

Do the Cattle Farms of Iran Produce Economically Efficient or Not?

Narges Banaeian

Department of Agricultural Machinery Engineering, Faculty of Agricultural Engineering and Technology, School of Agriculture and Natural Resources, University of Tehran, Karaj, Iran

Abstract: The technical efficiencies of a sample of extensive Iranian cattle farms collected by Ministry of Agriculture were analyzed using a nonparametric Data Envelopment Analysis (DEA) model. Mean pure technical efficiency in a DEA model in which all variables were normalized with the number of cows was 0.79, indicating that there is ample potential for more efficient input utilization in cattle farming. The normalized measurement of variables captures the fact that most scale-inefficient farms (52%) are operating under decreasing returns to scale. This implies that even smaller farms have expanded to a size larger than is optimal relative to the number of cows in their herds. A comparison conducted in all region of Iran, Yazd and Khuzestan provinces were the most efficient and inefficient region of Iran in cattle farming, respectively. In an attempt to explain variation in efficiency scores, the study focuses on certain managerial practices often not accounted for. Results showed that dairy cattle are more efficient than beef cattle; also ANOVA test revealed that the choices of Holstein breed and herd with more than 200 cows have a positive significant impact on the efficiency level of cattle farms.

Key words: Cattle farms, cost saving, data envelopment analysis, Iran, scale efficiency

INTRODUCTION

The world's milk and beef cattle market is going through a commercial crisis. The modifications in consumer habits and the low population increasing rate have notably decreased the demand of products. In livestock production, Iran is also affected by this fact. Traditional beef production in the country has been supported by a high internal demand increase due to immigrations and politics of development. In this scenario, management systems for livestock enterprises are deficiently developed, with minimum cost politics, obtaining a low price product which is destined for internal market.

Today, the complexity of livestock production systems in a rapidly changing environment is widely recognized. With the increasing consciousness about excess production and the induced burden on the Common Agricultural Policy (CAP) budget, the main point of concern for the industry, as well as for EU officials and the academics, has shifted from output growth to efficient farm management.

Within this context, several researchers have focused on combining managerial and economic approaches with animal science (Rougoor *et al.*, 1997; Tauer and Stefanides, 1998; Rougoor *et al.*, 2000; Sorensen and Ostergaard, 2003). Over the last few years, performance analysis of decision entities has been given considerable attention, based on the realization that comparable firms,

operating under similar constraints and circumstances and producing similar outputs, exhibit wide variations in their competence. Economic theory asserts that the goal for efficient management is the optimal utilization of inputs to produce outputs in such a manner that maximizes economic returns. Based on Farrell's (1957), innovative article several approaches to efficiency and productivity assessment have been developed that can be classified into two broad categories: parametric and non-parametric frontier models. The former rely on the specification of an ad hoc functional form, impose certain a priori restrictions on the production technology, and estimate the parameters of the production or the cost function statistically. Alternatively, the latter construct a linear piecewise function from empirical observations of inputs and outputs, thereby avoiding the need to assume functional relationships between inputs and outputs or to make distributional assumptions regarding the residuals in a regression analysis.

Most of the non-parametric applications are based on the Data Envelopment Analysis (DEA) model as proposed by Charnes *et al.* (1978). In recent years, DEA has become a central technique in productivity and efficiency analysis, applied in different aspects of economics and management sciences. DEA has been used in comparing organizations (Athanasopoulos and Shale, 1997; Abbott and Doucouliagos, 2003; Sheldon, 2003), firms (Fare *et al.*, 1996; Chen and Ali, 2004) and regions or countries (Karkazis and Thanassoulis, 1998). In

agriculture, DEA has also been applied to studies of various products ranging from horticulture and cotton to aquaculture (Shafiq and Rehman, 2000; Sharma *et al.*, 1999; Iraizoz *et al.*, 2003; Banaeian *et al.*, 2010). Assessing the efficiency of pig farms is done by Lansink and Reinhard (2004) and Galanopoulos *et al.* (2006). Also researches on livestock farms are growing (Cloutier and Rowley, 1993; Fraser and Cordina, 1999; Reinhard *et al.*, 2000; Fousekis *et al.*, 2001, Gaspar *et al.*, 2009) which are mostly focused on dairy farms. A key question arising from frontier analysis is whether it is possible to determine common characteristics among best practice units. Existence of such characteristics implies that a certain pattern (behavioral and/or managerial personal characteristics) can be associated with efficiency levels and its influence on farm performance assessed. In the literature, numerous empirical studies attempted to explain variation in the success of farms by regressing efficiency scores on a set of explanatory variables.

Most studies concentrate on the influence of personal characteristics such as age, education, experience and specialization, or physical aspects such as farm size and certain input usage (Lansink and Reinhard, 2004; Fousekis *et al.*, 2001; Wilson *et al.*, 2001; Iraizoz *et al.*, 2003).

However, Rougoor *et al.* (1998) suggests that the attempt to explain variation in efficiency based solely on physical or biographical variables may be insufficient; even a farmer with high personal skills may be inefficient, provided his decision-making process (planning, implementation and control of decisions) is poor. Within this context, the efficiency of Iran commercial cattle farms measured, also on certain managerial aspects of cattle farming focused and investigated the extent to which a set of alternative breeding and production practices may affect a farm's performance.

The Holstein population of Iran established with the importation of registered heifers from Europe, US and Canada during 1970s and the first years of 1980s (Dadpasand *et al.*, 2008). With the expanding population of Holstein, Jersey and other foreign breed in whole regions of Iran, official organization of the livestock improvement, Animal Breeding Center, has been developed, as well. So far, over 1,200,000 native and crossbred cows have been registered. There appears to be great potential to improve economic efficiency by selecting best breed, location and managing amount of inputs for farmers.

The aim of this study is presenting DEA approach as a tool to improve the cost efficiency in agricultural management. At first, a brief description of the Iran herds and data culled in 2010 are given. Technical, pure technical and scale efficiency is calculated and efficiency is studied for provinces and herds based on size, purpose and breed.

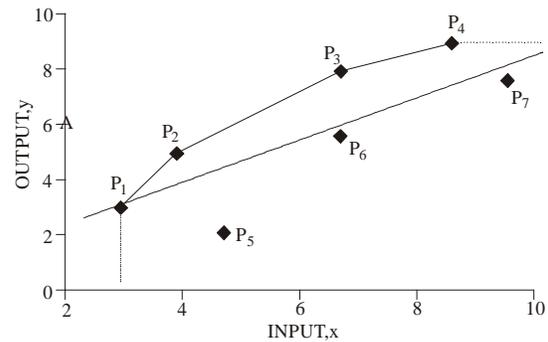


Fig. 1: Comparison of DEA approach and parametric approach (Regression Analysis)

MATERIALS AND METHODS

Model specification: The current paper uses the DEA approach to analyze the data. DEA optimizes the performance measure of each production unit or decision-making unit (DMU) (Charnes and Cooper, 1985). It results in a revealed understanding about each DMU instead of depicting the features of a mythical “average” DMU as in parametric analysis. In other words, the focus of DEA is on the individual observations as represented by optimizations (one for each DMU) in contrast to the focus on the average and the estimation of parameters that are associated with single optimization statistical approaches in parametric analysis.

In parametric analysis, a single regression equation is assumed to be applicable to all DMU. The approach requires the imposition of a specific functional form (i.e., regression equation, production function, etc.) relating the independent variables to the dependent variable. The selection of functional form also requires specific assumptions about the distribution of errors (independently and normally distributed) and many other restrictions. In contrast, DEA does not require any assumption about the functional form. It calculates a maximum performance measure for each DMU relative to all other units in the observed population with the sole requirement that each farmer lies on or below an external frontier. Each DMU that is not on the frontier is scaled against a convex combination of the DMUs on the frontier side closest to it. In addition, DEA can also analyze problems having multiple outputs with different units of measure.

The concepts used in the parametric and DEA approaches are demonstrated in Fig. 1 where the case of seven DMUs with single inputs and single outputs is considered. The input and output are shown on the x and y axes, respectively. The filled rhombuses represent different DMUs in the data set. The dotted line represents the linear regression line in the parametric approach, depicting the trend in the data points. This approach

implicitly recognizes all DMUs on or above this line as efficient.

In the case of DEA, however, one draws the envelope (or frontier) of the data set by joining the boundary points by straight lines. In Fig. 1, P_1, P_2, P_3 and P_4 are the boundary points. The solid line joining these points forms the envelope for the data set. The DMUs lying on the boundary and represented by points P_1, P_2, P_3 and P_4 are considered as efficient DMUs.

A unit can be made efficient either by reducing the input levels and getting the same output (input orientation) or by increasing the output level with the same input level (output orientation). The input oriented analysis is becoming more common in DEA applications because profitability depends on the efficiency of the operations. Further, on a tentative basis, it has been suggested in the literatures that inputs are generally more predictable and credible compared to the output oriented DEA models (Sengupta, 1987). In the present study, we have adopted an input oriented DEA approach for efficiency estimation.

It is evident in Fig. 1 that many DMUs that were considered efficient in the parametric analysis are not considered efficient in the DEA approach. Further, this approach can spell out the degree of inefficiency for each DMU and, thus, pinpoint the source of inefficiency. The DEA approach can even help rank the efficient DMUs and isolate the truly efficient DMUs from the others. Thus, the practices followed by the truly efficient DMUs can form a benchmark as the best operating practices for the inefficient farmers.

Estimation of various efficiencies: DEA defines efficiency in three different forms: technical efficiency, pure technical efficiency and scale efficiency. Technical efficiency is basically a measure by which DMUs are evaluated for their performance relative to other DMUs. Its value is, however, influenced by scale efficiency, which quantifies the effect of the presence of variable returns to scale in the DMUs. Pure technical efficiency is, thus, technical efficiency that has the effect of scale efficiency removed. The concept of these efficiencies is illustrated in Fig. 2.

In Fig. 1, we drew an envelope of the data set for the DMUs considering variable returns to scale. In Fig. 2, the line MN represents the envelope of the data set with constant returns to scale. It is a straight line that passes through the origin and the extreme data points. DMUs lying on this line are considered efficient. The DMU P_1 , the only point lying on this line, is, thus, efficient under the assumption of constant returns to scale; but due to the onset of decreasing returns to scale; the other DMUs do not lie on this line. So, the scale efficiency for P_1 is unity, whereas for the other DMUs, it is less than unity.

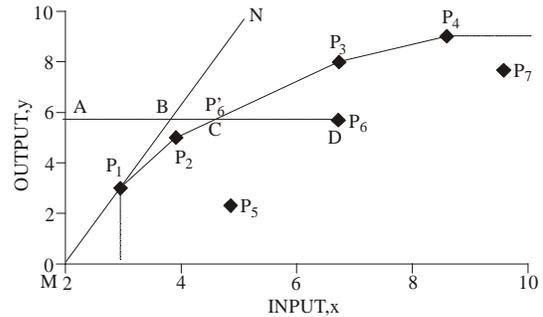


Fig. 2: Demonstration of various efficiencies

Let us consider DMU P_6 . Its input and output are given by AD and MA, respectively. B and C are the points of intersection of the line AD with the line MN and the line segment of the envelope of the data set. One can interpret AB as the ideal input required to produce the output B on MN, if constant returns to scale were to prevail. However, considering decreasing returns to scale to be a realistic phenomenon, one can relax the input requirement to be equal to AC to be able to produce the output B on MN. One can now define the various efficiencies as follows:

$$\begin{aligned} \text{Pure Technical Efficiency} &= AC/AD \\ \text{Technical Efficiency} &= AB/AD \\ \text{Scale Efficiency} &= AB/AC \end{aligned}$$

The relationship among these forms of efficiency is given as (Banker *et al.*, 1984):

$$\text{Technical Efficiency} = [\text{Pure Technical Efficiency}] \times [\text{Scale Efficiency}].$$

It may be noted here that the technical efficiency combines the effects of both pure technical efficiency and scale efficiency. Determining these efficiencies of DMUs facilitates planners pinpointing the sources of inefficiencies. Awareness about the sources of inefficiencies is crucial to policy planners, especially for planning the strategies that are meant to improve performance (Lovell, 1993).

In Fig. 2, P'_6 is a hypothetical DMU having input equal to AC and acts as a benchmark for the inefficient DMU P_6 . One may notice that P'_6 is represented as a convex combination of the efficient DMUs P_2 and P_3 . Thus, a DMU is said to be inefficient in producing the output from a given input if any other DMU or combination of DMUs can produce a larger output for the same or less amount of inputs or if any other DMU or combination of DMUs can reduce amount of inputs without reducing the output (Sahoo, 1999). Such a DMU will always lie inside the envelope rather than on it.

It is easy to graph and visualize the case of DMUs having single inputs and single outputs. However, in the

Table 1: Statistics on input and output data (\$/Unit)

	INPUTS			OUTPUTS		
	Feed	Fuel, electricity and water	Other expense	Milk	Manure	Other received
Max	663912.12	19108.55	59471.23	521554.94	18581.12	1470.18
Min	102.01	2.67	11.31	44.31	6.54	0
Average	45787.05	1317.85	4101.51	35969.31	1281.46	101.41
SD	124294.41	3548.62	10988.98	97817.29	3403.41	277.32

multiple inputs, multiple outputs case; we cannot always visualize the efficient units graphically. We need to resort to analytical means to identify these efficient units.

The usual measure of efficiency (i.e., Efficiency = Output/Input) is often inadequate due to the existence of multiple inputs and outputs. The measurement of pure technical efficiency, where there are multiple and incommensurate inputs and outputs, was first addressed by Farrell (1957) and developed by Farrell and Fieldhouse (1972). It focuses on the concept of a hypothetically efficient DMU, defined as a weighted average of efficient DMUs, to act as a comparator for an inefficient DMU. This hypothetically efficient DMU is known as a virtual DMU and acts as a benchmark for an inefficient DMU. A common measure of efficiency is:

$$\text{Efficiency} = \frac{\text{Weighted sum of outputs}}{\text{Weighted sum of inputs}}$$

Sample selection and data description: Culling data and conformation scores were extracted from the records collected from whole commercial cattle of Iran by the Ministry of Agriculture in 2010. After editing, 18,830 unit of industrial cattle farms (herds) and 2,048,563 dairy and beef cows were available for the analysis. The cows were from 28 provinces and all cows were registered in official herd book of the National Animal Breeding Center of Iran.

The analysis was based on three input resources, payment of water, electricity and fuel, feed and other expenditures, while the process output is expressed as three received resources of milk, farmyard manure and other revenues (hundred dollars per farm). Table 1 presents the descriptive statistics of the variables used in the analysis. A wide variation in both the input use and the output is noticeable.

The data analysis was carried out with the help of the DEA solver software, Version 7.1 (Cooper *et al.*, 2010). The software was used to calculate constant and variable returns to scale with radial distances to the efficient frontier and to rank DMUs using the benchmark method.

RESULT AND DISCUSSION

Mean technical, pure technical and scale efficiency: Results obtained by the application of the input-orientated DEA are illustrated in Table 2. DEA technique creates efficiency indices by comparing the performance of each farm with the best production practices observed, which

Table 2: Commercial cattle farms of Iran

Input oriented	Total		
	Technical	Pure technical	Scale
Average efficiency scores			
Efficiency	0.743	0.792	0.938
SD	0.23	0.24	0.19

define the efficiency or production frontier. The mean radial technical efficiency of the sample is 0.743 and 0.792 under CRS and VRS assumptions, respectively. This implies first, that on average, farms could reduce their inputs by 25.7% (20.8%) and still maintains the same output level, and second, that there is considerable variation in the performance of commercial cattle farms in Iran. Given that inefficiency variation among the sample farms was large, we investigated whether efficient cattle farms share certain common characteristics in terms of management practices.

For comparison reasons, we note that our findings lay in-between Lansink and Reinhard (2004) who report 0.89 and 0.9 average technical efficiency under CRS and VRS, respectively in Netherlands and Galanopoulos *et al.* (2006) whose corresponding figures are 0.78 and 0.82 for the Greece in pig farms. Also Hanson and Ohlmer (2008) in Swedish dairy farms showed that the average efficiency scores range from 0.616 for short-run economic efficiency to 0.889 for short-run technical efficiency.

The interpretation of the scale efficiency scores allows for some interesting remarks. Mean scale efficiency is 0.938, implying that the average size of Iran commercial cattle farms is not far from the optimal size, although an additional 6.2% productivity gain would be feasible - assuming no other constraining factors provided they adjusted their farm operation to an optimal scale. By contrast, Gaspar *et al.* (2009) reported a lower (0.71) scale efficiency for livestock farms in the Spain.

The measurement of the efficiency has taken place from inputs per farms thus allow making a different interpretation from the scale efficiency that, instead of referring to the dimension of the farm, is referred to the intensification. Return to scale of farms were calculated as well and 17.02, 52.65 and 30.33% of Iran cattle farms were operating under constant, decreasing and increasing return to scale, respectively. The majority of the scale-inefficient farms are operating under decreasing returns to scale (i.e., at a point corresponding to the upward portion of the Long-Run Average Cost curve) and the remaining under increasing returns to scale. Efficiency analysis

Table 3: Distribution of provinces efficiency

I	0.99-0.9	0.89-0.8	0.79-0.7	0.69-0.6	Less than 0.6
Yazd	Qazvin	Hamedan	Kurdistan	Gilan	Hormozgan
Kerman	Kohgiluyeh and Boyer-Ahmad	Golestan	Tehran	West Azarbaijan	Lorestan
Sistan	Isfahan	Khorasan	Fars	Qom	Markazi
Zanjan	Chaharmahal and Bakhtyari		Mazandaran	Kermanshah	Semnan
Ardebil				Bushehr	Ilam
East Azerbaijan					Khuzestan

Table 4: Mean actual and efficient input use levels of provinces in variable return to scale

	Inputs			Outputs			
	Feed	Water, fuel and electricity	Other expense	Milk	Manure	Other revenues	Total
Input Oriented							
Actual	15945.75	458.96	1428.40	12526.63	446.28	35.32	
Target	14576.54	415.37	1176.07	12526.63	446.28	35.32	
Difference	1369.21	43.58	252.32	0	0	0	1665.12
Output Oriented							
Actual	15945.75	458.96	1428.40	12526.63	446.28	35.32	
Target	15945.75	458.96	1428.40	13821.27	615.85	39.16	
Difference	0	0	0	1294.64	319.16	3.83	1468.04

theory suggests that the latter are obviously small farms that need to increase their size in order to achieve cost savings, whereas the former are larger farms that have expanded more than necessary and thus would be better off by reducing their size.

Provinces efficiency: Table 3 presents distribution of provinces efficiency done by input oriented, constant return to scale DEA models. Yazd, Kerman, Sistan, Zanjan, Ardebil and East Azerbaijan efficiency score were calculated 1. Yazd province was the most efficient province which appears 20 times in reference set benchmarking of inefficient provinces. Hormozgan, Lorestan, Markazi, Semnan, Ilam, Bushehr and Khuzestan provinces placed in lowest level of efficiency and Khuzestan with 19.48% efficiency score becomes the most inefficient province.

The interpretation of actual and target inputs and outputs in input and output oriented models respectively brings out some interesting points. Using the information of input oriented model in Table 4, it is possible to advise a producer regarding the better operating practices followed by his/her peers in order to reduce the input cost levels to the target values indicated in the analysis while achieving the output level presently achieved by him. It gives the average cost spent, targeted (thousand dollars per unit) and possible cost savings. So input oriented model shows that if each provinces operate efficient, will save 1665.12 thousand dollars from cattle farms, while are producing the same outputs. The study shows that feeding is perhaps the most crucial element of cattle farming. It is evident that the maximum contribution to the total cost savings is from feed, which indicate that cattlemen should pay more attention to management of feed consumption. Also considering to the largest part of feed expense in consumed costs, the choice of feeding, control over the bought feed mixes and quality and

Table 5: Average efficiency scores according to purpose, size and breed

<i>Classification by purpose</i>				
	Dairy cattle	Beef cattle		
TE	0.775	0.681		
PTE	0.807	0.780		
SE	0.960	0.873		
<i>Classification by size</i>				
	less than 100 cows	100-199 cows	more than 200 cows	
TE	0.740 ^a	0.619 ^a	0.980 ^b	
PTE	0.796	0.666	0.981	
SE	0.929	0.929	0.998	
<i>Classification by breed</i>				
	Holstein	Jersey	Foreign	Native
TE	0.92 ^a	0.72 ^b	0.64 ^b	0.62 ^b
PTE	0.95	0.81	0.75	0.85
SE	0.96	0.88	0.85	0.72

adaptation to the cattle's particular needs will be ensure and should therefore be associated with higher efficiency levels.

In second model (output oriented model) differences between actual and target outputs calculated 1294.64, 319.16 and 3.83 for milk, manure and other revenues respectively. It means that if provinces placed on the efficiency frontier, with the same amount of inputs will be able to produce on average 1468.04 thousand dollars more revenue.

Efficiency by purpose, size and breed: In Table 5 mean technical efficiency scores calculated at constant and variable returns to scale according to production purpose, cattle size and breeds of cow. Although efficiency scores in beef and dairy cattle are very close to each other, results show that dairy cattle are more efficient. As can be seen, the most difference has been appeared in technical efficiency and calculated 0.775 and 0.681 for dairy and beef cattle, respectively. Therefore it is feasible that cattlemen in beef cattle should give more consideration on management of inputs consumption to achieve better production efficiency.

The classification of commercial cattle farms according to their size class shows that on average the larger farms are more technically efficient than medium and small-sized farms (Table 5). In cattle where the farms exhibit the highest mean TE score, the average number of cows is more than 200. Large farms are also more scale-efficient. In an attempt to explain these results, one may note the association of farm size and efficiency scores. Consequently, it can be argued that size is a crucial element in the economic viability of cattle farms. Smaller farms are impeded by greater technical inefficiencies whereas the large farms achieve better performance benefiting both from increased technical efficiencies as well as from greater economies of scale.

Table 5 presents the distribution of efficiency scores across the four study breeds. The origin of the breed and genotype has also a significant effect on the cattle's characteristics. When considering the Holstein cattle are the most technically efficient, and are considerably more efficient than other breeds. On the other hand, only Holstein breed shows significant technical inefficiency and differences between other breeds were insignificant. According to result native breeds of Iran placed in lowest level of efficiency. The most famous native Iranian cattle breeds are Sarabi, Golpayegani, Mazandarani and Sistani which due to increasing efficiency level, more effort should be applied in management of them.

At the end of this study, it is proposed that DEA is a useful tool in helping to benchmark the dairy and beef industry, which is continually striving to improve its productive efficiency. DEA takes a systems approach in that it takes account of the relationship between all inputs and outputs simultaneously. DEA yields a more consistent measure of efficiency than the more frequently reported partial indicators of farm efficiency. In addition, DEA yields a relative measure of efficiency and it identifies those inputs and/or outputs that are being under-utilized. From an extension perspective this is extremely useful information as it can assist in identifying industry best-practice.

CONCLUSION

In this study a DEA model has been applied in order to investigate the degree of technical and scale efficiency of commercial cattle farming in Iran. This procedure allows the determination of the best practice farms and can also provide helpful insights for farm management. By using these farms as benchmarks, inefficient farms can determine which changes in resource use are necessary in order to increase their overall performance and, ultimately, their profitability.

The mean radial technical efficiency of the sample is 0.743 and 0.792 under CRS and VRS assumptions, respectively. Thanks to the input-oriented analysis it can

be established that the farms could maintain similar production levels by introducing a 25.7% (20.8%) reduction of their inputs.

Yazd province was the most efficient province which appears 20 times in reference set benchmarking of inefficient provinces and Khuzestan with 19.48% efficiency score becomes the most inefficient province. On average input oriented model shows that if each provinces operate efficient, will save 1665.12 thousand dollars from cattle farms, while are producing the same outputs and output oriented model shows that if inefficient provinces placed on the efficiency frontier, with the same amount of inputs will be able to produce on average 1468.04 thousand dollars more revenue. So with a proper management, huge budget in each province will be saved and used in other essential matters.

This study has been investigated the efficiency of both dairy and beef cattle in Iran, and also the effect of breeds and regions have been reviewed. Results show that dairy purpose cattle farms are more efficient than beef cattle farms; also ANOVA test revealed that the choices of Holstein breed and herd with more than 200 cows have a positive significant impact on the efficiency level of cattle farms. Thus the use of dairy, Holstein and large cattle farms are positively correlated with efficiency, suggesting that these can be associated with increased farm performance.

These results are of importance for the cattle farming sector. Following the general tendency of worldwide agricultural trade liberalization due to the ongoing WTO negotiations, the level of competition is expected to increase. The cattle farming sector will unavoidably be affected as well, leading to a more market-orientated sector characterized by increased competition and imports, reduced statutory subsidies, export supplements and intervention measures.

The methodology presented in this paper demonstrates how farmers may benefit from applying operational management tools to assess their performance. Undoubtedly, additional research is required to generalize the evidence provided in this study, in particular regarding the explanation of the underlying differences in efficiencies in the use of a particular input and the assessment of the constraints to changes in operational practices that would improve efficiency. Nevertheless, some interesting insights regarding the performance of the cattle farming sector in Iran, along with an indication of the relationship between certain managerial practices and technical efficiency, may have been provided.

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