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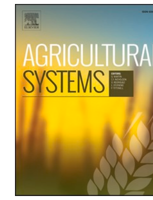


Economic risk assessment of the quality labels and productive efficiency strategies in Spanish extensive sheep farms

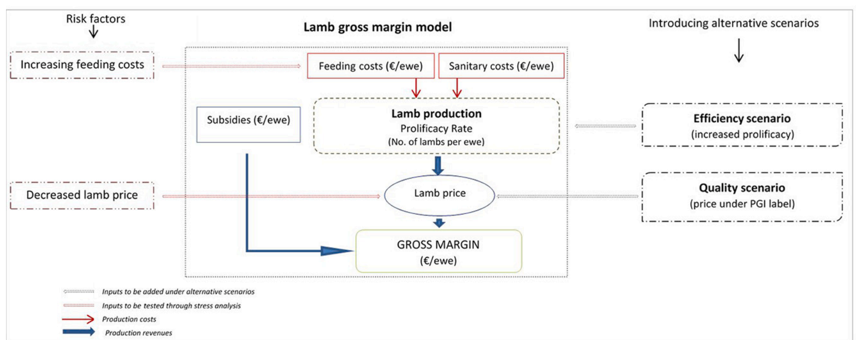
Bertolozzi-Caredio Daniele [*,1], Soriano Barbara, Bardají Isabel, Garrido Alberto

CEIGRAM Department, Universidad Politécnica de Madrid, Calle Senda del rey, 13, Madrid 28040, Spain

HIGHLIGHTS

- Due to the low profitability of extensive sheep farming in southern Europe, strategies to improve economic performance are needed.
- The paper aims to evaluate the performance of a quality label and an increased prolificacy strategy under price and cost risks.
- The increased prolificacy performs much better in terms of average gross margin, whereas the quality label appears vulnerable to price drops.
- The joint implementation of quality and productive efficiency strategies could compensate for their respective weaknesses.
- The paper brings to light weaknesses of quality labels, and quantifies their economic performance in lamb production.

GRAPHICAL ABSTRACT



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ABSTRACT

CONTEXT: The socio-economic decline of extensive sheep farming caused by its low profitability in southern European Union (EU) regions threatens marginal depopulated rural areas' survival. In the face of new future institutional and climate challenges, there appears to be an urgent need for strategies to improve economic performance.
OBJECTIVE: This paper aims to evaluate the economic performance and risk of two alternative demand-oriented and productive efficiency strategies: i) protected geographical indication certification, and ii) increased ewe reproduction prolificacy.
Method: Based on regional farm records and price data and a survey of 54 local farmers, we formulated a stochastic gross margin model to simulate and analyze four strategic scenarios (baseline, quality labelling, productive efficiency, and joint strategies) under two specific stressors, namely decreased lamb prices and increased feeding costs.
RESULTS AND CONCLUSIONS: We found that feeding costs constitute the main risk factor, whereas price instability has less influence. Our findings highlight improvements in performance under a quality scenario,

* Corresponding author.
E-mail addresses: daniele.bertolozzi@upm.es (B.-C. Daniele), barbara.soriano@upm.es (S. Barbara), isabel.bardaji@upm.es (B. Isabel), alberto.garrido@upm.es (G. Alberto).
[1] Present Address: Calle de Santovenia, 16, Madrid, 28008, Spain.

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albeit with higher vulnerability to price variability with respect to the baseline scenario. In contrast, the productive efficiency scenario performs much better in terms of average gross margin and reduced vulnerability to feeding costs, albeit with a larger variation for the expected outcomes.
SIGNIFICANCE: The paper casts light on the vulnerability of the quality label under price risk, and suggests the potential for the joint implementation of both quality production and productive efficiency strategies, which could compensate for their respective weaknesses.

1. Introduction

Over the last decades, concerns about the future of extensive livestock farming in Europe have grown, especially with respect to grazing sheep farming (Morris, 2017). The reasons for such concerns are rooted in the close relationship between extensive sheep farming and marginal, less-favoured areas where other agricultural activities would be (de Rancourt et al., 2006). In addition, extensive sheep farming plays an irreplaceable environmental role through the provision of several ecosystem services and the maintenance of the rural population, as well as acting as a barrier against the abandonment of otherwise unusable land (Rossi, 2017; Rodríguez-Ortega et al., 2018).

In spite of the potential benefits of extensive sheep farming, several social, economic, institutional, and environmental challenges are threatening the sector across the EU (Rossi, 2017) and especially in the Mediterranean regions of the southern EU where there is overall socio-economic impoverishment (Giannakis and Bruggeman, 2015). Some relevant examples are the widespread social decline due to rural depopulation (ESPON, 2018), a shortage of workers willing to enter the sector (Schuh, 2019) and weak generational renewal (Bertolozzi-Caredio et al., 2020), possibly aggravated by the prospects of oncoming climate challenges (Thomasz et al., 2020). The reasons for such trends have been ascribed mainly to the endemic low profitability of sheep farming systems, also connected to low efficiency and weak market positioning (Gursoy, 2006; Gazzarin and El Benni, 2020). Also, sheep farms are strongly dependent on subsidies (EU Farm Economics Overview, 2018), meaning that any change in the policy framework has a significant impact on the sector's survival (de Rancourt et al., 2006; Soriano et al., 2018). An example is the upcoming post-2020 CAP reform (Matthews, 2018).

A significant threat for the survival of sheep farming in the EU is the reduction in lamb meat consumption (Rossi, 2017), which is particularly evident in Spain where the per-capita lamb consumption has halved over the last two decades (MAPA, 2019). Different factors could influence this trend, such as a change from red to white meat consumption (Rabadán et al., 2020), higher lamb prices and strong-tasting (Alcalde et al., 2013), and competition with increasing lamb meat import into the EU (Rossi, 2017).

Typically, strategies to improve livestock production profitability (as in other agricultural sectors) can be grouped as demand-oriented or production efficiency approaches (e.g., Pölling and Mergenthaler, 2017; Bohan et al., 2018). Of the demand-oriented approaches, great importance has been attached to the role of protected geographical indication (PGI) labels in livestock sectors (Chamorro et al., 2012). PGIs help take advantage of product-related traditions, origin and quality (Bardaji et al., 2009) in order to meet new, growing social expectations, fetch higher prices and enter new markets (Réquillart, 2007). Previous research (Bernués et al., 2012; Bernabéu et al., 2018) underlines the potential of PGI lamb production certification based on consumer preferences in Spain. Several studies have explored the economic potential of quality labels and PGIs across EU agriculture (Santeramo and Lamonaca, 2020). Still, not much attention has been paid to the specific case of extensive sheep farming and even less to farm risk reduction effects. For example, Ferrer-Pérez et al. (2020) carried out an analysis to compare conventional and PGI lamb price trends over the last decade in Spain but did not analyze their impact on farm performance. According to Réquillart (2007), there is a need to evaluate the effect of PGI on profitability better.

On the other hand, prolificacy is a major factor in lamb production efficiency (Gazzarin and El Benni, 2020). Previous research underscores the role of increased prolificacy in reducing production costs (Bohan et al., 2018) and, generally, improving efficiency (Earle et al., 2017). As prolificacy was found to be generally low in the Mediterranean area (Gursoy, 2006), most attention focused on innovations to increase prolificacy (Viñoles et al., 2009; Gootwine, 2020). However, less research attempted to quantify the impact of prolificacy on farm profitability and risk in the Mediterranean region. Some studies investigate correlations between prolificacy, efficiency and profitability (Toro-Mujica et al., 2011; Ripoll-Bosch et al., 2014). On the other hand, Morgan-Davies et al. (2017) test a scenario of increased animal efficiency in Scotland, but overlook the linkage between efficiency and prolificacy. Related to our goal, Bohan et al. (2018) explore the potential of increased prolificacy to improve the Irish sheep farms' profitability. The impact of productive efficiency, especially sheep prolificacy, on the profitability and risk of farms in the Mediterranean area, needs to be addressed.

In this research, the case under study is the extensive sheep farming sector in Aragón, North-Eastern Spain, oriented to lamb production. Previous research in the case study area confirms that sector's stakeholders perceive that demand-oriented PGI production and higher prolificacy open up higher profitability pathways (San Martín et al., 2020). A key requirement to evaluate and compare alternative strategies is the identification and quantification of risks (Zinnanti et al., 2019). Risk, in fact, implies variability around expected profitability, with a particular focus on the unfavourable outcomes; that is, the probability that a negative event affecting profitability might occur.

In line with this outlook, this paper targets two specific objectives: 1) compare the current economic performance and vulnerability of demand-oriented and productive efficiency approaches drawing on four scenarios, namely conventional production (baseline scenario), increased prolificacy (productive efficiency scenario), PGI label (quality scenario), and integrated efficiency and quality production (joint scenario); and 2) evaluate the above scenarios under two economic risks, namely, i) decreased lamb prices, and ii) increased feeding costs.

Using regional farm accountancy data (FADN), the methodology was to define a gross margin model and evaluate the alternative scenarios' profitability density functions using Monte Carlo simulations. Stochastic simulations are commonly used to evaluate economic performance and vulnerability, as well as a variety of climate and financial risk-specific assessments (e.g., Castañeda-Vera and Garrido, 2017; Lien et al., 2007; Graveline et al., 2012; Kadigi et al., 2020). These analyses are often based on the evaluation of risk factors over a density function representing a model's outcome by means of risk indexes and sensitivity analyses (Monjardino et al., 2013; Luo et al., 2017). This was, in fact, the first step of our analysis. In addition, we evaluated performance and vulnerability subject to two pre-established price and cost risks by means of a stress analysis.

The paper is structured as follows. Section 2 describes the case study, defines the profitability model, scenarios and risk factors, and explains the analysis procedure. Section 3 reports the results of the risk analysis initially without stressors and then with price and cost stress. Sections 4 and 5 discuss the results and conclusions, respectively.

2. Materials and methods

2.1. The case study

The case under study is Aragón's extensive sheep farming system in north-eastern Spain, which is Spain's empirical context in the SURE-Farm project[2]. Like sheep farm typologies identified in different Mediterranean regions (Mena et al., 2016), the sector is characterized by small- to medium-sized family farms with a flock size ranging from 200 to 1000 heads, mostly tended by family labour and strongly dependent on leased land (Pardos et al., 2008).

The sector within our empirical context is characterized by a declining socio-economic trend, which is in line with overall tendencies documented for extensive sheep farming in marginal and less-favoured areas of the EU Mediterranean regions (de Rancourt et al., 2006; Giannakis and Bruggeman, 2015). In fact, the sector has seen over the last decades a decrease in farm numbers, land abandonment, intensification and transition to other productive systems, such as pig and calf fattening (Fau, 2016;). The reasons for such trends have been ascribed, by local stakeholders, mainly to the system's low profitability (Pardos et al., 2008; Becking et al., 2019), which is basically due to low sale prices and increasing costs (especially feeding costs). However, this low profitability has been aggravated by climate- and institutional-related issues, like increasing droughts (impacting feeding costs) and reduced subsidies, as well as by a gradual drop in lamb meat consumption (Soriano, 2020).

2.2. Definition of the farm model and scenarios

The breeding of ewes characterizes lamb production. This system's key cycle is the pregnancy and gestation of ewes, with offspring fattened and sold as lambs. Thus, the ewe represents the production unit characterized by a prolificacy rate (lambs born per ewe in a year, net of miscarriages), which can vary depending on management techniques and technologies. The lamb price determines the revenue generated by a ewe and varies depending on whether it is sold with the *Ternasco de Aragón* PGI label or as a standard product. A sheep farm economic model can be depicted as shown in Fig. 1. Based on this lamb production system's characteristics, alternative scenarios and stressors can be addressed in the analysis. On the one hand, the performance and vulnerability can be tested against the baseline scenario to represent potential improvements (see Sections 2.3.1 and 2.3.2). On the other, specific risks can be incorporated into the model to highlight different scenarios' performance under stress (see Section 2.4).

Sheep farm profitability can be defined at different levels and measured by alternative indexes. Previous research on lamb production economic performance account for flock production (Farrel et al., 2020), margin per hectare (Bohan et al., 2018), gross or net profit per ewe (Milàn et al., 2003; Krupová et al., 2014), and lamb prices (Kopke et al., 2008). In this paper, we opted for assessing the unitary gross margin per ewe (€/ewe), as this helps to assess the economic efficiency of units of production (i.e., the ewe) on which lamb production is based.

The farm model is defined as follows:

$$\widetilde{\pi}_{ntz} = \left(\widetilde{r}_{tz}\widetilde{P}_{tz}\right) - \left(\widetilde{Cf}_{ntz} + \widetilde{Cs}_{ntz}\right) + \widetilde{S}_{ntz} \tag{1}$$

Where z represents scenarios, π_{ntz} is the stochastic gross margin per ewe (€/ewe) achieved by the nth farm in the year t, r_{tz} is the prolificacy rate in the year t, P_{tz} is the price per lamb in the year t, and S_{nt} is the coupled payment (€/ewe). The index considers the specific variable costs of production: feeding costs (Cf) and sanitary costs (Cs). This model as well as the diagram in Fig. 1 are a simplified description of lamb production, as they do not consider fixed costs such as infrastructures and labour costs. Fig. 2 shows the cost decomposition per ewe (based on average values from our 230 farm sample records), where feeding costs account for 57% of the expenses.

Labour costs were not included as farms under study typically do not hire external workers, partly because there is a widespread shortage of farm workers in the region and farms are mostly unable to pay external labour (Pardos et al., 2008). Though sheep farms rely on significant extensions of non-owned land (Fau, 2016), their leasing costs are relatively small, as shown in Fig. 2. Also, the relative importance of general and labour costs can differ between farms, which make it difficult aggregating and comparing them (Zinnanti et al., 2019). As shown in Fig. 2, sanitary costs cover a limited portion of costs. However, due to the increasing risk of new diseases in the sector (San Martín et al., 2020), we opted for including these costs into the model to evaluate potential risks.

2.3. Data

2.3.1. Baseline scenario

In the baseline scenario, the model assumes conventional lamb prices, an average prolificacy rate in Aragón, and includes variable costs, and coupled subsidies per ewe. Table 1 shows the data on prices, weight of sold lambs, and prolificacy rate used in the model.

The ewe prolificacy rate measures the average number of lambs born to each lambing ewe in a specific year, net of abortions, and survived at the moment of weaning. In our case, we used the average annual ewe prolificacy rate at regional level in the period 2010–2017 (ECREA, 2020). There are other strategies such as rearing, replacement management and feeding system that in turn influence the ewe prolificacy and improve the efficiency. Prolificacy can be a proper indicator of productive efficiency, because it ultimately reflects management choices.

The conventional lamb price series (expressed in €/kg of slaughtered lamb) is provided by the Price Observatory of the Spanish Ministry of Agriculture (MAPA, 2020c), covering the period 2004–2017. These are producer prices. These prices have been deflated to the reference year (i.e., 2017) by using the yearly general index provided by the Spanish National Statistics Institute (INE, 2020). To calculate the price per lamb, we used the average weight of lambs sold and slaughtered in Aragón in the period 2004–2017 (MAPA, 2020b): the price per kg was multiplied by the average weight for each year to get an average price per lamb in each year. Although the lamb price was deflated, a trend component was still present, which was eliminated from the series (Zinnanti et al., 2019).

The feeding and sanitary costs were derived from the accountancy data of a sample of 230 extensive sheep farms provided by the Spanish National Agrarian Accounting Network (RECAN). The sample includes observations of Aragón farm financial results over four years (2014–2017). The costs are reported in €/ewe and include the expenses for the lambs born per ewe, which are added to the ewe unit. Table 2 shows the observed farms per year and cost values per year (mean and standard deviation). More detailed statistics about the dataset are reported in Section 2.4.

In our case study, sheep farms receive a coupled payment per ewe (Cimpoies, 2015). The subsidy consists of a payment per head, allocated for a minimum herd size of 30 ewes with a prolificacy rate of at least 0.6. As all the sampled farms met such requirements, they were omitted from the model. We added the coupled support assigned in the reference year (i.e., 2017) to the model, which was 12.11 €/ewe (FEGA, 2018).

[2] SURE-Farm project: toward SUstainable and REsilient FARMing systems (https://surefarmproject.eu/).

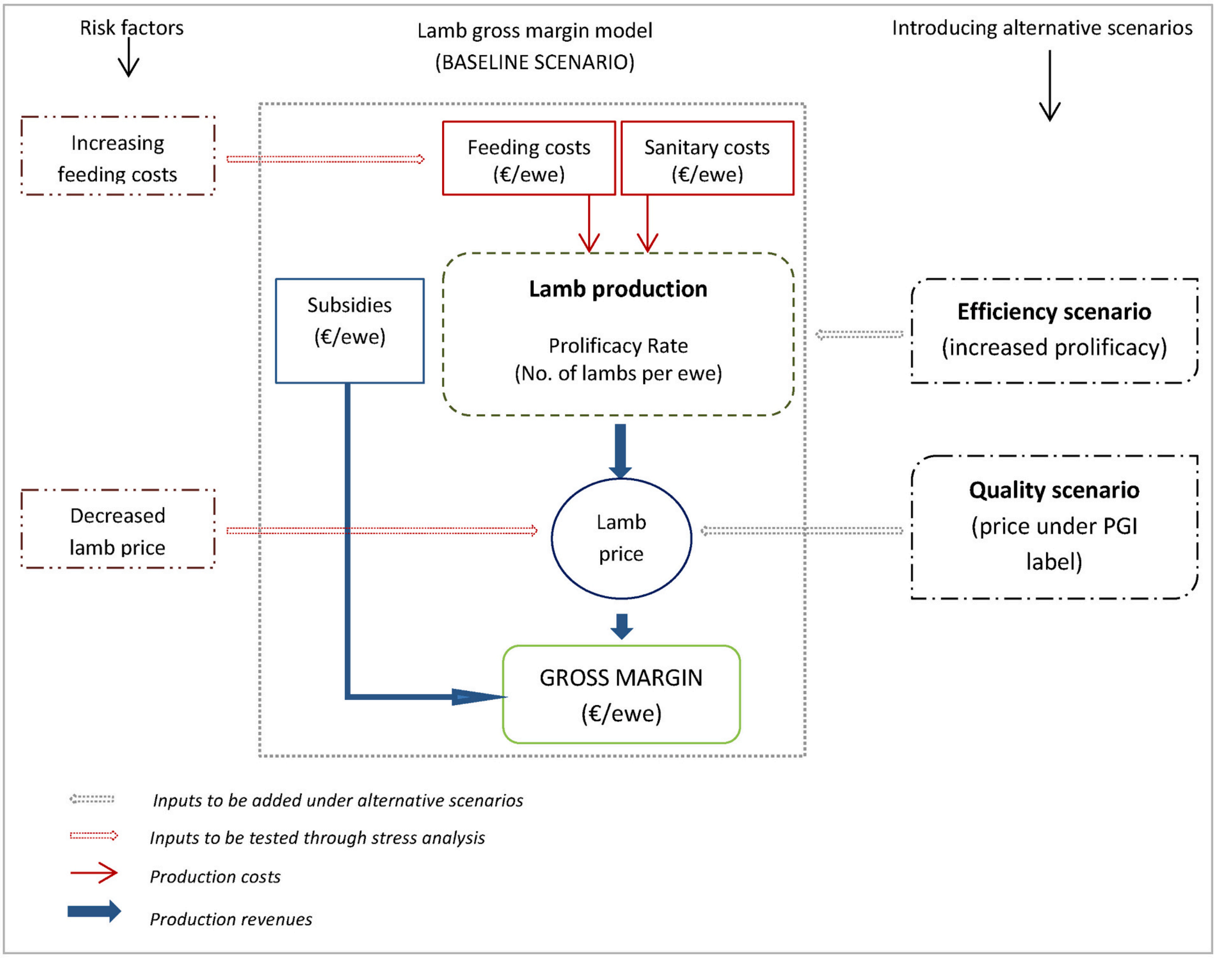

Fig. 1. The diagram of the farm gross margin model, the main risk factors affecting feeding costs and price, and two alternative strategic scenarios implying increased prolificacy and PGI prices.

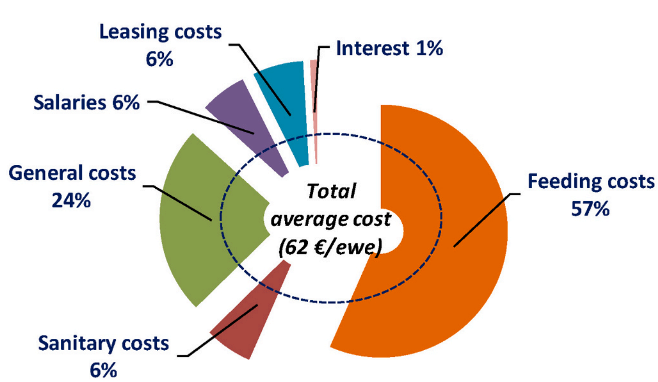

Fig. 2. Percentage decomposition of costs per ewe. Source: own elaboration based on the case study farm records.

2.3.2. *Quality scenario*

In our study area, one of the main concerns of farmers is the low lamb price (Becking et al., 2019). The strategic option farmers can pursue is to adhere to the *Ternasco de Aragón* PGI[3] (Sans et al., 1999). This PGI is a quality label set up in 1996 and awarded by the *Ternasco de Aragón* supervisory body to farms following a specified protocol to ensure traditional, quality production. This quality label fetches higher lamb prices with respect to conventional lamb. The research question that we aim to answer is to what extent can PGI prices improve the sheep farm performance. Therefore, a first alternative to the baseline scenario is a quality scenario based on *Ternasco de Aragón* prices over conventional prices. Data on PGI price in €/kg and an average weight of sold and slaughtered PGI-labelled lambs in the period 2008–2017 are provided by the Spanish Ministry of Agriculture (MAPA, 2020a). For conventional prices, the price in €/kg was multiplied by the average weight of lambs sold and slaughtered every year in the series under the PGI label in Aragón to obtain an annual price per lamb from 2008 to 2017. A further difference between conventional and PGI lamb price is the weights of sold lambs, which is slightly higher in conventional production. This difference is due to a specific restriction of the PGI production protocol under which producers are bound to sell lambs bearing the *Ternasco de Aragón* label with a maximum weight of 12.5 kg. Data are reported in Table 1. The PGI prices used to model this scenario were also detrended.

2.3.3. *Productive efficiency scenario*

In the case study area, one of the main objectives to enhance production efficiency is to increase the prolificacy rate (San Martín et al., 2020). This goal can be achieved through diverse breed selection and choice techniques (Viñoles et al., 2009; Gootwine, 2020). The prolificacy rate can vary significantly across farms (Amer et al., 1999). In our baseline scenario, we used the average rate reported at the regional level

[3] http://www.ternascodearagon.es/consejo-regulador-ternasco-de-aragon/

Table 1
Data series of conventional and PGI prices €/kg (real values deflated to 2017 and detrended), average weights of sold lambs (kg), and prolificacy (lambs/ewe) used in the analysis. Lamb price (€/lamb) was obtained by multiplying price €/kg by lamb weight for the respective year.

Year	Conventional prices (€/kg)	Average lamb weight (kg)	Conventional price (€/lamb)	PGI prices (€/kg)	Average PGI lamb weight (kg)	PGI Price (€/lamb)	Average prolificacy rate (lambs/ewe)
2004	5.6	12.0	70.8	–	–	–	–
2005	5.9	12.0	74.7	–	–	–	–
2006	5.5	12.0	69.6	–	–	–	–
2007	5.4	12.0	66.3	–	–	–	–
2008	5.6	11.9	67.7	6.1	11.1	73.0	–
2009	5.7	11.9	68.4	6.0	11.1	71.0	–
2010	5.5	12.1	67.1	6.1	10.9	70.1	1.03
2011	6.0	12.0	70.9	6.9	11.1	78.1	1.02
2012	6.0	12.0	71.0	7.2	11.1	81.1	1.12
2013	5.9	11.9	68.9	6.1	11.0	66.0	1.06
2014	6.4	11.7	72.8	7.0	11.0	75.5	1.06
2015	6.0	12.1	70.1	6.9	11.0	73.0	1.10
2016	6.1	12.1	71.0	7.4	11.0	77.2	1.13
2017	5.9	12.4	68.8	6.8	10.9	69.1	1.05
Source:	MAPA (2020c)	MAPA (2020b)	Own elaboration	MAPA (2020a)	MAPA (2020a)	Own elaboration	ECREA (2020)

Table 2
Sampled farms and deflated cost values (€/ewe) by year.

	Year	2014	2015	2016	2017	Total
	Observed farms	60	59	57	54	230
Feeding costs	mean	33.2	37.1	35.9	36.2	35.6
(€/ewe)	std.dev.	16.1	21.0	16.4	17.9	17.9
Sanitary costs	mean	3.7	4.0	4.1	3.5	3.8
(€/ewe)	std.dev.	1.8	1.9	1.8	2.0	1.9

between 2010 and 2017 (on average, 1.1). The researchers surveyed 54 farmers from Huesca (a province within the case study region of Aragón) in 2018. The survey analysis revealed significant variability of prolificacy rates between farms (from 0.9 to 2.2), with average prolificacy rates being higher than the regional average, indicating that surveyed farms relied on more efficient breeds. Although our survey was limited to one province, we devised an alternative scenario, namely the productive efficiency scenario, to observe how sheep farms' economic performance would change if all farms were as efficient as the surveyed farmers in Huesca. To run the efficiency scenario, the baseline farm model is modified by replacing the prolificacy rate at a regional level with the improved prolificacy rate of Huesca. More detailed statistics about the dataset are reported in Section 2.4.

Nevertheless, an increased prolificacy rate entails higher feeding costs as the number of lambs per ewe increases. Previous studies based on statistics from the case study area (Oliván and Pardos, 2000; Pardos et al., 2007) find that farms with a prolificacy rate higher than the cut-off value of 1.3 show a 23–26% increase in feeding costs per ewe for farms with lower prolificacy. Based on this evidence, we can assume that farms with prolificacy above the reference threshold of 1.3 need to account for a 25% increase in feeding costs per ewe on average. Therefore, we integrated the gross margin model (Alcalde et al., 2013) into the efficiency scenario utilizing a conditional function:

$$\text{if } \widetilde{r}_{tz} > 1.3; \text{ then } \widetilde{Cf}_{n,t,z} \text{ is increased by 25\%; else } \widetilde{Cf}_{n,t,z} \text{ is not increased}$$

Assuming a capped feeding cost at 25% for $\widetilde{r}_t > 1.3$ is certainly a modelling simplification. While data are derived from other studies on the same case study area, they are outdated (2007, the most recent). To the best of our knowledge, there is no available data on lamb nutrition and corresponding costs for our case study. Data from other regions are possibly not appropriate to be used because the nutritional requirements depend on genetic, environmental and managerial factors, which can differ significantly between regions (Cannas et al., 2019). Though limited, our simplified model allows for considering a feeding cost-prolificacy linkage.

Lastly, a fourth scenario was derived by integrating the quality and efficiency scenarios, which models both improved prolificacy rates and PGI prices.

2.3.4. Main risk factors

Previous investigations in the case study area identified several institutional, economic, social, and environmental challenges threatening the performance and prospects of extensive sheep farms (Becking et al., 2019; San Martín et al., 2020; Soriano, 2020). However, with regard to farm economic performance, two main risk factors can be defined: falling lamb prices and rising feeding costs. Fig. 3 plots these data series.

Falling lamb prices is an essential determinant of low sheep farm profitability (Becking et al., 2019;), most likely explained by the sharp decline in lamb consumption in Spain (Alcalde et al., 2013). The annual lamb consumption decreased from 2.1 kg/capita in 2011 to 1.33 kg/capita in 2019 (MAPA, 2019). As this consumption trend is likely to persist in the coming years, concerns about possible drops in lamb price are widespread.

Previous research in the case study area shows that feeding costs are much higher than other specific costs (Pardos et al., 2008). Accordingly,

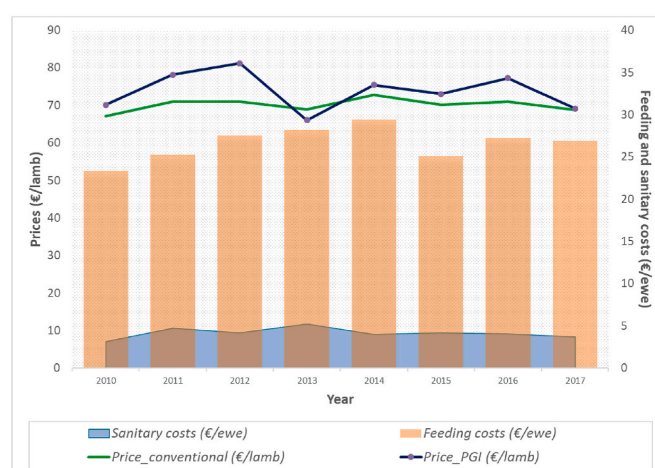

Fig. 3. The development in conventional and PGI lamb price (€/lamb), and feeding and sanitary costs (€/ewe) in Aragón – Years 2010–2017. Source: own elaboration based on data from FADN "(European Farm Accountability Data Network: https://ec.europa.eu/agriculture/rica/)" (costs) and MAPA (2020a, 2020b, 2020c) (prices).

Fig. 2 shows that feeding costs represent 57% of farm expenses. Feeding costs have been increasing for the last twenty years, leading to important farm management changes and a sizeable reduction in profitability (Olaizola et al., 2008). The feeding cost trend can also be affected by periodic droughts reducing grazing potential (Thomasz et al., 2020). The increase in feeding costs is probably the main factor affecting lamb production profitability and is, therefore, a key factor of risk.

2.4. Data analysis

All inputs in our model (Eq. 1) are stochastic variables. For all inputs, a probability density function (PDF) was either assumed or fitted. For the coupled support, we allowed a $\pm$ 10% variation range from the given value of 12.11 €/ewe (i.e., the support provided in 2017). This is explained by the fact that coupled support is determined on a year-by-year basis and depends on the estimated total number of eligible ewes at a regional level; therefore, the subsidy could vary slightly (FEGA, 2020).

Table 3 shows the other model input distributions and statistics. The fitting distributions were identified by observing the four moments (μ, σ, skewness, kurtosis) for each input variable. The best-fitting distributions were selected for feeding and sanitary costs (Triangular and Beta-General, respectively) by the BestFit @Risk function (Zinnanti et al., 2019). The Akaike information criterion (AIC) was used to rank the tested distributions, namely normal, PERT, Gamma, LogNormal, Triangular, Beta, LogLogistic, Pearson5 and uniform. In the case of prices, prolificacy rates and subsidies, however, the data series were too short to perform a best-fit distribution function. Based on the observed moments, three commonly used distributions were assumed (Triangular, PERT, uniform). Prices revealed positive skewness. Therefore, we used a PERT function to best fit the positive asymmetry of the available data. Due to the use of only three values, subsidies were modelled by a uniform distribution. The Monte Carlo simulations were based on the above PDFs, and the correlations between input variables were incorporated into the model (see the correlation matrix in Table 4).

In the first step, the four scenarios were run under no stressors. The economic performance was measured by the mean (μ), standard deviation (σ), and coefficient of variation (CV). We also computed other indicators of risk, such as the semi-standard deviation (SSD) and the semi coefficient of variation (SCV) that measure the downside risk exposure (in practice, the σ and CV of all values below the mean, the left-hand side of the distribution), to target the risk of obtaining values below the expected model's average outcome (Hardaker et al., 1997). With outcome, we refer to the set of simulated gross margin values obtained when running the model. The downside risk evaluation also helps identify the economic losses that a farm can sustain. In addition, the value at risk (VaR) index gives a measure of potential losses. The VaR is measured as the percentage share of the difference between the mean and the expected outcome value at a 95% confidence level on the average gross margin (Dowd, 2007; Zinnanti et al., 2019). We also reported the break-even probability (BEP) that indicates the probability of returning a profit and is measured as the percentage of non-negative gross margin outcomes ($\pi \geq 0$) over total outcomes. Lastly, the kurtosis statistic indicates the probability of extreme events occurring: the higher the kurtosis, the higher the probability.

Sensitivity analyses were carried out to gain insight into the main risk factors. A sensitivity analysis measures the extent to which input variables impact the profitability outcomes. Tornado charts were used to display a ranking of the input distributions that influence the output. There are different types of tornado charts. First, we decided to compare the input regression coefficients by scenario in a multiple tornado chart. By so doing, it is possible to observe the magnitude and direction of the effect of input variables on the output in each scenario. Subsequently, we opted for an analysis of the regression mapped values by input variable (Zinnanti et al., 2019; Kamali et al., 2017). This analysis measures the amount of change in the output (mapped values) due to a one standard deviation change in one input variable, while other input variables remained unchanged at their mean value. The mapped values are beta coefficients from a regression in which the mean gross margin is the dependent variable, and the independent variables are random functions of the input variables, where all variables are standardized. This approach compares variables with different units of measurement (Zinnanti et al., 2019). Results are shown by means of multiple tornado charts in which each bar represents the change in the output (gross margin) corresponding to a one standard deviation change in a specific input variable.

In the second step, the analysis simulated the four scenarios under stressors. Two stressors were selected: decreased lamb price and increased feeding costs. The stressors were introduced by running the simulations while limiting the PDFs of selected input variables to a specified percentile. We carried out the analysis at two stress levels: 10 and 50 percentile. First, we limited the lamb price to its 0–10% PDF (to simulate lowest possible prices only) for the price stressor; the feeding costs to their 90–100% PDF (to simulate highest possible costs only). Then, the analysis was repeated by limiting simulations to 0–50% and 50–100% for prices and costs, respectively. First, the stressors were introduced in the model one by one, and the impact on performance was observed separately for each stressor. Then, the stressors were introduced simultaneously to capture the whole effect on performance. To analyze the effect of stressors on scenario outcomes, we measured the percentage variation between the average gross margin outcome under stress, and the expected average under no stress, as well as the percentage BEP. Besides, scenario PDFs were compared by stress type.

In addition, a sensitivity analysis was performed to assess the impact of a reduction in subsidies on gross margin. This was carried out by running the models under different values of the coupled subsidies through the iterative reduction of the variable output value by percentage levels. In our case, the gross margin outcome was observed at five levels of the coupled subsidies output value —base outcome (0% change), −25%, −50%, 75%, and − 100% (complete removal)— across

Table 3
Input variable distribution parameters in the stochastic model.

	Prolificacy rate	Improved prolificacy rate	Price (€/lamb)	PGI price (€/lamb)	Sanitary costs (€/ewe)	Feeding costs (€/ewe)	Coupled Subsidies (€/ewe)
Minimum	1.02	0.90	66.3	66.0	0.0	4.6	10.90
Maximum	1.13	2.20	74.7	81.1	9.2	96.6	13.32
Mean	1.07	1.40	69.9	73.4	3.8	35.6	12.11
Mode	1.06	1.20	70.6	73.2	2.9	55.0	–
Median	1.06	1.40	69.8	73.0	3.5	34.4	–
Std. Deviation	0.04	0.26	2.3	4.6	1.9	17.9	–
Skewness	0.35	0.93	0.5	0.1	0.5	0.7	–
Kurtosis	1.58	4.32	3.3	2.4	2.7	3.3	–
5% (percentile)	1.0	1.0	66.3	66.0	1.1	12.8	–
95% (percentile)	1.1	2.0	74.7	81.1	7.2	71.3	–
Fitting distribution	*Triang*	*Triang*	*Pert*	*Pert*	*Triang*	*Beta General*	*Uniform*

Table 4
Input variables correlation matrix in the stochastic model.

	Price	PGI price	Prolificacy	Improved prolificacy	Feeding costs	Sanitary costs
Price	1					
PGI price	−0.285	1				
Prolificacy	−0.671	−0.036	1			
Improved prolificacy	0.217	0.343	−0.379	1		
Feeding costs	0.275	−0.539	−0.551	0.045	1	
Sanitary costs	0.112	0.030	−0.108	−0.076	0.149	1

the four strategic scenarios.

3. Results

3.1. Economic performance and vulnerability

Table 5 reports the performance and risk indexes comparing the four scenarios (baseline, quality label, productive efficiency, and joint strategies). Fig. 4 shows the fitted PDFs for each scenario.

As reported in Table 5, all scenarios show an almost full BEP (around 98 and 99%), meaning that the probability of obtaining a negative gross margin outcome is almost zero in all scenarios. There is a clear difference in economic performance, especially for the efficiency and joint scenarios, where the increase in average gross margin is much more evident (70.8 and 75.7 €/ewe, respectively, as opposed to 47.35 and 50.75 in the baseline and quality scenarios). Baseline and quality scenarios show a similar vulnerability to risk, although quality labelling yields slightly larger potential losses and greater probability of extreme events (with VaR and SCV being 2% higher than in the baseline scenario). Also, baseline and quality scenarios result in SCV being greater than the CV, indicating potentially higher overall losses with respect to the average expected gross margin. While the efficiency scenario significantly increases the average gross margin, it does not avoid a significant probability of extreme events (with VaR and CV being equal to 62% and 37%, respectively). It also shows a SSD of 16, greater than the baseline scenario (where SSD is equal to 13). Likewise, the joint scenario yields the best performance, but still shows a significant risk of potential losses. It has a 2–3% higher CV, SCV and VaR than the efficiency scenario. In fact, vulnerability indexes are similar across scenarios, with a high probability of losses in all cases. This applies especially to VaR, which ranges from 62% to 74%.

Figs. 5 and 6 show the impact analyses of input variables on gross margin outcomes, using regression coefficients and regression-mapped values, respectively. With regard to the input regression coefficients shown in Fig. 5, feeding costs represent the main influencing factor (ranging from −0.7 to −0.96). However, their influence drops within the quality, efficiency and joint scenarios. Sanitary costs behave similarly, although they have a noticeably lower impact than feeding costs (from −0.1 to −0.06). Lamb prices appear to play a major role in the quality and joint scenarios (where coefficients reach 0.15 and 0.14), but conventional lamb prices have a smaller impact in the efficiency and joint scenarios (equal to 0.09). Coupled subsidies have little (near-zero) influence in all cases, but their importance seems slightly higher in the baseline and quality scenarios, where coefficient values are 0.04 and 0.03.

Fig. 6 shows that feeding costs constitute a major factor in all cases.

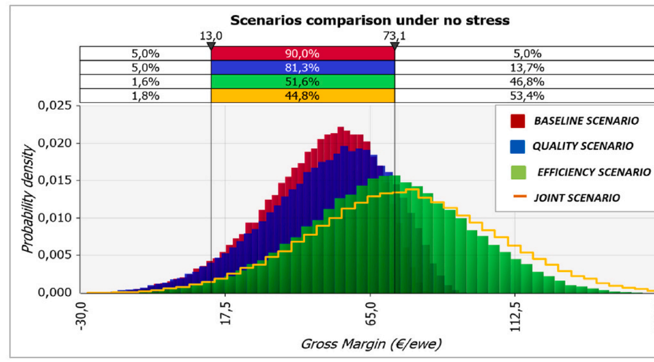

Fig. 4. Probability density functions of gross margin (€/ewe) across the strategic scenarios under no stress.

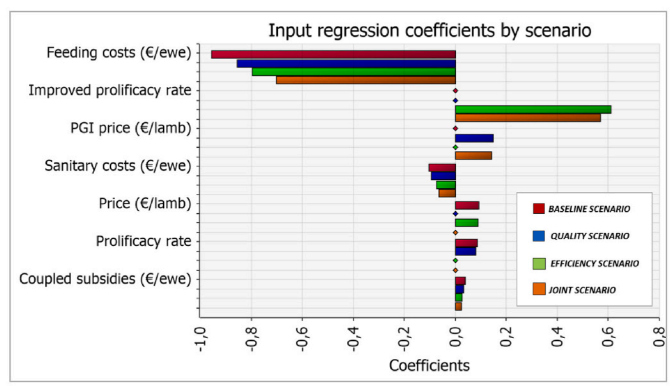

Fig. 5. Input variable regression coefficients across the strategic scenarios.

Their variation entails slightly higher decreases for gross margin in the efficiency and joint scenarios (by about 21 €/ewe), compared with the baseline and quality scenarios (17 €/ewe). Variations in sanitary costs could bring about gross margin losses of 2 €/ewe in all cases. PGI lamb prices are more important in the quality and joint scenarios (with a gross margin variation of 3–4 €/ewe). The impact of the prolificacy rate increases remarkably in the efficiency and joint scenarios, showing potential gross margin increases of up to 16–17 €/ewe. As already mentioned, the coupled subsidies do not have much influence, as they are quite stable over time.

Table 5
Descriptive statistics of gross margin (€/ewe) and vulnerability indexes across the strategic scenarios.

		Economic performance and vulnerability indexes								
		Gross Margin €/ewe (mean)	σ	SSD	Skewness	Kurtosis	CV (%)	SCV (%)	VaR (%)	BEP (%)
Scenarios	Baseline	47.35	18.4	13.0	−0.61	2.97	39	42	72	98.7
	Quality	50.75	20.5	14.3	−0.54	2.91	40	44	74	98.5
	Efficiency	70.84	26.3	16.0	−0.06	2.87	37	32	62	99.6
	Joint	75.74	29.8	17.8	−0.002	2.85	39	34	65	99.5

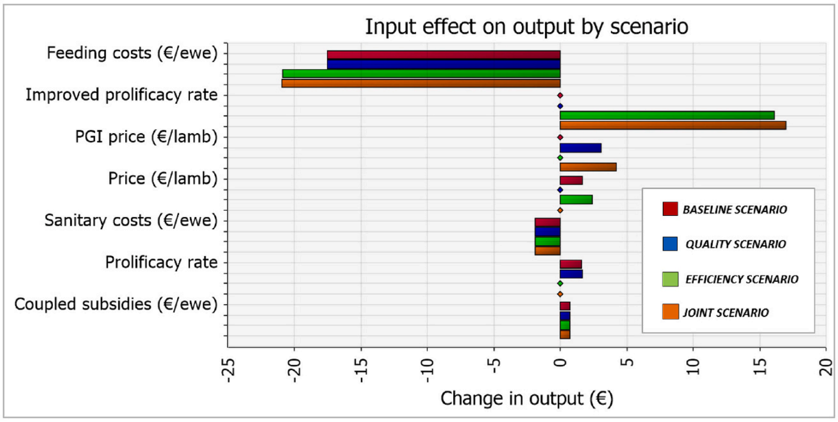

Fig. 6. Multiple tornado graph showing the regression mapped values by input variable across strategic scenarios.

3.2. Performance under stressors

Table 6 reports performance under lamb-price and feeding costs stressors, reporting losses in gross margin. In all scenarios, farms are much more vulnerable to an increase in feeding costs, irrespective of the stress intensity. All scenarios are subject to significant losses under feeding cost stress. In particular, sharp reductions of BEP are evident in the baseline and quality scenarios (88% and 89% BEP, respectively) under intense feeding cost stress. Should that level of stress be persistent, farms would not be able to cover the variable costs (incurring negative gross margin), eventually leading to bankrupt and closure.

As expected, simultaneous stresses would have the greatest impact. However, they appear to be mitigated under the efficiency and joint scenarios. Although there is a lower impact of feeding cost stress in this scenario, it yields losses similar to the baseline scenario if subjected to price stress (around 3% and 5%, in the 10% and 50% stress percentiles, respectively). This suggests that higher prolificacy provides farms with a cushion against vulnerability to feeding cost risks, although they would be equally vulnerable to price drops as farms with lower prolificacy. Interestingly, subjected to price stress, the quality scenario performs worse than the baseline and efficiency scenarios in terms of gross margin losses (percentage losses are doubled), highlighting some vulnerability to price drops.

Fig. 7 compares gross margin distributions of scenarios under different stressors. The baseline and quality scenarios reveal similar responses to price and simultaneous stressors, as also suggested by the average gross margin in Table 3 (which is similar). The efficiency scenario performs best under all stressors, but its gross margin outcome is much more variable. This is consistent with the high standard deviation reported in Table 5. This suggests that a farm relying on increased prolificacy is likely to be more profitable, but the expected outcome will be less certain.

Table 7 shows the sensitivity of the gross margin outcome to reductions in coupled subsidies by scenario. As previously described in Fig. 6, coupled support is relatively more important in the baseline and quality scenarios without stressors. Accordingly, larger gross margin drops are found in the baseline and quality scenarios when the value of the coupled subsidies is reduced in the simulation. In the case of withdrawal of all coupled subsidies (−100%), for example, support accounts for about one-quarter of the gross margin in the baseline and quality scenarios and about one-sixth in the efficiency and joint scenarios.

4. Discussion

This paper provides an assessment of economic performance and vulnerability of four alternative strategic scenarios (baseline, quality, efficiency, joint) through a stochastic gross margin model, measuring the potential impact of price and feeding cost risks.

In the baseline scenario, the most important threat to farms is feeding costs. This is consistent with previous research (Pardos et al., 2008; Morris, 2017). Lamb price variation is a minor risk component. This sheds light on the general concern about lamb price trends mentioned by the stakeholders in the region (Becking et al., 2019). Our findings suggest that the price concerns result from long-term low prices rather than price variability.

Our analysis offers contradictory evidence regarding the impact of the PGI label. Whilst the quality scenario improves gross margin under no stressors and under increasing feeding costs, the gains are minor, and vulnerability to extreme events increases slightly. Secondly, and most importantly, this strategy performs worse (in terms of percentage losses) than conventional production under the price stressor, highlighting a significant vulnerability to price drops. PGI lamb prices are on average higher than conventional prices, but more unstable. This is consistent with the study carried out by Ferrer-Pérez et al. (2020), which describes the long-term positive correlation between conventional and PGI lamb prices in Spain, and PGI price trend volatility over the last decade. Consistent with this research (which focused on Aragón's north-western neighbouring region, Navarre), PGI prices variability also appears to be higher than for conventional lamb in our case study. The paper does not investigate the reasons behind the PGI lamb price variability and further research should be pursued to explore this aspect in Spain and the EU.

A recent literature review on PGI studies by Santeramo and Lamonaca (2020) demonstrates that the relevance of PGI varies depending on product types (e.g., high-low value) and regional or country-specific factors. In our case study, the impact of the strategy of adhering to PGI is relatively low with respect to other cases (e.g., Bardaji et al., 2009). Our findings could explain why the share of sheep farms opting for the *Ternasco de Aragón* PGI is relatively low. In 2017, 668 farms were registered under the PGI (33% less than in 2008), whereas the number of lambs sold under the PGI dropped by 12% over the same period (MAPA, 2020a). However, other factors could explain farmers' decision to join PGIs, including the willingness to join cooperatives, reduced certification costs, and public support (Belletti et al., 2007; Réquillart, 2007; Bardaji et al., 2009). In addition, it is troublesome to distinguish the quality of PGI products from conventional production, which is quite often based on the same breeds, farm practices and region (Sans et al., 1999).

Despite their vulnerability to price variability, PGI labels might be a tool against the decline of lamb consumption (Chamorro et al., 2012). Spanish lamb consumers are less sensitive to price and more attracted by quality and origin certifications (Bernabéu et al., 2018). Besides, Font i Furnols et al. (2009) calculate that about 60% of Spanish consumers prefer lamb totally or partially fed on grassland, whereas Bernués et al. (2012) highlight that a growing trend in Aragón is the demand for easy

Table 6
The average gross margin (€/ewe), percentage loss and break-even probability (%) by strategic scenario under stressors.

	Scenarios															
	Baseline				Quality				Efficiency				Joint			
	Gross Margin €/ewe (mean)	σ	Gross Margin loss (% var.)	BEP (%)	Gross Margin €/ewe (mean)	σ	Gross Margin loss (% var.)	BEP (%)	Gross Margin €/ewe (mean)	σ	Gross Margin loss (% var.)	BEP (%)	Gross Margin €/ewe (mean)	σ	Gross Margin loss (% var.)	BEP (%)
Lamb price stress																
10percentile	44.6	18.7	−5.8%	98.1	45.68	19.2	−10.0%	98	66.91	26	−5.5%	99.4	68.44	26.8	−9.6%	99.4
50percentile	45.96	18.6	−2.9%	98.4	48.23	19.7	−5.0%	98.3	68.83	26.1	−2.8%	99.5	72.09	28	−4.8%	99.4
Feeding costs stress																
10percentile	12.24	9.3	−74.1%	88	15.64	11.4	−69.2%	89	29.15	17.8	−58.9%	96.2	34.05	20.9	−55.0%	96.0
50percentile	33.26	13.9	−29.8%	97.5	36.66	16	−27.8%	97.2	54.11	21.9	−23.6%	99.3	59.01	25.3	−22.1%	99.1
Simultaneous stress																
10percentile	9.05	9.62	−80.9%	82.8	10.57	10.1	−79.2%	83.8	25.21	17.1	−64.4%	94.0	26.75	17.9	−64.7%	94.2
50percentile	31.87	14.1	−32.7%	96.8	34.14	15.2	−32.7%	96.8	52.11	21.6	−26.4%	99.0	55.37	23.5	−26.9%	98.9

cooking products. These trends in consumers' habits may represent an opportunity for improving quality labelling strategies in future.

On the other hand, the margin for improvement brought about by the efficiency scenario stands out in all cases. This is consistent with previous research carried out in different EU regions (Bohan et al., 2018; Gazzarin and El Benni, 2020), revealing a positive correlation between increased prolificacy and improved economic performance. While the average expected gross margin is more likely to be higher than within other scenarios, uncertainty surrounding expected gross margin is high as well. An explanation for this result could be the high variability of within-farm (from one year to another) and between-farm prolificacy. This high variability can be explained by several factors, such as breed genetics, slaughtering methods (by age as opposed to by weight), abortions (also linked to environmental factors) (Amer et al., 1999), and feeding techniques (Viñoles et al., 2009).

Therefore, a possible interpretation is that increased prolificacy is a strategy worth pursuing, although it will not reduce profit variability. Consistent with previous research carried out in Aragón by Ripoll-Bosch et al. (2014), we also found that higher prolificacy diminishes the relative importance of coupled subsidies in farms' gross margin. In recent years more and more farmers are implementing breed selection, novel rearing and feeding systems, and introducing new breeds (Becking et al., 2019; Bertolozzi-Caredio et al., 2020). The farmers' involvement in research projects for breed selection and management systems, as well as the technical support of cooperatives, appear as a promising way to increase farms' efficiency and ewe prolificacy.

The joint scenario performs better than all scenarios in terms of average gross margin, but it is susceptible to price stress with a generally high uncertainty surrounding expected outcomes. The joint strategies could help address multiple risks and help offset their respective weaknesses: increased prolificacy and adherence to PGI help assure higher average gross margin and reduced variability. Regarding the specific case study, a recent multi-stakeholder focus group (San Martín et al., 2020) identified increased prolificacy and PGI labelling as belonging to alternative future paths (semi-intensive and hi-tech extensive, respectively). Instead, our findings suggest that productive efficiency and demand-oriented strategies could be integrated into a single strategic approach.

However, farms' adaptations to price changes have not been analyzed in this paper. We should consider that, for instance, farms' adjustments to price variability might lead to reductions in supply, production costs or investments (Assefa et al., 2017). Though relatively stable, in our case conventional prices are perceived low by farmers, whereas PGI lamb prices are more volatile. This fact might convince farmers to intervene in their production costs by, for example, increasing the ewe prolificacy. In turn, higher prices might lead to (maintain) higher productive costs.

The relative importance of coupled payments has decreased in the sector over the last twenty years (Soriano et al., 2018). Galanopoulos et al. (2011) argue that the less efficient sheep farms are more dependent on support, although evidence in the literature is contentious (Martinez-Cillero et al., 2018). Our findings show that the relative share of coupled subsidies in gross margin diminishes sharply within the efficiency scenario, suggesting that increased prolificacy has the potential to reduce the relative weight of coupled support in farm gross margin. While previous research explored the relations between support and technical efficiency (Minviel and Latruffe, 2017), none, to the best of our knowledge, focused on the interplay between increased sheep prolificacy and public support, which may be an interesting aim for future investigations.

5. Conclusion

This paper aimed to analyze the performance of two alternative demand-oriented and productive efficiency strategic scenarios (i.e., quality labelling and increased prolificacy) under different stressors

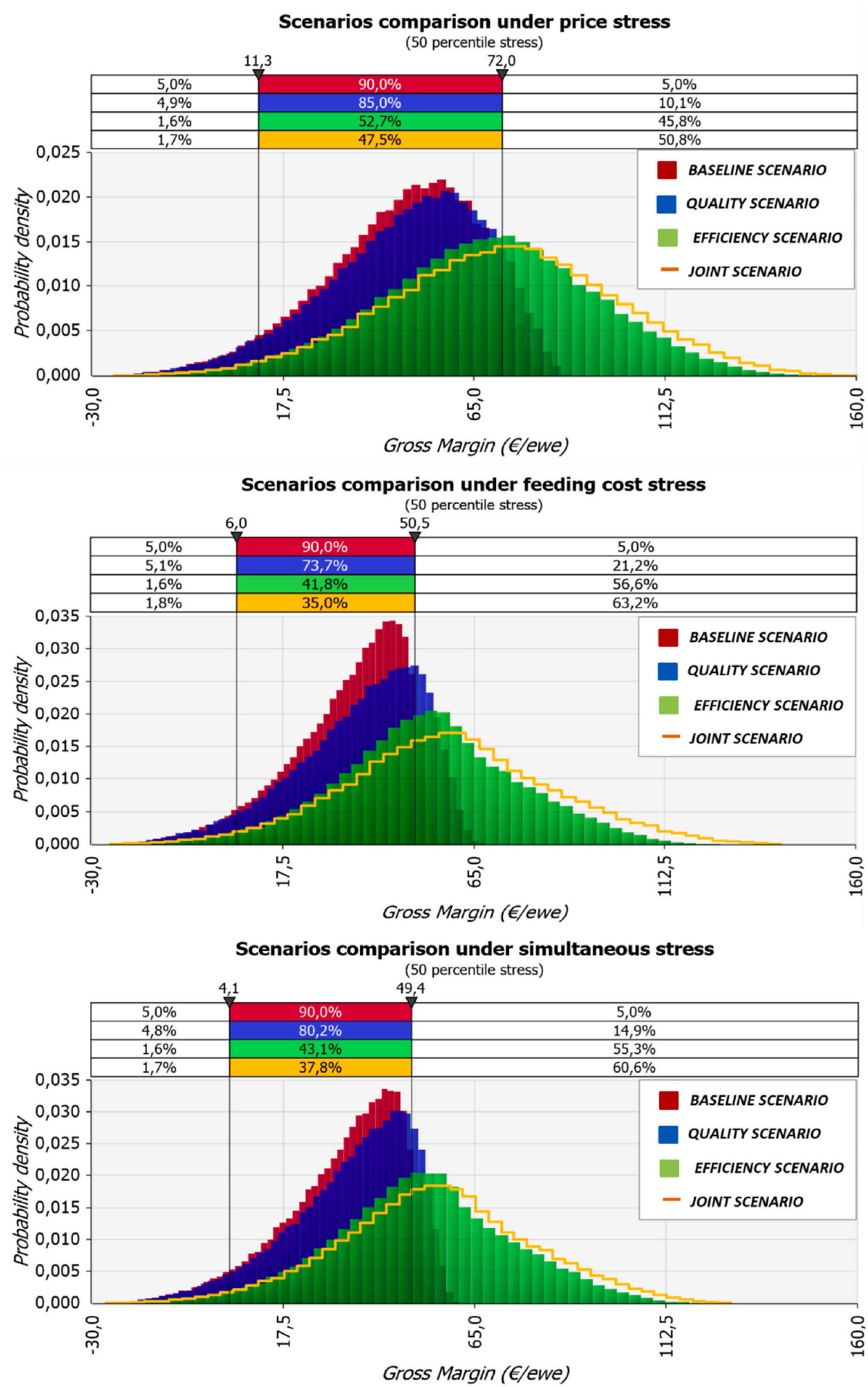

Fig. 7. Comparison of gross margin density distributions (€/ewe) under price, feeding cost and simultaneous stressors (percentile 50% stress level).

Table 7
Gross margin loss (%) under subsidy decreases.

	Base gross margin outcome (€/ewe)	Gross margin reductions in % under different % decrease in subsidies value			
		−25%	−50%	−75%	−100%
Baseline	47.3	−6.4%	−12.8%	−19.2%	−25.6%
Quality	50.7	−6.0%	−11.9%	−17.9%	−23.9%
Efficiency	70.8	−4.3%	−8.5%	−12.8%	−17.1%
Joint	75.7	−4.0%	−8.0%	−12.0%	−16.0%

(price drops and increased feeding costs) in an extensive sheep farming system. To do this, we formulated a stochastic model of gross margin jointly with vulnerability indexes and compared performance across strategic scenarios.

Our results suggest that feeding costs are the leading risk factor, whereas lamb prices have a smaller impact on vulnerability. The quality labelling strategy (i.e., protected geographical indication) could be an ineffective solution for reversing declining economic returns per raised ewe, our gross margin indicator. This strategy is more vulnerable to price drops than conventional lamb meat prices, while it yields scant improvements under feeding cost stressors. In spite of this, future research on extensive sheep farming should investigate the effects of public support on quality labels. In addition, the reasons behind the PGI price variability should be investigated.

The increased prolificacy scenario performs much better than the baseline and quality scenarios in terms of average gross margin. Also, the scenario seems a promising option, especially for mitigating increasing feeding costs, which are the main source of risk. However, there is high uncertainty surrounding increased prolificacy with regard to expected outcomes. The integration of demand-oriented and efficiency strategies may help compensate for their respective weaknesses and address multiple risks.

Lastly, the relative contribution to gross margin of coupled support is lower under the efficiency than the baseline and quality scenarios, pointing to potentially lower dependence on support for more efficient farms. However, future research should investigate the relationship between public support and increased prolificacy.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

Alcalde, M.J., Ripoll, G., Panea, B., 2013. Consumer attitudes towards meat consumption in Spain with special reference to quality marks and kid meat. In: EAAP Scientific Series (No.133) 97-107. Wageningen Academic Publisher, the Netherlands. http://www.eaap.org/publications/eaap-scientific-series/.

Amer, P.R., McEwan, J.C., Dodds, K.G., Davis, G.H., 1999. Economic values for ewe prolificacy and lamb survival in New Zealand sheep. Livest. Prod. Sci. 58 (1999), 75–90. https://doi.org/10.1016/S0301-6226(98)00192-4.

Assefa, T.T., Meuwissen, M.P.M., Oude Lansink, A.G.J.M., 2017. Price risk perceptions and management strategies in selected European food supply chains: an exploratory approach. NJAS - Wageningen J. Life Sci. 80, 15–26. https://doi.org/10.1016/j.njas.2016.11.002.

Bardaji, I., Irazoiz, B., Rapun, M., 2009. Protected geographical indications and integration into the agribusiness system. Agribusiness 25 (2), 198–214. https://doi.org/10.1002/agr.20198.

Becking, J., Bardají, I., Soriano, B., 2019. FoPIA-Surefarm Case-study Report Spain. SURE-Farm deliverable 5.2. SURE-Farm H2020 project (No. 727520).

Belletti, G., Burgassi, T., Marescotti, A., Scaramuzzi, S., 2007. The effects of certification costs on the success of a PDO/PGI. Qual. Manag. Food Chain 107–121. https://doi.org/10.3920/978-90-8686-605-2.

Bernabéu, R., Rabadàn, A., El Orche, N.E., Dìaz, M., 2018. Influence of quality labels on the formation of preferences of lamb meat consumers. A Spanish case study. Meat Sci. 135 (2018), 129–133. https://doi.org/10.1016/j.meatsci.2017.09.008.

Bernués, A., Ripoll, G., Panea, B., 2012. Consumer segmentation based on convenience orientation and attitudes towards quality attributes of lamb meat. Food Qual. Prefer. 26 (2012), 211–220. https://doi.org/10.1016/j.foodqual.2012.04.008.

Bertolozzi-Caredio, D., Bardaji, I., Coopmnas, I., Soriano, B., Garrido, A., 2020. Key steps and dynamics of family farm succession in marginal extensive livestock farming. J. Rural. Stud. 76 (2020), 131–141. https://doi.org/10.1016/j.jrurstud.2020.04.030.

Bohan, A., Shaloo, L., Creighton, O., Earle, E., Boland, T.M., McHugh, N., 2018. Investigating the role of stocking rate and prolificacy potential on profitability of grass based sheep production systems. Livest. Sci. 210 (2018), 118–124. https://doi.org/10.1016/j.livsci.2018.02.009.

Cannas, A., Tedeschi, L.O., Atzori, A.S., Lunesu, M.F., 2019. How can nutrition models increase the production efficiency of sheep and goat operations? Anim. Front. 9 (2), 33–44. https://doi.org/10.1093/af/vfz005.

Castañeda-Vera, A., Garrido, A., 2017. Evaluation of risk management tools for stabilising farm income under CAP 2014-2020. Economía Agraria y Recursos Naturales – Agricult. Resour. Econ. 17 (1), 3–23. https://doi.org/10.7201/earn.2017.01.01.

Chamorro, A., Miranda, F.J., Rubio, S., Valero, V., 2012. Innovations and trends in meat consumption: an application of the Delphi method in Spain. Meat Sci. 92 (4), 816–822. https://doi.org/10.1016/j.meatsci.2012.07.007.

Cimpoies, L., 2015. EU farm support policy: an analysis of direct payments implementation in Spain. In: Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development Vol. 15, Issue 4, 2015.

de Rancourt, M., Fois, N., Lavìn, M.P., Tchakerian, E., Vallerand, F., 2006. Mediterranean sheep and goats production: an uncertain future. Small Rumin. Res. 62 (2006), 167–179. https://doi.org/10.1016/j.smallrumres.2005.08.012.

Dowd, K., 2007. Measuring Market Risk, second ed. John Wiley and Sons, Chichester, West Sussex, United Kingdom.

Earle, E., Boland, T., McHugh, N., Creighton, P., 2017. Measures of lamb production efficiency in a temperate grass-based system differing in ewe prolificacy potential and stocking rate. J. Anim. Sci. 95 (8), 3504–3512. https://doi.org/10.2527/jas.2017.1427.

ECREA, 2020. Studies of Costs in Livestock Farms. Spanish Ministry of Agriculture. Accessed in 2020. https://www.mapa.gob.es/es/ministerio/servicios/analisis-y-prospectiva/ECREA-Informes_Ganaderia.aspx.

ESPON, 2018. Fighting Rural Depopulation in Southern Europe. ESPON EGTC, Luxembourg (May 2018). https://www.espon.eu/sites/default/files/attachments/af-espon_spain_02052018-en.pdf.

EU Farm Economics Overview, 2018. Directorate-General for Agriculture and Rural Development. European Commission. https://ec.europa.eu/info/sites/info/files/food-farming-fisheries/farming/documents/eu-farm-economics-overview-2015_en.pdf.

Farrel, L.J., Kenyon, P.R., Tozer, P.R., Ramilan, T., Cranston, L.M., 2020. Quantifying sheep enterprise profitability with varying flock replacement rates, lambing rates, and breeding strategies in New Zealand. Agric. Syst. 184 (2020), 102888. https://doi.org/10.1016/j.agsy.2020.102888.

Fau, L.R., 2016. El ovino y el caprine en Aragón, evoluciòn en los ultimos 20 años (Sheep and Goats in Aragón, Trends in the Last 20 Years). Aragón Government. http://bibliotecavirtual.aragon.es/.

FEGA, 2018. Coupled Aids for Sheep Farms, 2017 Campaign. Spanish Fund for Agricultural Guarantee. https://www.fega.es/sites/default/files/Ayuda_Asociada_Ovino_C2017_rev_septiembre_2018.pdf?token=3jdtnfOI.

FEGA, 2020. Campaign Data of Aids to Ovine Sector. Spanish Fund for Agricultural Guarantee. https://www.fega.es/es/el-fega/documentos-fega/datos-campanas-clasificadas-porsector/sector/Ovino%20y%20Caprino.

Ferrer-Pérez, H., Abdelradi, F., Gil, J.M., 2020. Geographical indications and price volatility dynamics of lamb prices in Spain. Sustainability 2020 (12), 3048. https://doi.org/10.3390/su12073048.

Font i Furnols, M., Realinia, C.E., Guerreroa, L., Olivera, M.A., Sañudob, C., Campob, M. M., Nutec, G.R., Cañequed, V., Álvarezd, I., San Juliáne, R., Luzardoe, S., Britoe, G., Montossie, F., 2009. Acceptability of lamb fed on pasture, concentrate or combinationsof both systems by European consumers. Meat Sci. 81 (2009), 196–202. https://doi.org/10.1016/j.meatsci.2008.07.019.

Galanopoulos, K., Abas, Z., Laga, V., Hatziminaoglou, I., Boyazoglu, J., 2011. The technical efficiency of transhumance sheep and goat farms and the effect of EU subsidies: do small farms benefit more than large farms? Small Rumin. Res. 100 (2011), 1–7. https://doi.org/10.1016/j.smallrumres.2011.05.008.

Gazzarin, C., El Benni, N., 2020. Economic assessment of potential efficiency gains in typical lamb production systems in the alpine region by using local resources. Small Rumin. Res. 185 (2020), 106066. https://doi.org/10.1016/j.smallrumres.2020.106066.

Giannakis, E., Bruggeman, A., 2015. The highly variable economic performance of European agriculture. Land Use Policy 45 (2015), 26–35. https://doi.org/10.1016/j.landusepol.2014.12.009.

Gootwine, E., 2020. Invited review: opportunities for genetic improvement toward higher prolificacy in sheep. Small Rumin. Res. 186 (2020), 106090. https://doi.org/10.1016/j.smallrumres.2020.106090.
Graveline, N., Loubier, S., Gleyses, G., Rinaudo, J.D., 2012. Impact of farming on water resources: assessing uncertainty with Monte Carlo simulations in a global change context. Agric. Syst. 108 (2012), 29–41. https://doi.org/10.1016/j.agsy.2012.01.002.
Gursoy, O., 2006. Economics and profitability of sheep and goat production in Turkey under new support regimes and market conditions. Small Rumin. Res. 62 (2006), 181–191. https://doi.org/10.1016/j.smallrumres.2005.08.013.
Hardaker, J.B., Huirne, R.B.M., Anderson, J.R., 1997. Coping with Risk in Agriculture. CABI Publishing.
INE, 2020. Spanish National Statistical Institute. Accessed in 2020. https://www.ine.es/dyngs/INEbase/es/operacion.htm?c=Estadistica_C&cid=1254736176802&menu=ultiDatos&idp=1254735976607.
Kadigi, I.L., Mutabazi, K.D., Philip, D., Richardson, J.W., Bizimana, J.C., Mbungu, W., Mahoo, H.F., Sieber, S., 2020. An economic comparison between alternative Rice farming Systems in Tanzania Using a Monte Carlo simulation approach. Sustainability 2020 (12), 6528. https://doi.org/10.3390/su12166528.
Kamali, F.P., Meuwissen, M.P., de Boer, I.J., van Middelaar, C.E., Moreira, A., Lansink, A. G.O., 2017. Evaluation of the environmental, economic, and social performance of soybean farming systems in southern Brazil. J. Clean. Prod. 142, 385–394. https://doi.org/10.1016/j.jclepro.2016.03.135.
Kopke, E., Young, J., Kingwell, R., 2008. The relative profitability and environmental impacts of different sheep systems in a Mediterranean environment. Agric. Syst. 96 (2008), 85–94. https://doi.org/10.1016/j.agsy.2007.06.003.
Krupová, Z., Krupa, E., Wolfová, M., Michalicková, M., 2014. Impact of variation in production traits, inputs costs and product prices on profitability in multi-purpose sheep. Span. J. Agric. Res. 12 (4), 902–912. https://doi.org/10.5424/sjar/2014124-6166.
Lien, G., Hardaker, J.B., Flaten, O., 2007. Risk and economic sustainability of crop farming systems. Agric. Syst. 94 (2007), 541–552. https://doi.org/10.1016/j.agsy.2007.01.006.
Luo, Q., Behrendt, K., Bange, M., 2017. Economics and risk of adaptation options in the Australian cotton industry. Agric. Syst. 150 (2017), 46–53. https://doi.org/10.1016/j.agsy.2016.09.014.
MAPA, 2019. Statistics on Food Consumption in Spain. Spanish Ministry of Agriculture. https://www.mapa.gob.es/es/alimentacion/temas/consumo-tendencias/panel-de-consumo-alimentario/series-anuales/default.aspx.
MAPA, 2020a. Differentiated Quality – Statistical Data on PGI Agrifood Products. Spanish Ministry of Agriculture. Accessed in 2020. https://www.mapa.gob.es/es/alimentacion/temas/calidad-diferenciada/.
MAPA, 2020b. Statistical Data on Livestock Slaughter. Spanish Ministry of Agriculture. Accessed in 2020. https://www.mapa.gob.es/es/estadistica/temas/estadisticas-agrarias/ganaderia/encuestas-sacrificio-ganado/.
MAPA, 2020c. Price Observatory. Spanish Ministry of Agriculture. Accessed in 2020. https://www.mapa.gob.es/es/alimentacion/servicios/observatorio-de-precios-de-los-alimentos/default2.aspx.
Martinez-Cillero, M., Thorne, F., Wallace, M., Breen, J., Hennessy, T., 2018. The effects of direct payments on technical efficiency of Irish beef farms: a stochastic Frontier analysis. Aust. J. Agric. Econ. 69 (3), 669–687. https://doi.org/10.1111/1477-9552.12259.
Matthews, A., 2018. The EU's Common Agricultural Policy Post 2020: Directions of Change and Potential Trade and Market Effects. International Centre for Trade and Sustainable Development (ICTSD), Geneva. http://web.uvic.ca/~kooten/Agriculture/EUPolicyMatthews(2018).pdf.
Mena, Y., Ruiz-Mirazo, J., Ruiz, F.A., Castel, J.M., 2016. Characterization and typification of small ruminant farms providing fuelbreak grazing services for wildfire prevention in Andalusia (Spain). Sci. Total Environ. 544 (2016), 211–219. https://doi.org/10.1016/j.scitotenv.2015.11.088.
Milàn, M.J., Arnalte, E., Caja, G., 2003. Economic profitability and typology of Ripollesa breed sheep farms in Spain. Small Rumin. Res. 49 (2003), 97–105. https://doi.org/10.1016/S0921-4488(03)00058-0.
Minviel, J.J., Latruffe, L., 2017. Effect of public subsidies on farm technical efficiency: a meta-analysis of empirical results. Appl. Econ. 49 (2) https://doi.org/10.1080/00036846.2016.1194963, 213:226.
Monjardino, M., McBeath, T.M., Brennan, L., Llewellyn, R.S., 2013. Are farmers in low-rainfall cropping regions under-fertilising with nitrogen? A risk analysis. Agric. Syst. 116 (2013), 37–51. https://doi.org/10.1016/j.agsy.2012.12.007.
Morgan-Davies, C., Wilson, R., Waterhouse, T., 2017. Impacts of farmers' management styles on income and labour under alternative extensive land use scenarios. Agric. Syst. 155 (2017), 168–178. https://doi.org/10.1016/j.agsy.2017.04.011.
Morris, S.T., 2017. International perspectives in sheep production: differences in systems and welfare risks. In: Advances in Sheep Welfare. Woodhead Publishing, Duxford, United Kingdom.
Olaizola, A.M., Chertouh, T., Manrique, E., 2008. Adoption of a new feeding technology in Mediterranean sheep farming systems: implications and economic evaluation. Small Rumin. Res. 79 (2008), 137–145. https://doi.org/10.1016/j.smallrumres.2008.07.022.
Oliván, A., Pardos, L., 2000. Importance of a sheep selection programme for prolificacy. In: Options Méditerranéennes, Série A(43),93:100. http://om.ciheam.org/article.php?IDPDF=600473.
Pardos, L., Maza Rubio, M.T., Fantova Puyalto, E., 2007. Influence of the prolificacy in meat sheep farms of rasa breed in Aragón. Arch. Zootec. 56 (215), 363–366. http://www.redalyc.org/articulo.oa?id=49521512.
Pardos, L., Maza, M.T., Fantova, E., Sepulveda, U., 2008. The diversity of sheep production systems in Aragón (Spain): characterisation and typification of meat sheep farms. Span. J. Agric. Res. 6 (4), 497–507. Available online at. www.inia.es/sjar.
Pölling, B., Mergenthaler, M., 2017. The location matters: determinants for "deepening" and "broadening" diversification strategies in Ruhr Metropolis' urban farming. Sustainability 2017 (9), 1168. https://doi.org/10.3390/su9071168.
Rabadán, A., Martínez-Carrasco, L., Brugarolas, M., Navarro-Rodríguez de Vera, C., Sayas-Barberá, E., Bernabéu, R., 2020. Differences in consumer preferences for lamb meat before and during the economic crisis in Spain: analysis and perspectives. Foods (9), 696. https://doi.org/10.3390/foods9060696.
Réquillart, V., 2007. On the economics of geographical indications in the EU. In: Conference Paper in "Geographical Indications, Country of Origin and Collective Brands: Firm Strategies and Public Policies" (Toulouse, June 14–15, 2007).
Ripoll-Bosch, R., Joy, M., Bernués, A., 2014. Role of self-sufficiency, productivity and diversification on the economic sustainability of farming systems with autochthonous sheep breeds in less favoured areas in Southern Europe. Animal 8 (8), 1229–1237. https://doi.org/10.1017/S1751731113000529.
Rodríguez-Ortega, T., Olaizola, A.M., Bernués, A., 2018. A novel management-based system of payments for ecosystem services for targeted agri-environmental policy. Ecosyst. Serv. 34, 74–84. https://doi.org/10.1016/j.ecoser.2018.09.007.
Rossi, R., 2017. The sheep and goat sector in the EU Main features, challenges and prospects. In: European Parliamentary Research Service (EPRS) Briefing PE 608, p. 663.
San Martín, C., Bardají, I., Garrido, A., Soriano, B., 2020. FoPIA-SURE-Farm 2 Case Study Report Spain. SURE-Farm Deliverable 5.3, (H2020, No.727520). https://www.surefarmproject.eu/deliverables/publications/.
Sans, P., De Fontguyon, G., Wilson, N., 1999. Protected product specificity and supply chain performance: The case of three PGI lambs. In: Conference Paper, 67th EAAE Seminar, pp. 417–421. https://econpapers.repec.org/paper/agseaae67/241751.htm.
Santeramo, F.G., Lamonaca, E., 2020. Evaluation of geographical label in consumers' decision-making process: a systematic review and meta-analysis. Food Res. Int. 131 (2020), 108995 https://doi.org/10.1016/j.foodres.2020.108995.
Schuh, B., 2019. Research for AGRI committee – The EU farming employment: Current challenges and future prospects. In: European Parliament, Policy Department for Structural and Cohesion Policies, Brussels. https://www.europarl.europa.eu/RegData/etudes/STUD/2019/629209/IPOL_STU(2019)629209_EN.pdf.
Soriano, B., 2020. Report on State and Outlook for Risk Management in EU Agriculture. SURE-Farm Deliverable 2.6, (H2020, No.727520). https://www.surefarmproject.eu/deliverables/publications/.
Soriano, B., Bertolozzi-Caredio, D., Bardaji, I., 2018. Assessing how policies enable or constrain the resilience of the extensive sheep grazing system in Northeast Spain (Spain): An application of the Resilience Assessment Tool (ResAT). In: SURE-Farm Deliverable 4.2, (H2020, No.727520).. https://www.surefarmproject.eu/deliverables/publications/.
Thomasz, E., Pérez-Franco, I., García-García, A., 2020. The economic impact of climate risk on extensive livestock: the case of lamb production in Extremadura, Spain. Sustainability 2020 (12), 7254. https://doi.org/10.3390/su12187254.
Toro-Mujica, P., Garcìa, A., Gòmez-Castro, A.G., Acero, R., Perea, J., Rodríguez-Estévez, V., Aguilar, C., Vera, R., 2011. Technical efficiency and viability of organic dairy sheep farming systems in a traditional area for sheep production in Spain. Small Rumin. Res. 100 (2011), 89–95. https://doi.org/10.1016/j.smallrumres.2011.06.008.
Viñoles, C., Meikle, A., Martin, G.B., 2009. Short-term nutritional treatments grazing legumes or feeding concentrates increase prolificacy in Corriedale ewes. Anim. Reprod. Sci. 113 (2009), 82–92. https://doi.org/10.1016/j.anireprosci.2008.05.079.
Zinnanti, C., Schimmenti, E., Borsellino, V., Paolini, G., Severini, S., 2019. Economic performance and risk of farming systems specialized in perennial crops: an analysis of Italian hazelnut production. Agric. Syst. 176 (2019), 102645. https://doi.org/10.1016/j.agsy.2019.102645.