DETERMINANTS OF TECHNICAL EFFICIENCY AMONG DAIRY FARMS IN TUNISIA

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Abstract

This study examines the determining factors of the technical efficiency of dairy farms in Tunisia. A stochastic production frontier and a two-limit Tobit models were used to analyze technical efficiency (TE) for a sample of 108 Tunisian cattle breeders. The empirical results suggest that TE ranges from 45% to 96% and that a purebred herd composition and a favorable location for breeding system including pasture and grazed grass lead to greater efficiency. In addition, we found that dairy farmers could increase their performance by joining a professional organization. The implications of these finding for development strategies of the Tunisian dairy sector were examined.

Key words: *milk production, performance, breeding system, frontier, Tobit model*

INTRODUCTION

To achieve food self-sufficiency in dairy products, experiencing a sustained increase, Tunisia has propelled the orientation of the replacement of local dairy breeds by imported breeds with important characteristics in terms of yield and economic profitability. The composition of the herd reversed from 2009 with a share of pure breeds (holstein, alpine brown, tarentaise) exceeding 50% (GIV Lait, 2018)[9]. An intensive and semi-intensive breeding system has emerged; even in regions with fairly restrictive climatic conditions, especially in the center of the country. This strategy immediately produced its effects quite a significant increase in production, reaching levels sometimes exceeding the country's needs. Indeed, milk production, around 1,400 million liters in 2015, exceeds the country's need for consumption of milk and products, which is around 109.9 l/capita (INS, 2015) [11]. In recent years, a reversal of the trend has begun to be observed, under the effect of the fall in fodder products following the succession of years of drought and the costly charge of concentrates propelled by the exorbitant prices at the import. The activity has become unprofitable pushing increasing number of farmers to sell their cows, especially in areas with limited options in terms of greenery. Indeed, the food needs of the new imported breeds are significant and a breeding system based solely on dry fodder and concentrate has proven to be unprofitable, especially since the retail prices remain administered by the State. In this context, it is essential to understand the factors assuring an adequate level of profitability of this activity. This will make it possible to better adapt the breeding system to guarantee the sustainability of the farm. Measuring the technical efficiency of dairy farms, referring to the maximum level of production that can be achieved given the quantities of production inputs and understanding the determining factors of a high level of efficiency will help meet this need. To measure technical efficiency, Farell (1957) [8] proposed to use a production frontier making it possible to compare the technical performance of firms respectably. This frontier illustrates the maximum level of production that can be achieved by involving different combinations of factors according to a specific technology. The most successful firms will be located on this border and will serve as a reference to determine the degree of inefficiency of firms located below the frontier. On the methodological level, the estimation of the production frontier can be carried out according to a parametric or not parametric approach. The first approach requires identifying a precise form of the production function. The measure of technical efficiency involves estimating the parameters of the chosen form of the production function. Aigner and Chu (1968) [2] introduced the deterministic form of this methodology, which utilizes deviations from estimated production frontier values as measures of technical inefficiency. Later works of Aigner et al. (1977) [3] and Meeusen and van den Broeck (1977) [15] led to the establishment of a stochastic approach, allowing measurement errors and random effects to be taken into account. This approach allows the decomposition of the error term, reflecting the difference between the levels of estimated and observed production, between the inefficiency technique and random errors.

Regarding the non-parametric approach, it incorporates all methods that do not use the specification of a particular form of the production function. We particularly distinguish the Data Envelopment method Analysis (DEA) which was introduced by Charnes and al. (1978) [4] and the Free Disposal Hall (FDH) analysis returning to Deprins et al. (1984) [6]. The aim of the paper is to identify the determining factors of the efficiency of Tunisian dairy farms. To this end, we use a stochastic production frontier to analyze the technical efficiency of a representative sample of dairy farmers. The calculated efficiency scores are then regressed on a set of explanatory variables including the dairy farm environment and the breeding system. The results of this analysis may be crucial for decision-makers in order to adapt the development orientations of the Tunisian dairy sector.

MATERIALS AND METHODS

Measurement and determinants of technical efficiency

To measure the technical efficiency of dairy farms in Tunisia, a stochastic production frontier model was employed. This model was originally proposed by Aigner et al. (1977) [3] and subsequently modified by Meeusen and van den Broeck (1977) [15]. This model has the following general form:

$$Y_i = f(x_i, \beta) e^{v_i - u_i} \quad \text{..........................(1)}$$

where: Y_i and x_i are, respectively, the output and the input vectors of inputs of farm$i$, The vector of unknown parameters to be estimated is denoted by β, while the functional form of the frontier is represented by $f(.)$, v_i is the vector of Gaussian random errors i.e.: $v_i : N(0, \sigma_{v_i}^2)$. u_i represents non-negative random factors, linked to the technical inefficiency of production. Indeed, $u_i = 0$ when the production level is on the frontier. They are assumed to follow a positive normal distribution, i.e.:u_i: $N^+ (0, \sigma_{u_i}^2)$.

The estimation of this empirical model is carried out according to the maximum likelihood method. For a sample of size n, the log-likelihood function has the following form:

$$lnL(Y, \beta, \sigma, \lambda) = -\frac{n}{2} \ln\left(\frac{\pi\sigma^2}{2}\right) + \sum_{i=1}^{n} ln\Phi\left(\frac{\varepsilon_i \lambda}{\sigma}\right) - \frac{1}{2\sigma^2} \sum_{i=1}^{n} \varepsilon_i^2 \quad \text{...(2)}$$

where: $\Phi(.)$ denotes the normal distribution function,

$$\varepsilon_i = v_i - u_i, \sigma^2 = \sigma_{v_i}^2 + \sigma_{u_i}^2, \lambda = \frac{\sigma_u}{\sigma_v}. \quad \text{........(3)}$$

If $\lambda = 0$, there are no technical inefficiency effects and all deviations from the frontier are due to errors.

The technical efficiency (TE) of a farm is defined as the ratio between the observed output Y_i and that corresponding to the frontier levelY_i^* given the used inputs. Thus, the technical efficiency of the farm$i$ is given by:

$$TE = \frac{Y_i}{Y_i^*} = \frac{f(x_i, \beta) e^{v_i - u_i}}{f(x_i, \beta) e^{v_i}} = e^{-u_i} \quad \text{...............(4)}$$

To measure the technical efficiency of dairy farms in Tunisia we used a Cobb-Douglass functional form of the frontier. Therefore, our empirical model admits the following logarithmic representation:

$$\ln(Y_i) = \beta_0 + \beta_1 \ln(X_{1i}) + \beta_2 \ln(X_{2i}) + \beta_3 \ln(X_{3i}) + \beta_4 \ln(X_{4i}) + v_i - u_i$$ ....(5)

where:
Y_i is the annual milk production of farm i in liters; X_{1i} is feeding costs; X_{2i} is the herd size; X_{3i} is the active labor on the farm; X_{4i} is land endowment (hectares).

To identify the determinants of technical efficiency of dairy farms in Tunisia, we used a two-limit Tobit model to regress efficiency scores on a set of explanatory variables given that the efficiency scores are bounded between zero and one. The literature review shows that inefficiency models generally integrate exogenous factors related to production systems, managerial, environmental and socio-economic characteristics. Given that this study focuses on a population of cattle breeders with similar socio-economic characteristics and managerial capacities, this regression employs variables that relate to the breeding system and environmental factors. Table 1 summarizes the variables utilized in this study along with their corresponding descriptions.

Table 1. Explanatory variables in the inefficiency effects model and their descriptions

Variables	Description
Region	Farmers region (1 if northern region and 0 otherwise)
PFA	Professional farmers' organization membership (1 if yes and 0 otherwise)
IFAA	Irrigated fodder agricultural area (Ha)
Herd	Herd composition (1 if purebred herd and 0 otherwise)
Concentrated-feeding (Cf)	Amount of concentrated feed per cow in kg

Source: author's conception.

The technical inefficiency model is specified by:

$$TE_i = \delta_0 + \delta_1 Region_i + \delta_2 PFA_i + \delta_3 IFAA_i + \delta_4 Herd_i + \delta_4 \ln(Cf)_i + \omega_i$$ ....(6)

Data collection

Detailed data on 108 small dairy farms were collected in 2001. A random sample was compiled to be representative of the different cattle breeding regions in Tunisia, as well as the different breeding systems (intensive, extensive and landless) with their variety in herd size and composition.

Table 2 summarizes the structure of the surveyed sample according to the stratification criteria.

Table 2. Sample structure

Variables	Definition	Percentage (%)
Region	North Otherwise	33.3 66.6
Herd size	< 3 3-8 > 60	45.0 49.2 5.8
Herd composition	Pure race Otherwise	55.3 44.7

Source: author's conception.

The questionnaire includes different sections. The first section is devoted to collect information on the specificities of the farm (region, areas, size of the herd and its composition). In the second section, respondents were asked to provide information on production levels and different cost categories. This includes feeding costs, deployed labor and operational expenses. The final section includes information on livestock management and market integration.

RESULTS AND DISCUSSIONS

Maximum likelihood parameter estimates for the production frontier model is presented in Table 3. All the estimated coefficients are significant and appeared with the expected signs. The coefficient λ is different from zero indicating a significant effect of technical inefficiency on the production of the dairy farm

The scale elasticity (i.e., the sum of all the elasticities of output) was 1.117, revealing a slight increasing return to scale. This result implies that the level of productivity that grows with improvements in technology and efficiency also depends on the scale of the farm.

The next step was to obtain the technical efficiency (TE) scores of the sampled dairy farms. Table 4 shows the distribution of TE scores.

Table 3. Estimated Cobb-Douglas Dairy Farm Production Function

Variable	Estimated coefficient	Standard Error	z-ratio
Feeding costs	0.219	0.044	5.01
Herd size	0.752	0.057	13.18
Active labor	0.109	0.040	2.66
Land endowment	0.037	0.021	1.76
Constant	5.953	0.490	12.14
σ_u	0.141		
σ_u	0.321		
λ	2.284		

Source: author's conception.

Table 4. Distribution of technical efficiency (TE) scores

TE interval (%)	Farms (n)	Farms (%)	Mean TE
]40, 60]	6	5.6	0.52
]60, 80]	37	34.3	0.72
]80,100]	65	60.2	0.87
Overall	**108**	**100**	**0.80**

Source: author's conception.

Results show that the sample overall average technical efficiency measure is 80%. Our findings are consistent with those of Lachaal et al. (2002) [12], who reported an average technical efficiency of 78%. This indicates that Tunisian dairy farms could increase their milk production by approximately 20% by improving the efficiency of their production inputs.

Frequency distribution results indicate that only 5.6% of the dairy farmers in our sample achieved a technical efficiency score below 60% (Table 4). Although that the majority of the farms (60.2%) achieved technical efficiency scores over than 80%, improving efficiency score for the remaining firms is essential for their durability. Indeed, given the administration of selling price of milk, reaching positive returns is not easy task for farmers. Results of the two-limit Tobit model presented in table 5 below, show determining factors of efficiency of Tunisian dairy firms.

Table 5. Estimated Two-limit Tobit Model

Variable	Estimated coefficient	Standard Error	z-ratio
Region	0.052	0.026	2.04
PFA	0.058	0.029	1.93
IFAA	0.016	0.008	1.93
Herd	0.112	0.031	3.59
Cf	- 0.012	0.017	0.69
Constant	0.713	0.058	12.29

Source: author's conception.

As expected, the most important factor in dairy farm efficiency in Tunisia is herd composition. Dairy farms raising only purebred cows are able to reach an efficiency score 11% higher than farms with the same characteristics and whose herd is made up of local or mixed breeds. Furthermore, a 5% higher efficiency score may be achieved by dairy farms located in the northern regions of the country with appropriate climatic conditions for high rainfall levels and abundance of grass. Similar results were found by Tauer et al (1987) [17] who claim that location in the northwest or central regions of New York will increase a farmer's technical efficiency by three and four percentage points respectively because these regions have the most productive soils and best weather in the state.

The importance of the breeding system on the dairy farm efficiency is also shown by the positive impact of irrigated fodder areas. Indeed, 1 hectare of irrigated fodder may increase farm efficiency by 1.6%. Although it is statistically insignificant, the quantity of concentrate per cow variable appeared with a negative sign, which implies that farms distributing large quantities of concentrate feed due to insufficient pasture and grazed grass are less efficient. This demonstrates that with high prices of imported inputs, aboveground farming systems based essentially on dry feed would no longer allow dairy farms to achieve high enough levels of efficiency to generate sufficient income.

On the other hand, the membership of dairy farms in a professional organization allowing the purchase of inputs at competitive prices makes it possible to achieve a 6% higher level of technical efficiency.

In recent years, the dairy sector in Tunisia has had difficulty overcoming the problems linked to the hardening of climatic conditions and the increase in world livestock feed prices.A growing number of breeders have been forced to sell their livestock due to lack of profitability. This demonstrates that the current situation implies that the sustainability of dairy farms in Tunisia is dependent on their ability to generate high yield levels to overcome these difficulties. This article aims to identify the characteristics of dairy farms that are capable of achieving high levels of performance. To accomplish this, technical efficiency scores of Tunisian dairy farms are estimated, and the factors that contribute to this efficiency are analyzed.

According to our findings, the main factors of efficiency of the dairy farm are a purebred composition of the herd and a breeding system including pasture and grazed grass. Although it is well known that purebred cows have higher milk productivity than local or mixed breeds, these results may have important implications for the Tunisian dairy sector. They indicate that breed choice is not sufficient to achieve high levels of performance. The breeding system should be adapted. Indeed, purebred cows can achieve high yields, but require higher feed supply. So, if the breeding system does not allow relying on natural pastures or grazed grass produced by the farm, the cost of feeding becomes unreasonable and the profitability of the dairy farm is no longer guaranteed.

Several studies have demonstrated the importance of pasture and grazed grass use on the profitability of dairy farming. Extended grazing seasons offer significant advantages, according to Läpple et al. (2012) [13]. Increased profitability is associated with a higher proportion of grazed grass in the diet, as demonstrated by Dillon et al. (2002) [7]. Conversely, as the proportion of purchased feed on dairy farms rises, production costs per hectare and per ton of fat and protein also increase, as shown by Shalloo et al. (2004) [16].

The characteristics of dairy farms in Tunisia contradict the implications of these results. Indeed, in the northern regions where rainfall is high and grass is abundant, the herds are mainly composed of local or mixed breeds, while in the arid regions of the center, cattle breeding is based exclusively on pure breeds. This implies that in the northern regions there are opportunities to improve the efficiency of dairy farming by replacing local or mixed herds with purebreds, whereas in other parts of the country where dairy farming cattle is practiced above ground the possibilities for improvement are very limited.

Furthermore, the membership of a professional organization is a relevant factor of efficiency of dairy farm in Tunisia.

Indeed, these organizations carry out group purchases of inputs for the benefit of their members and allow easier access to the market. A similar result was found by Abdelhafidh et al. (2018) [1] for Tunisian case. They assert that cooperative can largely support farmers and reduce the influence of the transaction cost and consequently improve the farms' productivity. The role of cooperative membership in enhancing dairy farms performance has been demonstrated in several foreign countries. In a study on the relationship between cooperatives and U.S. farm efficiency, Chen, Y. C. (1997) [5] found that cooperative membership has positive relationship with farm efficiency in the small and large herd size groups especially when farms have intensive relationship with cooperatives. Mahida et al. (2018) [14] show that membership in dairy cooperatives increases the efficiency coefficient of Indian farms by about 4%.

Hanisch et al. (2013) [10] conducted a study on the competitive yardstick effect of agricultural cooperatives on the prices paid to farmers. The study found that in the European dairy sector, agricultural cooperatives provide higher farm-gate prices to farmers.

CONCLUSIONS

Our empirical results can be very useful in determining the strategic direction of the development of the dairy sector in Tunisia. The main idea is that cattle breeding should be encouraged where it is possible to achieve high performance. Some regions with limited rainfall would simply be unsuitable for sustainable dairy production. Moreover, the creation of a greater number of dairy cooperatives will allow small farmers to be more efficient by reducing their costs and improving their managerial skills.

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