Assessing technical efficiency and its determinants for dairy cattle farms in northern Algeria: The two-step DEA-Tobit approach

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Abstract

The purpose of this paper is to analyze the technical efficiency of dairy cattle farms in Tizi Ouzou region as one of the main dairy basins in Algeria. To do so, a two-step analysis was applied. First, Data Envelopment Analysis (DEA) was used to quantify the technical efficiency of dairy cattle farms. In the second step, a Tobit model to examine factors affecting farms' technical efficiency is used. The analysis used cross-sectional data collected from 146 dairy cattle farmers. The study found that the average technical efficiency under VRS assumption is relatively high, suggesting that farms can reduce their inputs by an average of 17% while maintaining the same level of output. The study also highlights the crucial role that agricultural advisory system and traditional insemination play in enhancing technical efficiency. In this region, where cattle breeding is traditionally practiced on a small scale, increasing herd size can result in reduced performance. The study also recommended that agricultural policies should be adapted to local specificities and that a more supportive strategy should be adopted for small-scale family dairy farms instead of promoting the large farm model.

Keywords: *Technical efficiency, Data Envelopment Analysis, Efficiency determinants, Dairy farm, Algeria.*

1. Introduction

The dairy sector constitutes a significant aspect of the food landscape in Algeria, where the per capita consumption of milk products is substantial, averaging at 154 liters per year (MADR, 2019). To satisfy the growing domestic demand for milk, partly due to population growth since independence, Algeria has continued to spend massive sums to import dairy products including 90% of powdered milk to reach 1,5 billions $ in 2020 (Knips, 2005; Sraïri *et al.*, 2013; Ministry of Finance, 2020). This orientation was favored by the financial ease experienced by the country owing to hydrocarbon revenues, on the one hand, and to the international context characterized by the low prices of dairy products on the

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international market (Bellil and Boukrif, 2021). However, the collapse of oil prices during the late 1980s triggered adjustment plans to support national production for this traditional product. Indeed, in this perspective of reducing import bills, the Algerian authorities have invested considerable financial resources over the past decades reflected on a series of upgrade policies to restructure the dairy sector with an objective of reducing the country's dependency on milk imports (Bellil and Boukrif, 2021; Meklati *et al.*, 2020; Oulmane et *al.*, 2022).

Efforts to redress the situation in this sector have most often resulted in massive imports of highly productive and exotic dairy cows (Kalli *et al.*, 2018). Although the local dairy production has registered a positive increase – following these measures induced by the government – the growing national consumption is only based on 60% of the national production (Bessaoud *et al.*, 2019). This growth observed in local production over the past two decades is not the result of an improvement in milk production and productivity per cow, but is rather due to an increase in the number of dairy cattle spurred by import policies (Bellil and Boukrif, 2021). Indeed, these dairy support policies, have not improved the situation of milk production (Djermoun and Chehat, 2012; Kheffache and Bedrani, 2012).

The lack of adaptation of imported exotic breeds to local breeding conditions and management practices is generally put forward as the main justification for the low productivity recorded despite the genetic potential of these imported breeds (Kheffache and Bedrani, 2012). As in other Maghreb countries, crosses with local strains have multiplied, through artificial insemination, but often in an unplanned manner, reducing therefore zootechnical performances (Djemali and Berger, 1992), and the choice of suitable breeds is still an open question (Sraïri *et al.*, 2007). Moreover, the persisting policies applied to milk powder imports to fill the gap is also represented as a major constraint to the development of local production (Bousbia *et al.*, 2013; Sraïri *et al.*, 2013; Yerou *et al.*, 2019). While numerous studies have shared the observation that these various policies have not been able to achieve the expected results (Belhadia *et al.*, 2014; Bellil and Boukrif, 2021; Kheffache and Bedrani, 2012; Mamine *et al.*, 2011), very few studies have focused on the technical efficiency of dairy cattle, especially in terms of the use of already scarce resources.

In terms of the methodological approach, a series of approaches have been developed to assess farm efficiency (Ahmed *et al.*, 2020). One of the most widely used efficiency measurement methods is the nonparametric method, due to its advantage of not imposing functional forms on the data (AlFraj and Hamo, 2022; Oulmane *et al.*, 2019; Speelman *et al.*, 2011; Tesema and Gebissa, 2022). Based on the work of Farrell (1957), this method, namely the Data Envelopment Analysis (DEA) was originally developed by Charnes *et al.* (1978). It is defined as a linear programming methodology that empirically quantifies the relative efficiency of several similar entities or DMUs (Decision Making Units) (Cooper *et al.*, 2006). By considering farms as DMUs and coupled with regression analysis, many works have been interested in determining but especially in explaining the technical efficiency of these units (Battese and Coelli, 1988; Chavas *et al.*, 2005; Clemente *et al.*, 2015; Morantes *et al.*, 2022; Oulmane *et al.*, 2019). This analysis can better inform agricultural decision makers about the potentialities to promote the agricultural sector by enhancing farm performances.

In response to the growing demand for dairy products in Algeria, livestock productivity needs to be improved and is becoming an interesting research topic. Hence, this paper aims at analyzing and interpreting the technical efficiency of dairy cattle farms in a Northern region of Algeria, namely the Wilaya of Tizi Ouzou, and to address the determining factors that influence farm inefficiencies. To do this, a two-step analysis was implemented. In the first step, Data Envelopment Analysis (DEA) was used to measure the technical efficiency of dairy cattle farms. The second step, by using the Tobit model, the study aims to explore the relationship between these estimated scores of technical efficiency and other relevant variables, namely herd size, farming experience, use of agricultural advisory services, the surface intended to fodder production.

The paper is organized as follows: section 2 presents research methodology, namely the study area and the empirical strategy used in this study, section 3 presents results and discussion in terms of efficiency analysis, section 4 concludes.

2. Research methodology

2.1. *The study area*

For this study, the Wilaya of Tizi Ouzou is selected because of its vocation for bovine dairy production. Although it is a mountainous region with little fodder, this region is considered among the leading regions in the production of cow's milk, ranking the second place at national level in terms of milk production and collection (MADR, 2019). According to data provided by the Regional Directorate of Agricultural Services (DSA, 2019), the region has 40,700 cattle heads, more than 3,650 dairy cattle farmers and 22 dairies that collect more than 63% of the locally produced milk. Dairy cow production in this region has been increased since 2000. It has an average of 57.1 million liters during the period 2000-2007 (MADR, 2009) and reached an average of 113.6 million liters during 2009-2017 (DSA, 2019). The UAA is 98,000 ha of which only 5-6% (i.e. 7050 ha) is irrigated according to the Directorate of Agricultural Services (DSA, 2019). Due to the scarcity of water resources, the fragmentation of cultivated lands and the problem of fodder availability, livestock systems are characterized by the practice of soilless breeding, the use of subsidized corn silage produced in Saharan areas and the use of feed concentrate as a supplement.

For the present study, a total of 146 dairy cattle farms randomly generated were surveyed to collect both qualitative and quantitative data (i.e. 4% of the population). The surveys were conducted during 2021. Firstly, structural parameters of dairy cattle farms were inventoried, this essentially concerns the profiles of farmers, the size of farms, the herd size, access to productive resources, and access to agricultural advice. Secondly, functional parameters were investigated through the determination of livestock management practices, the determination of input consumption and costs, and the inventory of milk production. In parallel, semi-directive interviews were carried out with breeders to understand the dynamics of this sector and challenges facing its development.

2.2. *The empirical procedure: A two-stage DEA-TOBIT model*

The usually used two-stage approach follows a first stage estimation of efficiency scores using the DEA method, then, a second stage regression analysis using Tobit model seeking to reveal the determinants explaining the variation in terms of efficiency scores.

It is not question to survey the method here, but the main idea could be briefed as follows. Debreu (1951), Farrell (1957) and Koopmans (1951) were the pioneers of the efficiency concept. Koopmans define a firm as being efficient "if it is technologically impossible to increase output and/or reduce an input without simultaneously reducing at least one other output and/or increasing at least one other input". Farrell was the first to separate economic efficiency into two: technical efficiency – related to the use of optimal quantities of inputs – and allocative efficiency – related to cost, i.e. the use of a combination of inputs with the lowest cost. While the existence of several methods to calculate efficiency, namely, parametric and non-parametric methods – including the widely used DEA method (Bravo-Ureta and Pinheiro, 1993), this study focus in the later.

The DEA method is a pioneering non-parametric method of evaluating efficiency that uses mathematical programming rather than regression (Oluwatayo and Adedeji, 2019). It is also a method used to evaluate the efficiency of a set of decision-making units (DMUs: dairy cattle farms in our case) by comparing them to a set of best-practice DMUs. In recent years, this method has gained increasing attention in various fields of research. Within this field, agriculture is one of the most recent application areas for DEA (Angón *et al.*, 2015; Cecchini *et al.*, 2021; Emrouznejad and Yang, 2018; Ullah *et al.*, 2019).

One of the key strengths of DEA is its ability to handle multiple inputs and outputs, which makes it well suited for evaluating the efficiency of complex systems. From an efficiency frontier, the technical efficiency scores of different dairy cattle farms are calculated. Farms located on the frontier are considered technically efficient with a score of 1 (100%) and those located below the frontier are considered inefficient with a score ranging from 0 to 1 (Coelli *et al.*, 2005). Then the inefficiencies are estimated by measuring the distance between a given farm and the frontier – represented by those having the best inputs/outputs combination. The Constant Returns to Scale (CRS) suggested by Charnes *et al.* (1978) was the first DEA model for estimating technical efficiency. This model assumed that all DMUs are operating at their optimal scale, i.e. the variation in outputs is perfectly proportional to the variation of inputs. However, this is not the case particularly in agriculture.

The DEA model suppose that there are n DMUs, where each DMU i utilize N inputs and M output. For the i^{th} DMU, these are represented by the vectors x_i and q_i columns, respectively, X is the input matrix $N \times I$ and Q the output matrix $M \times I$; they represent the data of the DMU_I. The technical efficiency under CRS assumption can be estimated by solving the following program:

$$\begin{aligned} &\min_{\theta,\lambda} \theta \\ \text{s.t.} \quad &-q_i + Q\lambda \geq 0 \\ &\theta x_i - X\lambda \geq 0 \\ &\lambda \geq 0 \end{aligned} \qquad (1)$$

Where $\boldsymbol{\theta}$ is a scalar and λ is a $I \times 1$ vector of constants. The model is solved once for each farm and therefore gets a $\boldsymbol{\theta}$ value for each farm. The value of $\boldsymbol{\theta}$ obtained corresponds to the score of the technical efficiency of the first i^{th} farm.

Banker *et al.* (1984) subsequently followed up this work to propose a DEA model by considering Variable Returns to Scale (VRS). The latter assumption is considered to be more appropriate in the case of agriculture. Two orientations can be used; these are the input-oriented (minimizing the use of inputs) and the output-oriented approach (maximizing outputs) (Coelli *et al.*, 2002; Fried *et al.*, 2008). As farmers have more control over inputs than outputs, the input-oriented model is preferred. Also, in the situation of increasing scarcity of natural resources, it is more relevant to consider potential decreases in inputs than increases in outputs (Rodríguez Díaz *et al.*, 2004).

The technical efficiency under VRS assumption can be estimated by solving the following program:

$$\begin{aligned} &\min_{\theta,\lambda} \theta \\ \text{s.t.} \quad &-q_i + Q\lambda \geq 0 \\ &\theta x_i - X\lambda \geq 0 \\ &N1'\lambda = 1 \\ &\lambda \geq 0 \end{aligned} \qquad (2)$$

In summary, the technical efficiency under CRS assumption (TE CRS) is a subset of technical efficiency that assumes a constant scale of production. It measures the efficiency of a farm in achieving the maximum output level when all inputs are increased proportionally. However, the technical efficiency under VRS assumptions (TE VRS) takes into account the possibility of varying production scales and measures the efficiency of a farm when there are diseconomies or economies of scale. It considers the potential to adjust the scale of production to achieve higher efficiency levels. It is more flexible than TE CRS as it allows for variations in the scale of operations. The Scale Efficiency (SE) is a related concept that evaluates the overall efficiency of a farm by considering both technical efficiency and the optimal scale of production. It combines the concepts of TE CRS and TE VRS to provide a comprehensive assessment of efficiency, taking into account both the efficient utilization of inputs and the appropriate scale of operations.

Furthermore, the Returns to Scale (RS) score is calculated for each farm to assess their operational efficiency based on the relationship between the proportion of inputs and the corresponding output. In economics, the RS is classified as constant, increasing, or decreasing. This determination is made by calculating the total elasticity of production ε shown in the formula below (Coelli *et al.*, 1998):

$$\varepsilon = \sum_{i=1}^{n} E_i$$
$$E_i = \frac{\partial y}{\partial x_i} * \frac{x_i}{y} \quad (3)$$

The RS score provides insights into how a farm's production output changes concerning the scale of its input utilization. In the second step and for identifying the determinants which affect efficiency scores, the literature recommends using the truncated regression Tobit model because efficiency is a bounded quantitative variable (bounded between zero and one) (Wooldridge, 2002; Greene and Zhang, 2019). This method involves estimating a linear regression that expresses efficiency according to a set of socioeconomic variables. The Tobit model can be expressed as:

$$Y_i^* = \beta X_i + \varepsilon_i \quad i = 1, 2, \ldots, N$$
$$Y_i = Y_i^* \quad \text{if} \quad Y_i^* > 0 \quad (4)$$
$$Y_i = 0 \quad \text{if} \quad Y_i^* \leq 0$$

Where Y_i is the dependent variable (speed above the posted limit) measured using a latent variable Y_i^* for positive values and censored otherwise, β is a vector of estimable parameters, X_i is a vector of explanatory variables, ε_i is a normally and independently distributed error terms with zero mean and constant variance σ^2, and N is the number of observations (Washington *et al.*, 2020).

3. Results and discussion

3.1. *Statistical description and frequency distribution of dairy cattle farms' characteristics*

The analysis of the survey data shows that there are mainly small cattle dairy cattle farms, as the 3rd quartile of the sampled dairy cattle farms holds fewer than 10 dairy cows (Table 1) and 18 is average herd size (Table 3), among it, there are only 9 milking cows per farm – 42% of farms has less than 5 milking cows – (Table 1). The breeds are represented to 70% by improved cows (Holstein and Montbéliarde), the remainder are local cows or resulting from crossings. According to the Table 1, the output of milk production ranged from 3,000 to 300,000 liters/year with a mean of approximately 47,000 liters/year among the sampled dairy cattle farms, where the milk production per cow is around 540 liters/year.

Regarding the profiles of the breeders, the majority (95%) were male-headed, which is representative of the patriarchal nature of the society. Their average age is 46 years ranging between 27 and 80 years. As the breeding activity in this mountainous region has a historical vocation, a certain experience is developed in the management of livestock, built on no less than 18 years in this activity on average. Most of breeders are educated but with a level that does not go beyond secondary school for the majority, only 9% are illiterate.

Being located in an area where agricultural lands are scarce, surfaces intended for fodder production are therefore very limited (less than 4 ha per farm on average (Table 3). The analysis shows the importance of green fodder to boost milk production. Farms that produce green fodder have higher milk yields compared to farms that do not produce (5,528 and 5,097 liter/cow/year, respectively). However, fodder surfaces are unequally distributed between farms, and only 9.5% of the sample totaling 54% the fodder surface, and 38% of farms produce no fodder resources. This explains the massive recourse to the purchased livestock feed and concentrates, which economically weighs heavily on small dairy cattle farms, and especially with the increasing trend in prices of these concentrates on the markets, whose access is sometimes difficult. Indeed, on average, 214,000 DZD/year is the amount dedicated to the purchase of food for a single cow in lactation, and this amount can increase to 264,000 DZD/year for farms that do not produce their own fodder resources.

Finally, and in order to enroll the new production techniques in their practices and to manage the animal health aspects, the recourse to different agricultural advisory services is almost a common practice, this is the case for 86% of breeders.

Table 1 - Descriptive statistics of the variables used in efficiency analysis.

Parameters	*Output*	*Inputs*			
	Milk production (liter/year)	*Number of milking cows*	*Cost of feeding in kDZD/year*	*Volume of work in hour/year*	*Sanitary costs in kDZD/year*
Min.	3,000	1	2,340	2,920	0
Q_1	18,000	4	11,838	3,376	0
Median	32,400	7	16,260	5,110	10,45
Mean	47,038	9	18,661	6,120	32,03
Q_3	59,850	10	21,405	7,300	43,63
Max.	300,000	43	150,060	24,820	450,00
S.D.	*47,819*	*8*	*14,064*	*3,823*	*55,41*

3.2. *Assessing the technical efficiency of dairy cattle farms*

The data in Table 1 represents the inputs and the output used for the calculation of the efficiency scores according to the DEA model. Milk production per farm was retained as the only output in this analysis. For the set of inputs, the analysis included 4 inputs: 1) number of cows in lactation; 2) the cost dedicated to the acquisition of the different types of feed and concentrate; 3) the hourly volume provided for the management of the farms; 4) the cost spent on animal health.

The Table 2 illustrates the summary statistics of the input-oriented technical efficiency scores under variable returns to scale (VRS) and constant returns to scale (CRS) assumptions. It also illustrates their frequency distribution and scale efficiency (SE) scores.[1]

Under the CRS assumption, it was found that 10 out of the 146 dairy cattle farms achieved a technical efficiency score of 0.9 or higher, representing approximately 7% of the sample. The average technical efficiency for all dairy cattle farms was estimated to be 0.54. This implies that, on average, dairy cattle farms operating below optimal efficiency could potentially reduce their input usage by 46% while maintaining the same level of production. The CRS assumption is valid when all dairy cattle farms are operating at their optimal scale. However, according to Coelli *et al.* (2005), factors such as unfair competition and financial constraints can deviate a farm from operating at optimal scale. When relaxing the assumption of constant returns to scale and considering variable returns to scale in the model, the number of dairy cattle farms with a technical efficiency ≥ 0.9 increase to 65 out of 146 dairy cattle farms. The average efficiency also rose to 0.83 (83%), ranging from 0.42 to 1 with a standard deviation of 0.175. Considering the VRS assumption, it is found that farmers can save an average of 17% of the inputs used while maintaining the same level of production. For the least efficient farms with a score lower than 0.5, the potential savings in inputs amount to 10 825 kDZD/year and 9 219 hours of labor work. These findings are particularly significant considering the cost of food management for livestock, which heavily relies on imported resources subject to price fluctuations. Additionally, the scarcity of skilled workforce further highlights the importance of efficiency gains in optimizing resource utilization.

The results further indicate that the VRS model exhibited a lower standard deviation of the mean, implying a greater concentration of farms in the higher efficiency levels. In terms of scale efficiency, approximately 20% of dairy cattle farms performed at or near the optimal scale (0.9 ≤ SE). On the other hand, for the lowest efficiency scores (below 0.5), approximately 40% and 3% of the studied dairy cattle farms fell under CRS and VRS, respectively. Moreover, the assessment of scale efficiency revealed that these farms were not op-

[1] We note that we used R software for our estimations using "dear" package.

Table 2 - Scores of technical efficiency assessment under different specifications.

Efficiency Score	*DEA-CRS*		*DEA -VRS*		*DEA - SE*		*Input saving potential*			
	Number of farms	*%*	*Number of farms*	*%*	*Number of farms*	*%*	*Number of milking cows*	*Cost of feeding in kDZD/year*	*Volume of work in hour/year*	*Sanitary costs in DZD/year*
E < 0,5	58	40	4	3	34	23	5	10 825	9 219	51 604
0,5 ≤ E < 0,6	37	25	17	12	20	14	5	9 722	3 448	23 193
0,6 ≤ E < 0,7	28	19	24	16	22	15	4	7 139	2 502	20 106
0,7 ≤ E < 0,8	10	7	16	11	21	14	2	3 993	1 856	6 548
0,8 ≤ E < 0,9	3	2	20	14	20	14	1	3 519	833	2 204
0,9 ≤ E < 1	4	3	8	6	18	12	0	584	294	934
E = 1	6	4	57	39	11	8	0	0	0	0
Total	*146*	*100*	*146*	*100*	*146*	*100*	*17*	*35 784*	*18 153*	*104 588*
Min.		0,14		0,42		0,14	0	0	0	0
Q_1		0,40		0,67		0,50	0	0	0	0
Median		0,52		0,85		0,68	0	918	358	0
Mean		0,54		0,83		0,67	1	2 754	1085	5 673
Q_3		0,66		1,00		0,87	2	4 321	1557	5 038
Max.		1,00		1,00		1,00	13	17 742	12850	97 522
S.D.		0,19		0,17		0,22	3	4 358	2052	21 105

erating at an optimal scale, as indicated by an average scale efficiency score of 0.67. These findings suggest that a significant number of farms operate at an inefficient scale and would benefit from adjustments to improve their overall efficiency. Out of the 146 farms that were surveyed, 10 operated at CRS. This means that the output these farms increased by the same proportional increase in the inputs used. Tow (2) farms operated at decreasing returns to scale, i.e., the increase in output is proportionately lower than the increase in inputs. Meanwhile, the remaining 134 farms operated at increasing returns to scale, indicating that they obtained an output that increased by more than the same proportional change in inputs.

3.3. *Factors affecting technical efficiency of dairy cattle farms*

To provide informed recommendations for the implementation of effective policies in the dairy sector, it is crucial to identify the sources of variation in the assessed technical efficiency. In this regard, various external factors (as presented in Table 3) were regressed against the efficiency scores under the VRS assumption. This analysis aimed to determine the significance of each factor in influencing efficiency outcomes. The results of these regressions are presented in Table 4, shedding light on the relevance and impact of each factor in determining efficiency levels.

The Tobit regression analysis revealed significant findings regarding the factors influencing technical efficiency. Among the factors examined, five demonstrated high statistical significance at a 1% level, four exhibited moderate significance at a 5% level, and one factor showed weak significance at a 10% level. On the other hand, five factors did not display any statistically significant association with technical efficiency. These results provide valuable insights into the determinants of technical efficiency in the studied context.

Table 3 - Summary statistics for variables included in the Tobit regression.

Variables	*Continuous variables*				*Dummy/Ordinal variables*	
	Mean	*Min.*	*Max.*	*S.D.*	*Categories*	*Number of dairy cattle farms (%)*
Household size	5	0	21	3		
Experience in breeding	18	1	64	10		
Herd size	18	2	95	17		
Calving interval	12	10	18	1		
Frequency of access to extension service	15	0	200	26		
Forage production	4	0	65	8		
Education level					0: Illiterate	14 (10)
					1: Primary school level	30 (20)
					2: Middle school level	71 (49)
					3: Secondary school level	27 (18)
					4: University level	4 (03)
Agricultural training					0: No	114 (78)
					1: Yes	32 (22)
Non-farm activities					0: No	100 (68)
					1: Yes	46 (32)
Access to modern cows					0: No	12 (8)
					1: Yes	134 (92)
Enclosed breeding					0: No	109 (75)
					1: Yes	37 (25)
Access to artificial insemination					0: No	43 (29)
					1: Yes	103 (71)
Access to credits					0: No	124 (85)
					1: Yes	22 (15)
Access to advisory service					0: No	20 (14)
					1: Yes	126 (86)
Access to private advisory service					0: No	117 (80)
					1: Yes	29 (20)

The results reveal the positive significance of five factors, with agricultural advisory services standing out as having a substantial impact on the performance of on dairy cattle farms. The effect of advisory services on improving the technical performance of farms cannot be underestimated, especially in terms of improving farm management skills and fostering knowledge on new technologies and practices (Awunyo-Vitor *et al.*, 2013). In this regression analysis, it is pertinent to highlight that it is not the access to agricultural advisory services that accounts for observed performance (Table 4), instead, it is the frequency of such access that exhibits a positive and highly significant relationship. Furthermore, the quality of advisories provided by private services exerts a more substantial influence when compared to the perceived inefficiency of public advisory services. While private advisory services provide enhanced flexibility, personalized attention and specialized expertise, it is essential to recognize that they are typically associ-

Table 4 - Results of Tobit regression estimation for the efficiency determinants.

Variables	*Coefficients*	*z*	*p-value*	
Const.	0.414	2.679	0.007	***
Household size	−0.007	−1.384	0.166	
Experience in breeding	0.003	2.178	0.029	**
Herd size	−0.003	−2.964	0.003	***
Calving interval	0.034	3.371	0.001	***
Frequency of access to extension service	0.001	2.725	0.006	***
Forage production	0.003	1.394	0.163	
Education level	−0.026	−1.717	0.086	*
Agricultural training	0.080	2.420	0.016	**
Non-farm activities	−0.016	−0.555	0.579	
Access to modern cows	0.170	3.246	0.001	***
Enclosed breeding	−0.003	−0.108	0.914	
Access to artificial insemination	−0.103	−3.477	0.001	***
Access to credits	−0.085	−2.105	0.035	**
Access to advisory service	−0.028	−0.669	0.503	
Access to private advisory service	0.067	2.014	0.044	**
N	*146*	*p-value: 3.75e-10*		
Chi-square (16)	*75.989*			
Log likelihood	*70.763*			

*Note: asterisks are for the statistical significance level: *** for 1%, ** for 5%, * for 10%. No asterisk for no significance level.*

ated with a higher cost. Similarly, the variable "interval calving" exhibited a strong positive significance, suggesting that dairy cattle farms with longer calving intervals tend to be more efficient. This result may seem contradictory to the literature, which suggests that the longer the calving interval, the lower the efficiency. However, our study only focuses on data (inputs and outputs) from a single reference year, which may not fully reflect the long-term effects of increasing this interval. Therefore, the obtained result can be attributed to the fact that a longer calving interval contributes to extended lactation periods and improved animal health, ultimately resulting in enhanced technical efficiency (Bertilsson *et al.*, 1997). The positive effect of cow type on technical efficiency implies that utilizing modern cows, as opposed to local cows, leads to greater efficiency in dairy cattle farms. Modern cows, also known as high-yielding cows, have been selectively bred to produce more milk compared to local cows. Incorporating modern cows into dairy cattle farms can result in higher milk yields and improved efficiency in terms of production and cost-effectiveness (Gelan and Muriithi, 2012).

As expected in the scientific literature (Dhakal, 2022; Gonçalves *et al.*, 2008; Maina *et al.*, 2020; Parlakay *et al.*, 2015), agricultural training and experience in breeding have a positive influence on the technical efficiency of dairy cattle farms with statistical significance at the 5% level. These factors contribute to the facilitation of adopting new innovations, particularly those of a technical nature. Firstly, agricultural training equips farmers with the essential knowledge and skills required to improve their management practices. This includes areas such as feed management, disease prevention, and reproductive management. By implementing improved management techniques, farmers can enhance the productivity of their cows and reduce production costs, thereby increasing technical efficiency. Secondly, experience in breeding enables farmers to make informed decisions in selecting the best genetic traits for their cows. This aspect of expertise plays a crucial role in improving milk production, fertility, and other desirable traits. By carefully selecting breeding stock, farmers can optimize the genetic potential of their cows, leading to enhanced productivity and overall efficiency.

The results of the analysis reveal four factors that have a detrimental effect on the technical efficiency of dairy cattle farms. Among these factors, herd size and access to artificial insemination demonstrate a significant negative regression relationship at the 1% level. The decrease in technical efficiency of dairy cattle farms associated with smaller herd sizes can be attributed to the failure to achieve economies of scale. When herd size decreases, it indicates that the benefits of scale are not realized. Moreover, an increase in the number of dairy cows does not necessarily coincide with additional investments in infrastructure. Breeders often adopt a "reduce to better manage" approach, which can negatively impact efficiency. Larger herds tend to rely more on externally purchased feed, resulting in higher input usage and increased feed costs. Additionally, managing the nutritional needs of individual cows becomes more challenging in larger herds, leading to lower milk yields and higher feed expenses. Larger herds also face challenges related to disease transmission, which can result in higher veterinary costs and decreased productivity. The impact of herd size on dairy cattle farm efficiency remains a subject of debate in the existing literature. While some studies suggest a positive relationship between farm size and technical efficiency (Bravo-Ureta and Rieger, 1991; Hadley, 2006; Parlakay *et al.*, 2015), other studies confirm our findings of a negative relationship between herd size and technical efficiency in dairy cattle farms (Bardhan and Sharma, 2013).

The model reveals a strong negative influence of the mode of reproduction on technical efficiency, indicating that natural reproduction outperforms artificial insemination in terms of efficiency. This finding is not surprising considering the region's adherence to traditional breeding methods. By practicing natural insemination, dairy cattle farmers have the advantage of selectively choosing the best genitors, often from neighboring farmers. This approach allows for result-based selection, in contrast to the lack of control over offspring in artificial insemination. Additionally, the preference for natural breeding may be influenced by cultural and social factors, such as attitudes towards technology, the traditional role of bulls in breeding practices, and the desire to preserve the genetic composition of the local herd. It is worth noting that the observed preference for natural reproduction and its positive impact on technical efficiency should be understood in the context of the region's specific circumstances and traditional breeding customs.

The study findings indicate that access to financial resources, specifically through credits, exerts a significant negative impact on the technical efficiency of dairy cattle farms, with a significance level of 10%. This suggests that dairy farmers relying on credit to sustain their operations tend to have lower technical efficiency compared to their financially self-sufficient counterparts. The reliance on credits often leads to accumulating debt burdens, which can hinder farmers' ability to invest in technologies aimed at improving technical efficiency. For example, financially self-sufficient dairy farms have the financial means to invest in advanced technologies like mechanical milking, which can enhance labor efficiency and reduce costs. In contrast, farmers dependent on credit may face limitations in adopting such innovations due to financial constraints. Therefore, it becomes crucial for dairy farmers to prioritize strategies that promote financial self-sufficiency, as it can contribute to the long-term sustainability of their operations. Furthermore, the model results also highlight a negative impact of education level on the technical efficiency of dairy cattle farms, significant at a 10% level. Surprisingly, farmers with higher levels of education do not necessarily demonstrate superior technical efficiency compared to those with lower educational backgrounds. This finding may be attributed to the fact that farmers with lower education levels often possess practical knowledge and hands-on experience in effectively managing dairy cattle, resulting in higher technical efficiency. Farmers with lower education levels also have a stronger inclination towards adopting traditional and proven methods of managing dairy cattle. While this may limit their exposure to certain modern technologies, their familiarity and expertise in traditional practices might contribute to their higher technical efficiency.

4. Conclusion

In order to improve the performance of dairy cattle farms, it is crucial to address the major constraints identified in this study. One key aspect that requires attention is the enhancement of farm advisory services. Both public and private advisory services should focus on developing localized initiatives, such as on-farm visits and practical demonstrations, to provide farmers with tailored guidance and support. Increasing the accessibility and frequency of advisory services can empower farmers with the necessary knowledge and skills to optimize their farm practices. Moreover, policies should aim to strengthen the linkages between advisory services and farmers, facilitating knowledge transfer and fostering a continuous learning environment. By investing in farm advisory services, the sector can leverage expert guidance and best practices to enhance overall farm performance. Another area for potential improvement lies in the promotion of modern cow breeds. Encouraging the adoption of high-yielding cows, such as Holstein and Montbéliarde, can significantly enhance milk production and efficiency on dairy cattle farms. This can be achieved through targeted programs that provide incentives for farmers to acquire and maintain these improved breeds. Additionally, efforts should be made to ensure the availability of quality breeding stock and the preservation of traditional insemination practices. Supporting breeding networks, cooperative structures, and training programs can facilitate access to quality genetics and contribute to improved technical efficiency in the sector. While the current programs offered by the agricultural sector have shown effectiveness, their reach needs to be expanded to ensure more widespread participation. Currently, only 22% of farmers benefited from these training programs. By adopting a strategy to make these programs more accessible to a larger number of dairy cattle farmers, there is great potential for improvement in farm efficiency. This could involve initiatives such as increasing the availability of training sessions, utilizing digital platforms for remote learning, or establishing partnerships with local farmer organizations to facilitate knowledge dissemination. These measures, coupled with collaborative initiatives and support at the local scale, will contribute to the long-term sustainability of dairy cattle farms in the region.

One other notable finding of this study is the negative impact of the number of dairy cows on technical efficiency, which challenges the conventional understanding of economies of scale. In the specific context of the mountainous region of Tizi Ouzou, where cattle breeding is deeply rooted in tradition and characterized by small herds, increasing the number of cattle actually leads to a decrease in farm performance. This suggests that policies need to be tailored to the unique characteristics of localities. Rather than pushing for consolidation into larger farms, it would be more beneficial to support and strengthen small family farms in this region. Recognizing the limited availability of fodder resources, policies should focus on promoting sustainable and efficient feeding practices that are suitable for small-scale farms. This could involve providing technical support and resources for on-farm fodder production, improving access to high-quality feed, and promoting grazing management strategies.

Furthermore, it is crucial to acknowledge the significant economic and social role that dairy farming plays in this mountainous region. For many small dairy farmers, it represents a vital source of income and employment opportunities. Therefore, agricultural policies should prioritize initiatives that enhance the viability and sustainability of these small family farms. This could include measures such as providing financial support for farm diversification, facilitating access to credit and financial services, and fostering market linkages for local dairy products. By empowering and supporting small dairy farmers, these policies can contribute to the economic development of the region and help alleviate rural poverty.

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