

<https://doi.org/10.61308/TMEZ3552>

Technical efficiency analysis in Italian sheep and goat farms using FADN dataset

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Citation: Galluzzo, N. (2024). Technical efficiency analysis in Italian sheep and goat farms using FADN dataset. *Bulgarian Journal of Agricultural Economics and Management*, 69(3) 15-26.

Abstract: The sheep and goat farms are one of the main breeding in many Italian regions located in mountainous and disadvantaged rural areas. One of the main Italian Protected Designation Origin cheese as Pecorino Romano is made by sheep milk from many regions. The main purpose of this research was to assess by a quantitative approach the technical efficiency in sheep and goat farms part of the Farm Accountancy Data Network (FADN) in all Italian regions since 2008 to 2020. By the Multi-direction Efficiency Analysis (MEA) it has been possible to overcome one of the main bottlenecks of the technical efficiency estimation analysing which is the excess in each input able to impact to the technical efficiency. Main results have pointed out that the Italian sheep and goat farms have a higher technical efficiency compared to other studies carried out in other European countries. Land capital, labour and assets have been the main inputs able to impact to the technical efficiency. Furthermore, an important role of subsidies to the sheep and goat Italian farms exists.

Keywords: DEA; MEA; Common Agricultural Policy; semi-intensive; semi-extensive

INTRODUCTION

In Italy, sheep and goat rearing is typical of some regions located in the center of the peninsula used to produce milk and meat, while very uncommon breeds are used for the production of wool, which is the main by-product of sheep farming.

In Italy there are two main certificated and protected products as *Pecorino Romano* cheese and *Abbacchio* which are protected by the European Union through the Protected Designation Origin (PDO) and Protected Geographical Indication (PGI) marks of certified production. Recent studies have assessed as the vast majority of the sheep milk is used to produce certified cheese in many European countries where there are several farms specialised in sheep farming (Pulina et al., 2018; Arsenos et al., 2021; Theodoridis et al., 2014).

Over the time the sheep and goat farmings are decreased in Italy; sheep breeding is typically centred in mountain and hill areas characterizing the Italian landscape in several regions such as Apulia, Tuscany, Latium, Abruzzi, Molise and Sardinia. Although there are many studies on sheep and goat breeding in Italy, a literature review has pointed out that there is a shortage of researches on the analysis of technical efficiency in Italian sheep and goat farmings (Siasiou et al., 2020; Cecchini et al., 2021; Galluzzo, 2019; Batzios et al., 2023; Theodoridis et al., 2022; Kovács et al., 2022).

The recent statistical data published by Eurostat (2022) have assessed in 2021 71 million sheep and goats raised in all European Union countries whose 25.1 million in Spain, 16.8 million in Romania and 11.2 million in Italy (Eurostat, 2021). Comparing these values to other data published in 2018 by Eurostat no significant changes emerge

(Cecchini et al., 2021). These authors have found a stability in sheep and goat livestock stock since 2015 and more than 90% of the animals are concentrated in the central and southern Italian regions. According to Eurostat, in 2021 the development of output price indices from 2015 to 2021 for sheep, using as base year 2015 equal to 100, has pointed out an increase in 2020 and in 2021 moving from 100 to 105 in 2020 and from 100 to 120 in 2021 instead for the goats the development of output price indices did not change over the time has been to 120 in 2021 for the goats did not change.

Cecchini et al. (2021) have argued as 12% of the agricultural areas has been covered by farms specialised in sheep and goats located in disadvantaged rural areas able in the same time to protect the environment in the framework of multifunctionality. In the central Italian regions, the sheep farming systems can be semi-intensive or semi-extensive able to protect the environment due to a low use in chemical inputs and in energy able to use pastures during the day (Cecchini et al., 2021; Budimir et al., 2016). One of the main bottlenecks of the sheep and goat farming is a low level of income (Rossi, 2017) partially compensated by the subsidies allocated both by the first pillar of the Common Agricultural Policy (CAP) and by the payments to farms located in less favored areas by the second pillar of the CAP. In Italy sheep and goat farmings are a crucial tool for the socio-economic growth of rural areas by creation of direct and indirect employment opportunities and for the environmental protection and biodiversity in line with the guidelines proposed by the European Union in the Green Deal strategy (Theodoridis et al., 2014; 2022; Pulina et al., 2018; Arsenos et al., 2021).

Focusing the attention to other European countries it emerges as the dairy sheep sector has moved to an intensive production pattern which has implied radical and structural changes in extensive and semi-extensive farms in order to improve their efficiency and competitiveness (Theodoridis et al., 2022; Arsenos et al., 2021).

A LITERATURE REVIEW

A recent literature review about the studies carried out in some European countries about different type of livestock farmings has pointed out that there are significant unbalances among countries due to an increasing demand for some animals' products able to impact to the livestock industry as well (Kovács et al., 2022). These authors have investigated in two new member states of the European Union such as Hungary and Croatia the efficiency of the livestock sectors by a non-parametric approach as the Data Envelopment Analysis that has underlined that in five investigated livestock sectors such as dairy, beef, broiler, sheep and goat (the farm technical efficiency has been different. In particular Croatian farms part of the Farm Accountancy Data Network (FADN) have in the sheep sector the higher values of technical efficiency than Hungarian ones due to a different dimension of farms that has been able to impact to the technical efficiency in small farms more than in medium-size farms (Kovács et al., 2022). These results have partially corroborated other results proposed in literature about the nexus between dimension of farms and technical efficiency argued by other studies carried out in many European countries (Galluzzo, 2013; 2020; Kovács and Emvalomatis, 2011, Alvarez and Arias, 2004; Bojnec and Fertő, 2013; Bojnec and Latruffe, 2013; Minviel and Latruffe, 2017; Garrone et al., 2019).

In the light of a growing demands from civil society to an agriculture able to reduce its impact on the environment producing also positive externalities by increasing the social, economic and environmental sustainability of the primary sector, the sheep farming has to make lots of actions able to increase animal health and welfare (Cecchini et al., 2021). These authors have argued that farmers have to implement a new strategy to improve the efficiency and sustainability of sheep and goat farming with some effects to the technical efficient as investigated in other meat-producing sheep farms situated in marginal lands in central Italy where the adoption of a more extensive farming system and other strategies have af-

affected negatively the technical efficiency in farms (Cecchini et al., 2021).

In France some studies on dairy sheep farms in extensive and/or semi-extensive systems have pointed out as the adoption of best practices was fundamental because these actions impacted on the technical efficiency (Theodorotis et al., 2022). In general, assets, labour and specific costs such as costs correlated to the feeding are the main driver variables able to impact to the technical efficiency in a framework of economies of scale (Theodorotis et al., 2022). Furthermore, the type of farming practised such as grazing, loose housing or transhumance is able to influence the technical efficiency of the farm.

In fact, a recent study carried out in a European country has underlined that the Data Envelopment Analysis method used for the assessment of the technical efficiency of the transhumant farms was not efficient due to an inefficient allocation and use of inputs, even if other managerial characteristics and the educational level of farmers have had a significant effect on the technical efficiency (Siasiou et al., 2020).

In Greece the transhumance sheep and goats is a traditional practice in less-favoured and mountainous areas even if there has been a declining number of transhumance farms (Galanopoulos et al., 2011). These authors have estimated in transhumance farms the technical efficiency assessed using a non-parametric method like the Data Envelopment Analysis for the estimation of technical efficiency, which has been quite lowly affected by herd size. As proposed by a recent literature review (Minviel and Latruffe, 2017; Garrone et al., 2019) in sheep and goat transhumance farms the subsidies allocated by the Common Agricultural Policy (CAP) have had a significant impact on the technical efficiency for the low-efficiency, small-sized farms only (Galanopoulos et al., 2011) corroborating as there is an effect of EU subsidies on the technical efficiency of transhumance farms due to dimensions of farms and to other managerial variables (Siasiou et al. 2020; Galluzzo, 2013; 2020; Kovács and Emvalomatis, 2011, Alvarez and Arias, 2004; Bojnec and Fertő, 2013; Bojnec and Latruffe, 2013).

Other studies carried out in Greece have also pointed out that the mean technical efficiency score was also low close to 0.79 (Batzios et al., 2023). These authors have also argued that there were significant differences in the utilization of inputs among low and high milk yield sheep farms correlated to the farm size in terms of animals, labour and land capital use hence, significant managerial improvements are crucial factors in the low milk yield farms in order to implement the technical efficiency (Batzios et al., 2023). (Other studies in goat rearing in Turkey using the Data Envelopment Analysis method in the estimation of technical efficiency have varied widely due to feedstuff concentrate use and labor inputs, even if other exogenous variables such as farmer experience and skills, cooperative membership, milk yield per goat, and family and hired labor have had a direct effect on the technical efficiency (Gül et al., 2016).)

Other researches using a parametric approach in the estimation of the technical efficiency in Turkish sheep farms such as the Stochastic Frontier Analysis, which is a parametric approach in the estimation of the efficiency, has assessed a value of technical efficiency under the optimal threshold close to 1 due to an inefficient use of the existing resources in farms (Yilmaz and Gül, 2020). In Iceland the technical efficiency in sheep farms using annual census data for the years 2008 and 2017 instead of a sample of farms by the DEA has highlighted the need for farmers to reduce certain inputs such as labour costs and general productive overheads costs (Galluzzo, 2019). Comparing in this country two typologies of farming as dairy cows farms versus sheep farms, research's findings have pointed out that sheep farms have been technically more efficient than dairy cows (Galluzzo, 2019).

AIM OF THE RESEARCH

The main purpose of this research was to fill the gap that exists in the literature about the technical efficiency studies in Italian sheep and goat farms using a non-parametric estimation of the

technical efficiency. In fact, a literature review has pointed out that the assessment of technical efficiency in Italian sheep farms by the non-parametric approach does not exist (Galluzzo, 2019; Minviel and Latruffe, 2017; Garrone et al., 2019). Furthermore, the second stage of this research has been addressed in evaluating the impact of the financial subsidies allocated by the CAP to the technical efficiency of farms clarifying this aspect (Minviel and Latruffe, 2017; Garrone et al., 2019). In fact, in literature as argued by Minviel and Latruffe (2017) the relationships between CAP subsidies and technical efficiency is mixed.

The novelty of this research was to detect in the third stage of the study the inefficiency patterns in a sample of specialised Italian sheep and goat farms using the Multi-directional Efficiency Analysis (MEA) comparing also different Italian regions. By the MEA approach it is possible to define which input is in excess compared to the optimal value. Hence, the evaluation of input excess is fundamental in calibrating specific policies for farms through a different allocation of CAP funds and other financial measures.

For the assessment of the technical efficiency has been used an Italian sample part of the Farm Accountancy Data Accountancy (FADN) specialized in sheep and goat farming since 2008 to 2020.

METHODOLOGY

In literature, the estimation of the technical efficiency in farms or other enterprises can use two different methodologies: a parametric and a non-parametric method. Through non-parametric modelling or Data Envelopment Analysis (DEA), as used in this study, it is possible to estimate technical efficiency in Italian sheep and goat farms through a linear programming methodology over the time of investigation 2008 – 2020 (Coelli et al., 2005; Kumbhakar et al., 2015; Galluzzo, 2021). The DEA approach has two major advantages compared to the parametric approach: firstly, the possibility to assess multiple inputs and multiple outputs in the same time in the as-

essment of the technical efficiency, and secondly the ability to estimate a frontier of technical efficiency without an *a priori* defined function of production and other specifications in the model (Coelli et al., 2005; Galluzzo, 2021). According to Coelli et al. (2005), the DEA does not need to define preliminarily the relationship between input and output in order to estimate a frontier of production.

Data Envelopment Analysis (DEA) is a not so common and well-known non-parametric method measuring the overall technical efficiency in agricultural economic literature in a group of decision-making units (DMU_s , farms in this case) with multiple inputs and multiple outputs. The optimal level of efficiency is represented by all the DMU placed on the frontier of technical efficiency, that is the optimal combination of inputs and output due to a technology set, while the DMU_i placed under this frontier can be considered as inefficient, having a value lower than the optimal threshold that is equal to 1 (Coelli et al., 2005).

In this research has been used for the estimation of technical efficiency by the DEA the input oriented approach aimed at minimizing inputs in the productive process written as (Cooper et al., 2007; Bravo-Ureta et al., 2007; Coelli et al., 2005; Battese and Coelli, 1995):

$$\min_{\theta_B, \lambda} \theta_B$$

Subject to:

$$\theta_B x_o - X\lambda \geq 0$$

$$Y\lambda \geq y_o$$

$$e\lambda = 1$$

$$\lambda \geq 0$$

θ_B is the scalar value of the technical efficiency; X are the total input used in the productive process; $e\lambda$ is a vector of rows equal to 1; λ is a column vector with non-negative value; Y is the total produced output.

In particular, this research has used the input-oriented DEA whose aim is minimizing the input used keeping the output at the same level (Banker et al., 1984). For the use of DEA, it was verified the general rule, according to which, the number

of DMU_s to be estimated must be greater than the combination of inputs and outputs (Cooper et al., 2007), was respected. According to these authors, the number of DMU_s to be used for estimating technical efficiency has to be within a range obtained by multiplying inputs by number of outputs and three times the sum made by input plus output.

The sheep and goat farms investigated in this research were part of the FADN dataset and the input variables were: total labour in hours, land capital in terms of usable agricultural area in hectares, specific cost linked to the productive process and other costs in euro, total assets in euro and total output made by produced output plus total financial subsidies allocated by the Common Agricultural Policy in euro.

Despite its advantages mentioned above, however, one of the main points of weakness of the DEA is its impossibility to identify inefficiency or efficiency patterns in each of the input used and output variables. This bottleneck of the DEA can be overcome in the follow-on stage of the study by using a new approach called Multi-directional Efficiency Analysis, or MEA (Bogetoft and Hougaard; 2003; Asmild et al., 2003; Hansson et al., 2020). According to these authors, MEA has the advantage of simultaneously estimating efficiency in multi-input and multi-output models and also assessing inefficiency in each of the inputs used and outputs produced in the production process (Manevska-Tasevska et al., 2021). Using Multi-directional Efficiency Analysis, it is possible to estimate the patterns of inefficiency in inputs and outputs in terms of an excess of input used to achieve a given output.

The most positive aspect of the MEA is its ability to identify deviations from the production frontier, expressed in terms of productivity change, resulting from variables not incorporated in the analysis of technical efficiency (Bogetoft and Hougaard; 2003, Hansson et al., 2020). Consequently, the MEA scores are in a range between zero, in the case of totally inefficient farms, and 1, in the case of totally efficient farms where there is no excess in inputs or outputs. A score of 1 for an

investigated farm would indicate that there was no potential for improvement in the input and/or output variables, while an input efficiency score of less than one would indicate that the DMU_s should reduce the given input to be efficient.

The estimation of technical efficiency using both the DEA and the MEA approaches has been made using the RStudio software packages *dear*, *rDEA*, and *Benchmarking* (Bogetoft and Otto, 2011; 2024).

RESULTS AND DISCUSSIONS

The main descriptive statistics in the Italian FADN sample of specialized sheep and goat farms have pointed out an average value of labour input equal to 3348 hours per year that has implied as the sheep and goats' farms need of a significant use of labour in order to manage flocks of sheep due to two main breeding systems made by a semi-intensive or semi-extensive one (Tab. 1). This result is in line with other studies carried out in other EU countries (Cecchini et al., 2021; Budimir et al., 2016). In fact, the extensive farming system is based on large pasture areas that are replaced at well-defined intervals of time and it requires the supervision of animals with a significant use of labour. In the central Italian regions investigated in this study (Latium, Abruzzo, Molise, and Apulia) semi-intensive and semi-extensive sheep farming systems are largely spread. Semi-intensive and semi-extensive sheep farming systems are able to protect the environment thanks to a low use of chemical inputs, such as fertilisers and other synthetic products, and energy but, in any case, these two systems are able to efficiently utilise pasture during the day (Cecchini et al., 2021; Budimir et al., 2016). One of the main bottlenecks of these farming systems is the need of employing a significant quantity of labour affecting the technical efficiency and productivity of farms.

The land capital in terms of usable agricultural area has been very wide close to 42 hectares per farm made by pastures and other forage crops even if the maximum value has been close to 92

Table 1. Main descriptive statistics of the sample of Italian sheep and goat farming

Variable	Mean Std. Dev.	Min.	Max.
Labour	3348.955 853.5256	2090.17	8205.2
Land Capital	42.15654 16.53097	13.04	96.29
Specific costs	16735 8585.13	4956	49286
Other costs	6649.58 2741.371	2360	15309
Assets	312288.1 141541.7	103583	940716
Total output	59523.65 20938.22	27914	149462
CAP subsidies	10941.8 4866.59	2960	33241
LFA payments	1453.132 1667.339	0	16042
Second pillar payments	3184.18 2651.09	0	17932

Source: Author's elaboration on data <https://agridata.ec.europa.eu/extensions/FADNPublicDatabase/FADNPublicDatabase.html>.

hectares per farm and per year. Research's findings in this case have pointed out as these farms are characterized by a land capital endowment that is above the Italian average value assessed by the Italian National Institute of Statistics (Istat) which is under 20 hectares per farm. The input specific cost is two times the other cost input or rather total overhead cost and respectively equal to an average value of 16735 euro and 6649 euro.

The total assets in farms have been very significant and above the average value of 312.288 euro. Italian sheep and goats' farms have had predominately fixed assets and other investments that are not labour savings (Galluzzo, 2013). The total output produced plus CAP subsidies in Italian sheep and goat farms has been above 60.000 euro per farm over the time of investigation with a range of fluctuation very significant over the time of investigation.

The total subsidies and payments allocated by the Common Agricultural Policy have been in

average value close to 11.000 euro and the second pillar subsidies have represented one third of the total CAP disbursed subsidies by the European Union in the Rural Development Programme. Drawing some conclusions, the descriptive statistics have pointed out that almost half of the subsidies provided in the second pillar of the CAP consisted of payments for farms located in disadvantaged areas.

Table 2 shows that on 250 sheep and goat Italian farms part of FADN dataset the technical efficiency estimated by the DEA equal to 0.89 has been under the optimal threshold close to 1 and this has implied that many farms are not technical efficient without explaining which input have been the reason of the inefficiency. Comparing these results with a previous study carried out in all EU member states, it emerges as the average value of technical efficiency in Italian sheep and goat farms has been above to the average EU-27 equal to 0.84 (Nowak et al., 2015). However, fo-

Table 2. Main results of the technical efficiency estimated by the DEA and inefficiency assessed by the MEA in the FADN sample of Italian sheep and goat farmings

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
DEA					
Technical efficiency	205	0.8862793	0.0993267	0.6183006	1
MEA					
Labour	205	0.9267719	0.0613453	0.7551094	1
Land capital	205	0.8723834	0.0991355	0.6845534	1
Specific costs	205	0.9138651	0.0682767	0.7474927	1
Other costs	205	0.8869586	0.0926465	0.6177121	1
Assets	205	0.867761	0.1076723	0.6154536	1
Total output	205	0.9440742	0.0540803	0.7616583	1

Source: Author's elaboration on data <https://agridata.ec.europa.eu/extensions/FADNPublicDatabase/FADNPublicDatabase.html>.

ocusing the attention to Italian farms, the technical efficiency result was unsatisfactory and lower than the average value previously assessed by the study proposed in 2015 by Nowak et al. Comparing the finding's results of the technical efficiency estimated by the DEA in this study carried out in Italian sheep and goat specialized farms it emerges as the technical efficiency of Italian farms has been in average value higher than other studies carried out in European Union countries such as Greece (Batzios et al., 2023). These latter authors have estimated a technical efficiency in sheep farms equal to 0.79 while in this study the technical efficiency has been equal to 0.88.

By the MEA it has been possible to assess the excess of input able to impact to the technical efficiency previously estimated by the non-parametric approach DEA. Results have underlined as the input total assets, other costs and land capital have been characterised by an excess of 13-14% compared to the optimal value of input causing the inefficiency of farms. In fact, Italian farms specialised in sheep and goats have had an excess in land capital and in total assets, due to the typical breeding system as semi-extensive that is able to make inefficient these farms. One of the explanations of this excess in land capital

and total assets input is because Italian sheep and goats' farms are characterised by less capital-intensive types of farming with several hectares of usable agricultural areas cultivated with pasture and forage crops.

Both the analysis of technical efficiency and also the technical inefficiency analysis have underlined as the land capital endowment is a critical input able to impact to the efficiency corroborating the nexus between land capital and technical efficiency and also as fundamental has been the role of financial subsidies allocated by the CAP (Galluzzo, 2013; 2020; Kovács and Emvalomatis, 2011, Alvarez and Arias, 2004; Bojnec and Fertő, 2013; Bojnec and Latruffe, 2013; Minviel and Latruffe, 2017; Garrone et al., 2019). The results have pointed out a significant impact on the technical efficiency of land capital endowment and assets as argued by other studies (Minviel and Latruffe, 2017; Garrone et al., 2019; Galluzzo, 2020) even if the dimension of farms and type of subsidies can impact in a different way the technical efficiency (Galanopoulos et al., 2011; Siasiou et al. 2020; Galluzzo, 2013; 2020; Kovács and Emvalomatis, 2011; Alvarez and Arias, 2004; Bojnec and Fertő, 2013; Bojnec and Latruffe, 2013).

Focusing the attention to the financial subsidies allocated by the Common Agricultural Policy and their effects on the technical efficiency, research findings have clarified this kind of relationship. In fact, results in Italian sheep and goats' farms have been in line with other studies according to which subsidies reduce the technical efficiency (Minviel and Latruffe, 2017; Garone et al., 2019). However, this effect is attributed mainly to the subsidies provided under the first pillar of the CAP and not to by the payments provided by the second pillar and for disadvantaged rural areas, where are located most Italian sheep and goats' farms, and other aids paid by the

second pillar of the Common Agricultural Policy for the rural development.

Figure 1 shows the different rate of technical efficiency in all Italian regions over the time of investigation. In four regions out of 20 the sheep and goat farm part of the FADN have not been in a significant amount and have been erased by the analysis. Three north-western regions have had the highest value of technical efficiency and consequently no excess in each input used in the productive process have been detected. One of the explanations for the unbalances in technical efficiency in all Italian regions has a nexus to the dimension of farms and to the land capital en-

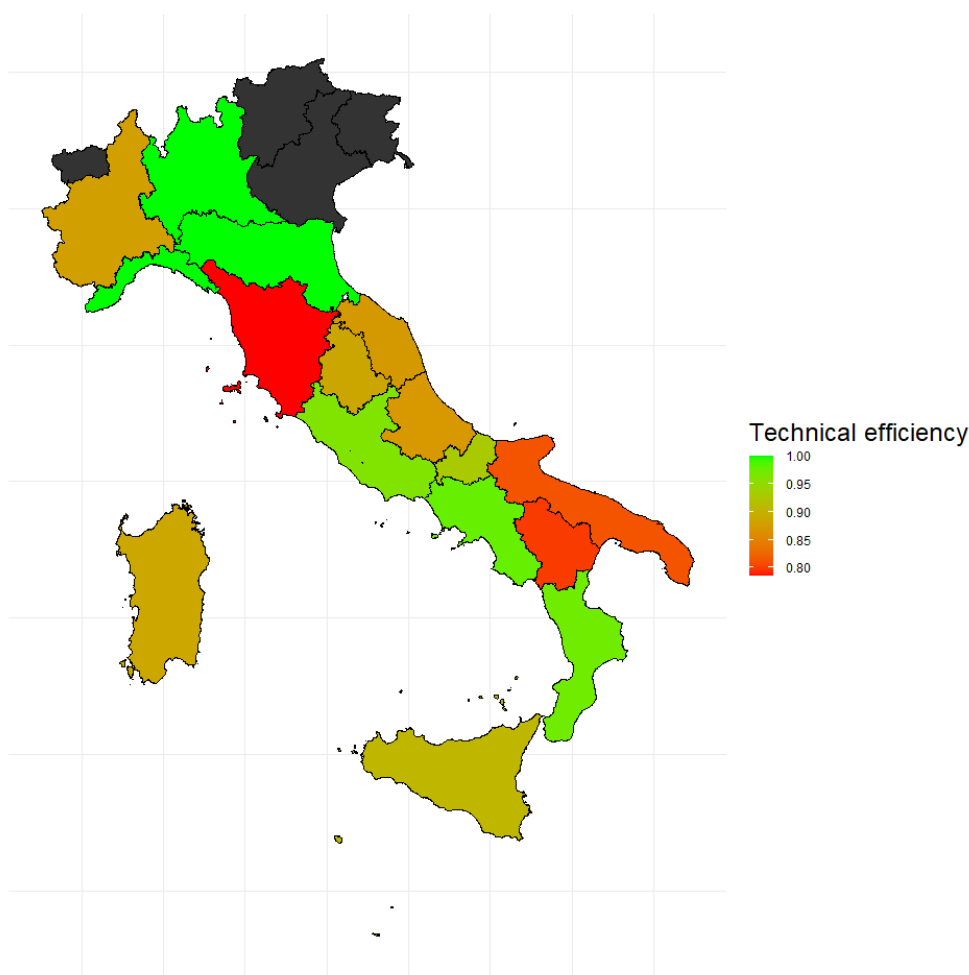


Fig. 1. Technical efficiency estimated by the DEA input oriented in all Italian regions

Source: Author's elaboration on data <https://agridata.ec.europa.eu/extensions/FADNPublicDatabase/FADNPublicDatabase.html>.

dowment, as argued in other studies (Galluzzo, 2013).

In three Italian regions out of 20 research's findings have pointed out as farms specialised in sheep and goats have been technically efficient with a value of the efficiency estimated by the DEA equal to optimal threshold equal to 1 (Table 3). In two Italian regions such as Tuscany and Basilicata located in the centre and in the south of Italian peninsula the assessment of the technical efficiency has pointed out the lowest value equal to 0.79 and 0.80. It is important to emphasize that sheep farming in Tuscany is very important and it is used to produce milk fundamental in making certified quality cheeses as *Pecorino Toscano DOP*. Hence, it is important for Tuscan farms to

better reallocate some inputs that are in excess of their optimal employment, such as other costs and total assets. It seems that an excess in assets equal to 24% compared to the optimal level is the main reason of the low level of technical efficiency in sheep and goat farms located in Tuscany.

Drawing some conclusions, comparing different input excess in all Italian regions, the input labour has been more inefficient in Tuscany and less inefficient in Campania. Focusing the attention to the land capital input the sheep and goat farms part of the Italian FADN dataset have had the highest level of excess in farms located in Basilicata; on the contrary the lowest level of excess in land capital endowment has been found in farms located in Campania region. In Latium

Table 3. Main results of the technical efficiency estimated in all Italian regions by the DEA and inefficiency assessed by the MEA in the FADN sample of Italian sheep and goat farmings

Region	Technical efficiency	MEA labour	MEA land capital	MEA specific cost	MEA other costs	MEA assets	MEA output
Piedmont	.8796787	.9113599	.8910866	.9123384	.858394	.913194	.9225649
Lombardy	1	1	1	1	1	1	1
Liguria	1	1	1	1	1	1	1
Emilia-Romagna	1	1	1	1	1	1	1
Tuscany	.785722	.8600199	.8433618	.8562367	.780005	.7579968	.9115813
Marche	.8732749	.9218079	.865948	.9219779	.8581085	.8404511	.9550606
Umbria	.8872643	.9274379	.8742353	.92305	.8843639	.8559446	.9458108
Latium	.9646369	.9806923	.9693835	.9701651	.959349	.9460121	.9872876
Abruzzo	.8709227	.9216638	.8347604	.9119806	.8686332	.8796054	.9360448
Molise	.929875	.9509433	.9374863	.9453562	.9233017	.9346598	.9415981
Campania	.9776804	.9821309	.9852562	.9611699	.973291	.9773383	.9836806
Calabria	.973843	.9561277	.9657169	.9605604	.9890393	.9636059	.9948627
Apulia	.812368	.8651169	.8569407	.867117	.8831106	.8554883	.9347011
Basilicata	.7988941	.8766538	.7573256	.8748437	.8082896	.7767262	.8596566
Sicily	.9057953	.942692	.8500597	.9271038	.9035342	.8690564	.9653844
Sardinia	.888123	.9423267	.7500545	.8553427	.8738678	.7631997	.9477125
Total	.8862793	.9267719	.8723834	.9138651	.8869586	.867761	.9440742

Source: Author's elaboration on data <https://agridata.ec.europa.eu/extensions/FADNPublicDatabase/FADNPublicDatabase.html>.

region farms specialized in sheep and goats have had the lowest level of excess in the input specific cost. The Campania region has farms specialized in sheep and goat farming with the lowest level of excess in assets compared to farms located in Tuscany, which have been less technically efficient because of an excess of 25% in the asset variable. For the total output the highest level of inefficiency has been found in farms located in Calabria and the lowest in Tuscany.

CONCLUSIONS

In Italy sheep and goat farmings represent an important source of income in farms located in mountainous and in disadvantaged rural areas and by the sheep milk it is possible to produce one of the main protected sheep cheeses as the Pecorino Romano PDO. By the sheep farming it is possible to protect land areas at risk of marginalization and rural permanent emigration. The role of financial subsidies allocated by the second pillar of the Common Agricultural Policy has been fundamental in increasing the socio-economic development and environmental sustainability as assessed by the estimation of the technical efficiency.

Results have assessed as the CAP subsidies have an effect of the technical efficiency which has been negative. Comparing different Italian regions many differences and unbalances among regions exist due to excess in some inputs such as assets and land capital as estimated by the Multi-direction Efficiency Analysis. This research has filled the gap in literature by the analysis of technical efficiency in Italian sheep and goat farms using an innovative approach such as the MEA it has been possible to assess the excess of specific inputs which are directly involved in the inefficiency in the Italian FADN sample of sheep and goat farms. In order to reduce the inefficiency in these farms it is fundamental to reduce the excess of land capital endowment and labour input. Furthermore, the nexus between dimension of farms and technical efficiency argued by other

studies carried out in many European countries (Galluzzo, 2013; 2020; Kovács and Emvalomatis, 2011, Alvarez and Arias, 2004; Bojnec and Fertő, 2013; Bojnec and Latruffe, 2013; Minviel and Latruffe, 2017; Garrone et al., 2019) has pointed out as there is the need of sheep farms in reducing the land capital; hence, an increase of land capital and large farms could be less technical efficient than medium size farms.

The input asset has been in excess compared to other input used in Italian sheep and goat farms due to fixed assets such as machinery and equipment and breeding livestock than stocks of other circulating capital. The policies implications in this analysis have underlined as the Common Agricultural Policy measures of supports should be addressed in stimulating a better allocation of asset input in Italian farms.

In the future, another field of research should also be to compare sheep and goat farms to other types of extensive breeding, such as cattle, as investigated in other countries (Galluzzo, 2019), with the purpose of evaluating if sheep farms were technically more or less efficient than cattle breeding in rural areas and in mountainous territories as well.

The novelty of this study has been twofold. In fact, by this research it has been possible to find the inputs which have been involved in the inefficiency of sheep and goat farms assessing the percentage of excess in each input causing the inefficiency. Furthermore, this study has clarified the effect of the total financial subsidies allocated by the CAP to the technical efficiency that has been negative. As mentioned above, this negative effect is mainly due to the subsidies provided by the first pillar of the Common Agricultural Policy. The policies of the CAP addressed to the rural development by the allocation of specific subsidies in the framework of the second pillar of the CAP have to be increased with a greater allocation of financial resources to farms located in disadvantaged rural areas even if less favored areas subsidies can partially compensate these enterprises that are characterised by a low farm income and an intense use of labour input.

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Постъпила – 21 януари 2023 г.; Одобрена – 27 юни 2024 г.; Публикувана – септември 2024 г.