c) Latxa sheep is fairly seasonal and parturitions happen in autumn and winter. Manchega is a non-seasonal sheep and parturitions occur throughout the year. This leads to more intensive husbandry practices in Manchega.
(d) Some Latxa farmers sell sheep milk to cheese factories. However, many of them also produce cheese for sale, or even sell sheep milk directly to the consumers, who produce curd at home. Both methods add value to the farm production, although they require extra labour time and investments, especially in machinery. Thus, Latxa farmers can be roughly classified as milk-sellers (most milk goes to the factory) or cheese-sellers (most milk is transformed into cheese). Among the 41 Latxa farms in this work, 13 were considered as milk-sellers (more than 80% milk sold), and 21 as cheese-sellers (more than 80% milk transformed into cheese). This strategy is less common among Manchega farmers. All Manchega farms in this work sell milk to the factories.

Data

Economic and technical data for Latxa flocks were gathered by management support technicians. Management support programmes have been established in the Basque Country, and therefore in the Latxa breed, for more than 15 years. They collect information on economic inputs and outputs and technical management of the farm such as yearly reproductive and productive performances. This information is routinely gathered, checked, and used for management support. Such a programme does not exist in Manchega farms; therefore, information for this work was collected through personal interviews. Economic inputs and outputs were collected from invoices as far as possible. Technical data were collected from the milk recording schemes. A few data were collected from the farmers' own records (number of replacement lambs) or by their best guesses (labour). Data used in this study were gathered in 2002 (Latxa) and 2003 (Manchega). Forty-one Latxa and 12 Manchega farms were included.

Data for this work consisted in a set of overall yearly economic indicators: feedstuff, veterinarian, financial and other costs; income from selling milk, lambs, or other products; and technical indicators such as total number of lambings, number of lambs born, total milk produced, milk transformed into cheese, replacement rate, etc. Table 1 shows different aspects of the farms under study. In general, economic data show a great variability and skewed distributions. For this reason, we will present in general medians and quantiles instead of averages, as medians are a more robust and informative measure of centrality for this kind of distribution.

Incomes

Milk. Incomes were declared by the farmers. Milk price (see Table 1) was therefore calculated as the ratio between incomes from milk or cheese sale and milk production. In the Manchega farms, all sales were as milk. Table 1 shows big variations of milk price, according, among other causes, to different final products. The median of milk price for Latxa milk-sellers was 0.92 € per l (very similar to prices in Manchega), whereas for cheese-sellers it was 1.84 € per l.

Lambs. Price was also calculated as total sales divided by total number of lambs. Here, a great part of the variability in prices (see Table 1) is due to seasonal variations (Latxa) or weight variations (Manchega). In the Latxa and Manchega systems, lambs are sold at weaning. Latxa lambs are sold, at a fixed weight, but lambing is seasonal and the price changes accordingly. For the Manchega breed, the prices depend on the average weight of lambs

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Table 1 *Features of the economic and technical data in the study*

	Latxa (no. = 41)			Manchega (no. = 12)		
	1Q†	2Q	3Q	1Q	2Q	3Q
No. of ewes	310	413	500	495	949	1541
Fertility (lambings per year and ewe)	0.77	0.85	0.93	0.89	0.91	0.93
Prolificacy	1.03	1.18	1.32	1.09	1.17	1.25
Milk yield (l per ewe in the flock)	79.92	93.74	107.40	116.70	144.65	172.90
Longevity (years)	5.16	5.58	6.51	4.58	5.04	5.61
Fixed costs (€ per year)	15 120	17 080	24 650	28 444	47 628	71 930
Labour time (man · year)	1	1.5	2	1	3	4
Feeding costs (€)	13 660	19 390	28 670	34 050	62 950	97 160
Milk price (€ per l)	1	1.48	1.84	1.01	1.10	1.13
Milk price, cheese-sellers	1.72	1.84	1.95	–	–	–
Milk price, milk-sellers	0.89	0.92	0.99	–	–	–
Lamb price (€ per lamb)	33.46	40.01	48.32	48.55	50.01	50.36
Profit (€)	6234	17 290	31 530	31 760	41 420	76 460
Feeding cost (€ per UFL)	0.112	0.133	0.166	0.114	0.125	0.150
Labour cost (€ per h)	3.14	3.72	4.90	4.37	5.07	6.85

† 1Q: first quartile; 2Q: median; 3Q: third quartile.

according to a set of thresholds. We have not considered lamb growth rate for two reasons. First, as the system is focused towards milk production, lambs are sold at a given date regardless of the weight. Second, and more important, there is no information collected about lamb weight (and related expenses and incomes) in the farms.

Other incomes. Other incomes were public aids, variation in flock size, livestock sale, and miscellaneous. Among the public aids, the only one considered as variable with the number of animals in the farm (and hence affecting the calculus of economic weight, depending on the method) was the EU agricultural policy subsidy. However, this income was set to zero because the EU aid system is changing and in the future the aid will *not* depend on the number of animals, as it used to be. Sale of old ewes is of very low profit as their meat is poorly appreciated by the consumer. Moreover, this trait is not recorded at the farm level, and its associated expenses (e.g. feed costs) are hard to compute. For these reasons, adult weight was not included as a trait in the profit function.

Expenses

Main variable costs were feeding and labour. Usually, labour costs are considered as fixed, but if the flock size increases more labour will be needed. Moreover, dairy sheep husbandry is a labour intensive task, involving feeding, milking, lambings, and so on. Therefore, in this work labour costs were treated as variable costs.

Feeding. Unfortunately, feeding data, as gathered, were not split into the different functions, i.e. production, reproduction, or replacement. Rather, an overall yearly expense was available. To split this cost into the different production functions, the following procedure was used. Standard feeding rations were elaborated for production, maintenance, reproduction and growing, following the Institut National de la Recherche Agronomique (1988) and Caja (1994) (Table 2). We assumed the same adult weight for all ewes. For each flock, the total amount of net energy, measured in UFL (one UFL is equal to 1700 kcal) was calculated as the sum of all theoretical needs, considering levels of production and number of animals. Then, the price per UFL was calculated as the total expense in feedstuff divided by the total (theoretical) needs of the flock in UFL. This procedure provided different costs per farm (as presented in Table 1), although it implicitly considered that feeding management was the same in different flocks. It implicitly considers as well that the feed required for each productive function has the same cost, which might not be true (e.g. use of concentrates to increase milk yield *vs*. use of common pasture for maintenance). Accordingly, the theoretical needs for each task were included in the profit function.

The costs of pasture food (opportunity costs, which might be important in the Latxa breed) are not considered, as these are not out-of-pocket expenses of the farm and therefore never measured. This might have underestimated some costs.

Labour. A similar approach was used for labour. It is worth noting that most Latxa and some Manchega farms are owned by the shepherds. Therefore, no salaries are paid. However, farmers declare their yearly labour time at the farm. Using this information, technicians consider, for accounting purposes, a salary that is two-fold the 'minimum salary' regulated by the Spanish government, which was 451.2 € per month in 2002 and 2003. Management technicians also provided their estimates of work time needs for different tasks as parturitions, care of the flock, milking, etc. (see Table 2). Note that cheese-making labour time was also included, considering that cheese-making offers higher incomes per litre of milk but

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Table 2 *Inputs related to variable costs*

	Feeding	
	Latxa	Manchega
Maintenance	223.2 UFL per (ewe · year)	292 UFL per (ewe year)
Gestation	34.2 UFL per ewe	36.6 UFL per ewe
Suckling	30.9 UFL (1 month suckling per ewe)	36.0 UFL (1 month suckling per ewe)
Milk	0.753 UFL per l	0.760 UFL per l
Replacement	227.37 UFL per replacement hogget	226.30 UFL per replacement hogget
	Labour	
Maintenance	2.2 h per (ewe · year)	
Lambing	2 h per ewe lambing	
Milking	2 min per (ewe · day)	
Milking	1 h/day (independent of the no. of ewes)	
Cheese-making	0.08 h/l of milk transformed into cheese	
Replacement	2.2 h per (replacement hogget · year)	

has also higher related costs. As for labour in lambing, we assumed the same for single or twin births. Triplets require more labour, but they are rather unusual among these breeds (less than 1% of births in Latxa) and were not considered. Then, the procedure was the same as for feeding: the total costs were calculated and divided by the total theoretical needs, providing a cost per hour variable among farms.

Amortizations, electricity, water and farm maintenance, are put together as 'fixed costs' in Table 1. Other costs included marketing, livestock purchase, veterinary fees and treatments. These are not shown in Table 1.

Traits

For each of the studied farms, we calculated the economic weights considering profit functions (Ponzoni, 1986; Goddard, 1998). Four traits were included in the profit functions: fertility, prolificacy, milk yield and longevity.

Fertility (yes/no) is an important functional trait as not all animals lamb in sheep husbandry systems, especially under extensive conditions or seasonal reproduction (which is the case of Latxa). Fertility was shown to be correlated to farm profit in Latxa flocks (Gabiña *et al.*, 2000).

Prolificacy (number of lambs born) is also a productive trait, usually considered in meat sheep breeding schemes. However, its genetic improvement is not emphasised by farmers in Manchega or Latxa, because most profit comes from milk yield and because it is well known that genetic selection for prolificacy is slow, because of its low heritability (Altarriba *et al.*, 1998).

Milk yield (litres per ewe per year) is the major source of income. This trait has been selected for in these breeds over the last 20 years, with good results of about 3 l/year in the Latxa breed (Legarra *et al.*, 2003) and 0.82 l/year in the Manchega breed (Serrano *et al.*, 2006). According to Barillet (1997), milk yield is an appropriate breeding objective in the beginning of a dairy sheep breeding scheme, as milk yield is economically important, easy to measure, and heritable. One of the purposes of this work is to confirm the economic relevance of milk yield in relation to other traits.

Longevity was considered as productive life, from adult (1 year old) until culling or death. This is an omnibus functional measure of involuntary culling or death traits. The economic weight of longevity should reflect the combined importance of the traits that cause culling of the animals (e.g. mastitis, problems in legs, milkability) in relation to other traits.

Therefore the profit function includes productive (milk yield, prolificacy) and functional traits (fertility, longevity). Only these four traits were included as, given the data available, inclusion of other traits (weight, feed intake, milk composition, udder traits) was difficult without making too many assumptions including the production system and economic repercussions. We have preferred to focus on the data already available and test the profit function in a wide variety of farms. A more detailed profit function including those traits could be considered under a simulation model (the so-called bio-economic models; Groen *et al.* (1997)). Two different procedures were used to define the economic weights. The first is a linear function, whereas the second applies a rescaling procedure (Smith *et al.*, 1986).

Linear profit function

The linear profit function was as follows.

$$\text{Profit} = \text{income} - \text{expenses}.$$

$$\begin{aligned}\text{Income} = {} & \text{number of ewes} \times (\text{fertility} \times (\text{milk yield} \\ & \times \text{milk price} + \text{prolificacy} \times \text{lamb price})) \\ & + \text{other incomes}.\end{aligned}$$

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$$\begin{aligned}\text{Expenses} = {} & \text{number of ewes} \times (\text{maintenance cost} \\ & + \text{gestation cost} + (\text{fertility} \times (\text{suckling cost} \\ & + (2 - \text{prolificacy}) \times \text{single parity lamb cost} \\ & + 2 \times (\text{prolificacy} - 1) \times \text{twin parity lamb cost} \\ & + \text{milk yield} \times \text{milk cost}) \\ & + \text{replacement cost}/\text{longevity})) \\ & + \text{other expenses}.\end{aligned}$$

Note that this profit function avoids double counting because the interaction among variables in total profit is already acknowledged (e.g. fertility multiplies prolificacy). In practice we used profit per ewe, which is obtained dividing the former expressions by the number of ewes. From the profit function, the partial derivatives for each trait, evaluated at the present values for other traits, give the corresponding economic weights. The gestation costs do not depend on fertility because management and feeding are almost the same for pregnant and non-pregnant ewes. Prices in the function are shown in Table 1. The costs, as obtained from Tables 1 and 2, are detailed as follows.

$$\begin{aligned}\text{Maintenance cost} = {} & \text{maintenance feeding} \times \text{UFL cost} \\ & + \text{maintenance labour} \\ & \times \text{man year cost}.\end{aligned}$$

$$\text{Gestation cost} = \text{gestation feedings} \times \text{UFL cost}.$$

$$\text{Suckling cost} = \text{suckling feeding} \times \text{UFL cost}.$$

$$\begin{aligned}\text{Single parity lamb cost} = {} & \text{suckling cost} \\ & + \text{lambing labour} \\ & \times \text{man year cost}.\end{aligned}$$

$$\begin{aligned}\text{Double parity lamb cost} = {} & \text{suckling cost}/2 \\ & + (\text{lambing labour} \\ & \times \text{man year cost})/2.\end{aligned}$$

$$\begin{aligned}\text{Milk cost} = {} & \text{milk feeding} \times \text{UFL cost} + \text{cheese} \\ & \text{making labour} \times \text{ratio} \times \text{man year cost}.\end{aligned}$$

$$\begin{aligned}\text{Replacement cost} = {} & \text{replacement feeding} \times \text{UFL cost} \\ & + \text{replacement labour} \\ & \times \text{man year cost} \\ & + \text{single parity lamb cost}.\end{aligned}$$

For milk cost, cheese making labour is weighted by the ratio between milk transformed into cheese and total milk produced, to consider the differences in cheese-making.

Cumulative discounting (e.g. Groen *et al.*, 1997) was not considered because all traits in the aggregate genotype are expressed only in females during their full lifetime, which implies that the discounting applies equally to all traits. This assumes that culling risk increases at a uniform rate during lifetime, and, therefore, the effect of increasing 1 year of longevity is expressed during all lifetime as a lower risk of culling or death. The more simplistic option, that longevity of all animals in the flock is increased uniformly from 4 to 5 years, is unrealistic. At any rate, as pointed out by Ponzoni (1986) the discounting correction has small effects on the economic values and negligible effects on the genetic gains. This correction should be applied for traits expressed differentially in life or to make a cost-benefit analysis of a starting breeding programme.

Rescaling

The profit function has been written at the farm level. However, problems related to the perspective have long been discussed, because different perspectives lead to different economic weights and paradoxes related to the size of the enterprise (Smith *et al.*, 1986; Amer and Fox, 1992; Goddard, 1998). To solve this point, a commonly accepted approach is that of 'rescaling' (Smith *et al.*, 1986; Visscher *et al.*, 1994). All perspectives and methodologies are equivalent when profit is zero: it is also expected that, in a competitive market, enterprise profit is expected to be zero or close to zero. Goddard (1998) suggested that enterprise profit should be examined, and that too high a profit should be considered as an indicator that some costs have not been correctly included. He suggests a rescaling procedure constraining the farm, after rescaling, to the input that accounts for this cost. According to this procedure, Visscher *et al.* (1994) constrained total feeding in the farm for pasture-based systems.

Profit for the farms in the study is quite high, according to Table 1 (note that labour costs of farm owners have already been subtracted, according to accounting practices). We consider that in the Latxa farms, labour costs are very difficult to compute and subject to restriction. The reason is that most Latxa farms are family-owned, and they fully exploit family labour time by husbandry and (when existent) cheese production. Thus, these farms do not want to grow as an enterprise. Moreover, they have difficulties in acquiring additional foreign labour because the Basque Country is a very industrial area. We thus applied the rescaling procedure described by Visscher *et al.* (1994) and Goddard (1998). The constraint included was total labour time at the farm. For Manchega farms, labour is divided into livestock and agricultural activities and it is difficult to assign labour time for each activity and the constraint is not so strong. However, the procedure was also applied in Manchega farms for the sake of comparison. The rationale behind the rescaling procedure is the following: as total labour time is fixed, a genetic change in a trait will determine a change in the labour time. For instance, increasing milk yield will increase milking time, whereas increasing longevity will decrease time devoted to replacement hoggets.

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Therefore, the farmer will change the number of animals in order to balance labour time. Visscher *et al.* (1994) showed how to evaluate this. The method is as follows.

Let P be the profit without considering rescaling, and P_1 profit after rescaling. Let $\mathbf{x}$ be the vector of values for the traits in the profit function. The vectors of economic weights before and after rescaling of the farm are, accordingly, $\mathbf{p}$ ($\mathbf{p} = \partial P/d\mathbf{x}$) and $\mathbf{p}_1$ ($\mathbf{p}_1 = \partial P_1/d\mathbf{x}$).

Consider W, the total labour time. The function $W = f(\mathbf{x})$ describes W as a function of $\mathbf{x}$. This function was constructed from Table 2. Visscher *et al.* (1994) showed that, for small genetic changes,

$$\partial P_1/d\mathbf{x} = \partial P/d\mathbf{x} - (\partial W/d\mathbf{x})(P/W), \text{ or, equivalently,}$$
$$\mathbf{p}_1 = \mathbf{p} - (\partial W/d\mathbf{x})(P/W)$$

where P/W is the farm profit per unit of work, evaluated before rescaling, that is, with the profit function described before *but* excluding labour costs, because, according to the rescaling procedure, we assume that they are hard to estimate and that they will be constant before and after genetic improvement. Note also that, for the same reason, $\mathbf{p}$, in our case, are not the same economic weights obtained from the previous linear profit function. The derivation of $\mathbf{p}_1$ considers the change in the number of animals due to the change of labour time originated by a genetic change in one of the traits.

Estimation of genetic gains

To test the effect in practice of the differences in economic weights, we estimated genetic gains according to selection indices based on different economic weights. Three different strategies were compared. The first uses a selection index based on the median of the economic weights, which will be shown in Table 4. The second strategy implies that each farm uses selection indices based on its own set of economic weights. Obviously, this is not feasible in practice, as several decisions of selection are taken collectively, as selecting the young artificial insemination (AI) rams, where a unified merit index is needed. The third one considers a genetic selection scheme selecting (and measuring) only milk yield, that is, the information on the other traits is not used for the estimation of breeding values. This is the present scenario. Gains in profit were calculated for each farm, multiplying the vector of farm economic weights by the genetic gains.

The genetic gains were estimated following a simplified breeding scheme, modelling the real Latxa breeding scheme (Legarra *et al.*, 2003). Several groups of candidates to selection were considered. Groups were: dams of rams, dams of dams, fathers of dams (with three subgroups: proven AI rams, rams on AI progeny testing, and natural service rams), and fathers of rams (proven AI rams). In the Manchega breeding scheme, only four tiers were considered: dams of rams, dams of dams, fathers of dams and fathers of rams. For each group, the genetic gain obtained by using a given vector of economic weights was calculated following selection index theory (e.g. Groen *et al.*, 1997). The sources of information are: three repeated phenotypes for each ewe; 20 daughters with one performance each for each proven ram; and the combination of both for the young prospective rams. The selection proportions are 0.03 for mothers of ram and 0.60 for mothers of ewes. For sires of ewes two consecutive selections are done: first, a selection proportion of 0.22 of lambs chosen for progeny testing; then, a selection proportion of 0.33 to select the best rams among the progeny tested. It was assumed that all four traits in the breeding objective were measured simultaneously (that is, in each female, in each lactation). The genetic progresses in the population were calculated adding up the progress in each group, following the Rendel and Robertson (1950) formula to take into account the differences in the generation interval. The different proportions of use of natural service rams (64%), testing AI rams (17%) and proven AI rams (19%) were included in the formula. For a breeding scheme in equilibrium, the methodology is equivalent to the gene flow method. No corrections were applied to consider the statistical nature of fertility and prolificacy (categorical traits) or longevity (a censored, non-normal trait).

There is no joint estimate in dairy sheep of all the appropriate genetic parameters. We combined information from different studies in sheep and cattle to form the covariance matrices needed for the procedure (Mavrogenis, 1996; Altarriba *et al.*, 1998; Rauw *et al.*, 1998; Rosati *et al.*, 2002; Tsuruta *et al.*, 2004). Parameters for milk yield were estimated in Latxa and Manchega (unpublished). The matrix of phenotypic covariances turned out to be non-positive definite and a 'bending' procedure (Hayes and Hill, 1981) was applied, setting its negative eigenvalue to 0.001. Final parameters are shown in Table 3. The Bulmer effect was ignored. All computations were run in R (R Development Core Team, 2005).

Results

Economic weights

Two different sets of economic weights (using linear and rescaling approaches) were calculated for each of the 41 Latxa and 12 Manchega farms. Each set consisted of weights for fertility, prolificacy, milk yield and longevity. The main results are presented in Table 4. An increase in

Table 3 *Parameters for the traits in the aggregate genotype in Latxa and Manchega*†

	Fertility	Prolificacy	Milk yield	Longevity	σ^2	c^2
Fertility	**0.06**	0.65	−0.30	0.5	0.20	0
Prolificacy	0.77	**0.08**	0.07	0	0.22	0.07‡
Milk yield	−0.30	0.08	**0.20**	0.12	1505	0.21
			0.14§		1463§	0.38§
Longevity	0.48	0.01	0.12	**0.13**	0.19	0

† Heritabilities in the diagonal, genetic correlations above the diagonal, phenotypic correlations below the diagonal. σ^2 is the total variance, c^2 the part due to common environment.
‡ The common environment correlation between prolificacy and milk yield was set to 0.08.
§ These are the values in the Manchega breed.

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Table 4 *Economic weights (per productive ewe at the flock, per year) for each trait considering a linear profit function and a rescaling approach*

	Latxa (no. = 41)			Manchega (no. = 12)		
	1Q†	2Q	3Q	1Q	2Q	3Q
Linear approach						
Fertility (€ per lambing)	106.29	138.60	166.19	109.23	137.66	153.88
Prolificacy (€ per lamb)	33.46	40.00	48.32	30.95	34.17	35.34
Milk yield (€ per l)	0.89	1.18	1.44	0.69	0.73	0.77
Longevity (€ per year)	1.24	1.66	2.06	1.60	2.16	2.71
Rescaling approach						
Fertility (€ per lambing)	79.75	104.77	150.80	106.46	134.27	148.82
Prolificacy (€ per lamb)	33.46	40.00	48.32	30.95	34.17	35.34
Milk yield (€ per l)	0.86	1.01	1.21	0.69	0.73	0.77
Longevity (€ per year)	1.21	1.54	1.93	0.87	1.33	1.49

† 1Q: first quartile; 2Q: median; 3Q: third quartile.

fertility provides a high overall increase in profit, as a result of lambs and milk selling. However, the high economic weight of fertility is also a matter of scale, as it implies a change from 0 (no lambing) to 1 (lambing). Increases in prolificacy or milk yield are also quite profitable. The economic weight of milk production in Manchega does not change from a linear to a rescaling approach. As was pointed out above (see Table 2), no relation was considered between labour time necessary for milking and the amount of milk yield and, therefore, an improvement in milk production does not involve an increase in labour. In Latxa, more milk yield implies more time making cheese. The economic weight of longevity does not seem very high. Kominakis *et al.* (1997), working with dairy sheep, cites economic weights of 0.57 € per l for milk yield and 34.70 € for number of lambs weaned at 42 days. These figures are quite similar to ours.

Approach. Differences between the simple, linear profit function and the rescaling approach can be seen in Table 4 and Figures 1 and 2. Changes are higher in Latxa than in Manchega. In general, the economic weights are reduced when using the rescaling approach.

Breeds. Differences among breeds are substantial, as reflected in Table 1. Economic weights are lower in the Manchega farms than in the Latxa breed for all traits except longevity.

Type of farms. As explained before, the differences between milk-sellers and cheese-sellers in Latxa translate into the economic data and therefore to the economic weights. The latter can be seen in Figure 3, where the economic weights of fertility and milk yield are higher for cheese-sellers.

Genetic gains

Table 5 shows the estimated genetic gains after one year of selection using selection indexes based in different economic weights: the 'median' set of economic weights (Table 4, linear and rescaled), farms' individual economic

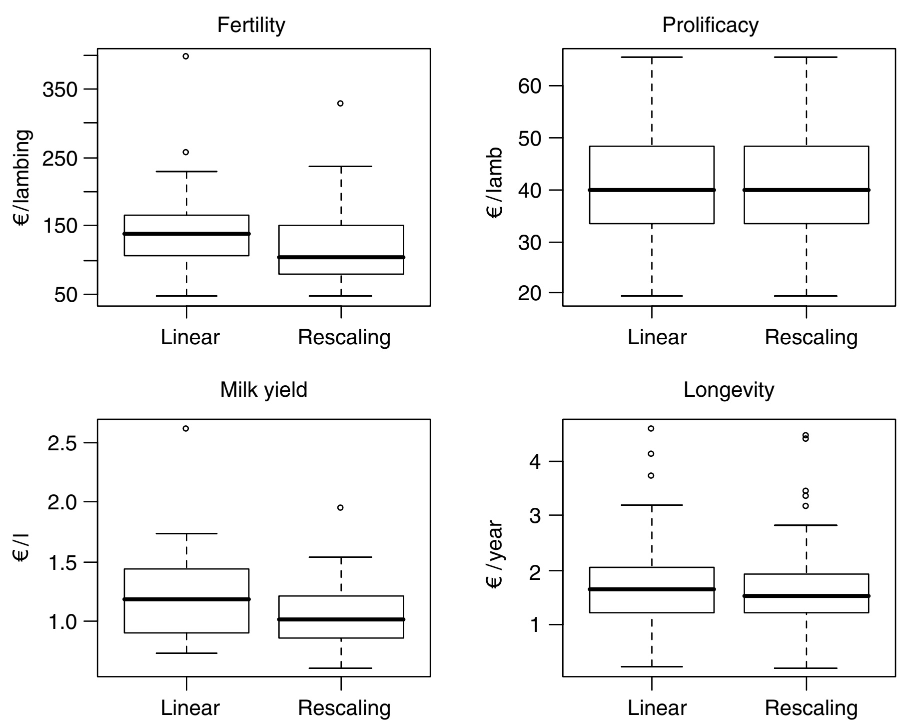

Figure 1 Box-and-Whisker plots of the different economic weights obtained in the Latxa breed using two approaches. The thick line is the median; the lower and upper lines of the 'box' are the first and third quartile. The box includes 50% of the data. The 'whiskers' extend to the farthest data point closer than 1.5 interquartile ranges from the 'box'. The circles can be considered 'outliers'.

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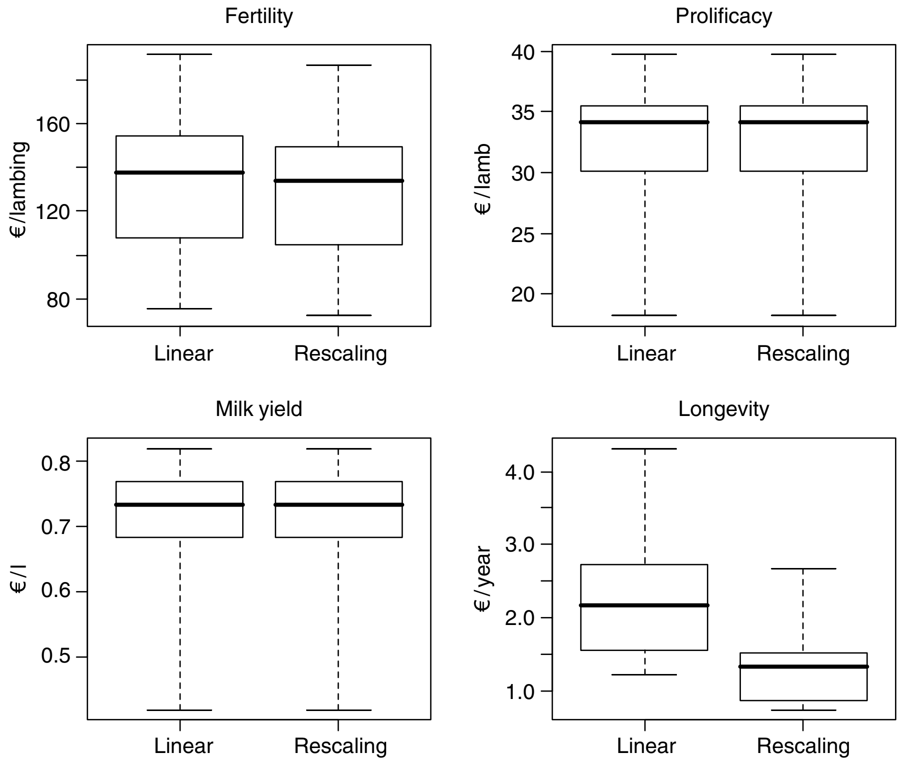

Figure 2 Box-and-Whisker plots of the different economic weights obtained in the Manchega breed using two approaches. For interpretation, see Figure 1.

weights, and milk yield as the only trait in the merit index (as it is now). There are no major differences in practice for the genetic gains using any procedure to estimate the economic weights. Neither there is a great loss in efficiency by using an overall aggregate genotype. Note that profit is calculated assuming as the 'true' gain the economic weights for each farm, and thus it is not comparable among linear/rescaling approaches because the 'true' increase in profit is different. However, including only milk yield leads to a great economic loss in the breeding

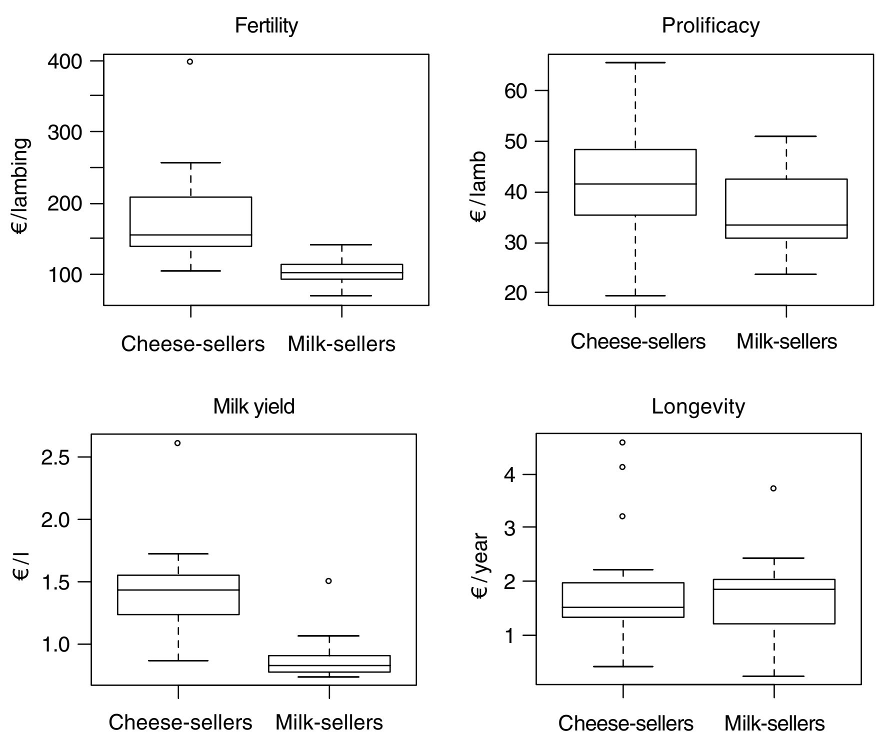

Figure 3 Box-and-Whisker plots of the economic weights in the Latxa breed for cheese-seller and milk-seller farms. For interpretation, see Figure 1.

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Table 5 *Genetic gains in the Latxa and Manchega breeds after 1 year of genetic improvement based on different economic weights*

	Criteria†				
	Set I, no rescaling	Set I, rescaling	Set II, no rescaling‡	Set II, rescaling‡	Set III
Latxa					
Fertility	0.004	0.003	0.004	0.004	−0.006
Prolificacy	0.010	0.010	0.010	0.010	0.002
Milk yield (kg)	2.61	2.71	2.57	2.61	3.06
Longevity (years)	0.013	0.011	0.013	0.012	0.004
Profit gain per ewe (€)	4.20	3.69	4.22	3.73	2.83
Profit gain per farm (€)	1746	1527	1757	1546	1189
Manchega					
Fertility	0.008	0.008	0.008	0.008	−0.007
Prolificacy	0.015	0.015	0.015	0.015	0.002
Milk yield (kg)	2.36	2.26	2.31	2.32	3.77
Longevity (years)	0.012	0.012	0.012	0.013	0.004
Profit gain per ewe (€)	3.39	2.89	3.51	2.94	1.97
Profit gain per farm (€)	3178.28	2707.94	3386.22	2829.38	948.45

† Sets: (I) using the 'median' set of economic weights; (II) using farms' individual economic weights; (III) using milk yield as the only trait in the merit index.
‡ Average genetic gains.

scheme, because of the correlated genetic loss in fertility. In this case, the increases in profit were assumed to be the economic weights in the linear approach. Therefore there might be a loss in economic gain of 32% in Latxa and 42% in Manchega if selection is based in milk yield only.

Discussion

Criticisms

The present study gives a perspective on the breeding objectives of the Latxa and Manchega breeds. We had to use a very simple profit function where important traits have been discarded. Moreover, the treatment of food and labour costs has probably increased the similarities among farms; however, we believe that the profit functions have succeeded in capturing part of the farm variability.

The prediction of genetic gains is based on a simplified breeding scheme, but usually this does not pose a major problem. However, the genetic parameters assumed (Table 3) do influence the predictions: changing the genetic correlation between fertility and milk yield from −0.30 to 0 would increase the profit gain under the scenario 'selection by milk yield'. It is important to ascertain these genetic parameters in dairy sheep.

Approach

Both methods (linear profit function and rescaling) provide similar economic answers. Using the rescaling approach, economic weights are reduced, thereby taking into account the changes in the farm produced under the constraint of fixed labour time. The exceptions are prolificacy, because we have postulated that no difference in labour time exists for single or double births, and milk yield in Manchega.

It is worth remarking that without rescaling, weights for milk and fertility are highly correlated (0.89), whereas for any other combination of traits the correlation ranges between −0.05 and 0.20. This is because of the nature of the profit function. The rescaling procedure lowers this correlation to 0.81.

The rescaling procedure is more appealing to us because it provides a tool to contrast the results for functional traits such as longevity, and can be applied to traits whose economic repercussions are unclear, such as (say) milking speed. However, it is also true that the constraint (labour time) and the appropriate functions to solve it (labour as a function of traits) have to be studied on a case-by-case basis. We believe them to be applicable in the case of Latxa, but not that much in the case of Manchega.

Breeds

Prolificacy and milk yield both show lower economic weights in Manchega, probably because of higher milk price and lower labour costs in Latxa. Longevity shows a different behaviour for each approach. Using the linear approach, longevity economic weight is higher in Manchega because of the higher replacement costs. However, using rescaling, this weight is higher in Latxa. The reason could be that because the costs of labour are higher in Manchega, under the simple linear function an increase in longevity is more profitable than in the rescaling approach, in which the change in labour costs is considered.

Type of farms

Cheese-making farmers, obtaining a better profit from the milk, have higher economic weights for milk and also for fertility, as a higher fertility implies more milk production. On the other hand, milk-selling farms have a (slightly) higher economic weight for longevity, as they need to increase efficiency; that is, they need to reduce costs and this might be achieved through an increase of longevity.

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Comparison with dairy cattle

It is difficult to compare the results of this study with those obtained for dairy cattle. The differences extend to management systems, quota (which does not exist in dairy sheep), and biology. Profit per cow is obviously not equivalent to profit per ewe. Moreover, depending on the study, units differ. One kg of dairy sheep milk is not the same as 1 kg of cow milk, and, besides, they do not show the same genetic variability. The same applies to longevity or fertility. However, it seems to us that the studies on economic weights in dairy cattle make more emphasis in functional traits (e.g. fertility, feed intake, somatic cell count, longevity), than in the present study, where economic weights for production traits are high (e.g., milk, prolificacy). For example, Pryce *et al.* (2004) stated that "expansion of £PLI [UK's national dairy selection index] to include mastitis resistance and measures of fertility could increase economic response to selection by up to 80%, compared with selection for milk production alone". Harris and Freeman (1993) showed that the economic weight of herd life "increased substantially under production quotas". However, Philipsson *et al.* (1994) stated that "failure to consider functional non production traits such as mastitis resistance and fertility in the selection index decreases efficiency 15 to 25%", which are figures similar to ours in Table 5. It is possible that the differences in emphasis are just a matter of opinion and also that they reflect the longer history of selection in dairy cattle, with increasing functional problems.

Genetic gains

All sets of economic weights (individual, medians, linear or rescaled) provided almost identical genetic and economic gains. This is in agreement with other works (e.g. Ponzoni, 1986) and simplifies the decisions to be taken by the breeding scheme, which can use any of them in practice. On the other hand, including only milk yield in the merit index leads to suboptimal gains, because of the correlated genetic loss in fertility. This is because of the negative genetic correlation between milk yield and fertility, which is well known in dairy cattle (e.g. Rauw *et al*., 1998; Andersen-Ranberg *et al*., 2005) but has not been investigated in sheep.

Implications

The study confirms the intuitive previous belief that milk yield is one of the economically most important traits. In practice (for genetic improvement purposes) fertility is the other more important trait. Although fertility is highly management dependent, it would be wise considering the set up of a systematic recording towards genetic evaluation. This might be difficult in Manchega, with parturitions all throughout the year. Including other traits as fertility in the breeding objective and in the merit index would need a cost-benefit analysis considering the cost of recordings and analysis.

In spite of its economic relevance, producers do not pay much attention to fertility, considering that an adequate management can cope with fertility problems. Rather, they are concerned about other functional traits such as udder shape. A study of type traits, as well as milk contents and somatic cell count, deserves investigation, although it needs much more economic data that possibly can not be gathered at the farm level; a farm model will be more adequate for this purpose.

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