Measuring the economic performance of mixed crop-livestock farming systems in Egypt

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DOI: 10.30682/nm2002i
JEL codes: C14, D24, Q12, Q18

Abstract

This study examines the relative technical efficiency of mixed crop-livestock farming systems and assesses their economic performance between the Upper and Delta regions of Egypt. A non-parametric data envelopment analysis (DEA) method is empirically applied for measuring technical efficiency using farm-level data for 838 mixed crop-livestock farmers. The findings show that the mixed crop-livestock farms in Egypt are operating at a low level of technical efficiency, indicating most farms are unable to catch up with the current production frontier and existing production technologies. Farms in the Delta region perform slightly better than those farms in Upper Egypt. Results also suggest that technical efficiency improvement is positively affected by farmers' education, having a farm milk production certificate, and being located in the Delta region, whereas farm size negatively affects the economic performance of mixed crop-livestock farming systems in Egypt.

Keywords: *Technical efficiency, Non-parametric DEA model, Livestock products, Farming systems in Egypt.*

1. Introduction

Livestock products are the best sources of highly digestible proteins and micronutrients, which are essential for human health and nutrition. The Egyptian population is expected to increase by 65% in the next three decades (FAO, 2017). In response to this population increase and the growing demand for animal products, livestock productivity in Egypt needs to be improved. Both cattle and buffaloes play an important role in the mixed crop-livestock production systems of Egypt. Furthermore, livestock and livestock products are a vital source of smallholder farmers' income: producing considerable amount of meat and milk, 80% of livestock is owned by smallholder farmers in Egypt (Ayeb and Bush, 2014).

Egyptian cattle and buffaloes play an important role as providers of milk and meat. Having 99% of the entire continent of Africa's buffaloes, Egypt is a prominent buffalo-producing nation (FAOSTAT, 2015). In total, 8.6 million cattle and buffaloes can be found in Egypt, of which 43% are buffaloes and 57% are cattle. The

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production of milk from buffaloes contributes about 47% to the total national milk production, while cattle contribute 51%. Buffaloes contribute about 41% to national meat production and cattle contribute 43% (FAOSTAT, 2016). Livestock are an integral part of agricultural farming systems in Egypt, with livestock products representing 40% of value-added agriculture. These products are important contributors to total food production as they convert low-value materials into valuable products. Buffaloes are mostly reared in smallholder farms under harsh socioeconomic conditions, leading to low productive and reproductive performances. About 42% of the buffalo populations are dairy cows, 6% are bulls, 32% are heifers, and 20% are male calves (Ibrahim and Abdelrazek, 2012). About 97% of the Egyptian buffalo population is raised in small size herds within semi-intensive traditional mixed crop-livestock production systems, which is the main livestock production system in Egypt. About 57% of Egypt's buffalos are kept in Delta, in northern Egypt, while 43% are kept in Middle and Upper Egypt in the southern part of the country (Fahim *et al.*, 2018).

To meet the growing demand for livestock products due to rising populations in recent years, the livestock sector could become the largest contributor to improving the capacity of agricultural production. However, Egypt's livestock sector has declined in recent years because of many technical reasons, including: a lack of fresh drinking water; groundwater contamination; a lack of biological diversity; the spread of infectious diseases; lack of antimicrobial resistance; and having to compete for vital and limited irrigated cropping areas. Due to these challenges, Egypt's options for expanding livestock production are limited. However, under the existing production structure, there does seem to be some potential for change to increase productivity by increasing the production efficiency (FAO, 2017).

Recently, the Egyptian government is making more efforts to enhance the efficiency of livestock systems. One of the main objectives of the Sustainable Agricultural Development Strategy Towards 2030 (SADS) is to develop the agricultural sector economically and socially in the direction of more sustainability by paying more attention to improving and enhancing the efficiency of livestock herds. This could especially help smallholder farmers improve their income and resiliency (FAO, 2017). The objective of this research article is to shed light on the economic performance of crop-livestock farming systems in Egypt, and to distinguish and compare these farming systems in different regions. This will be achieved through a measure of technical efficiency (TE), which is a prerequisite for the economic viability and sustainability of a firm (Tzouvelekas *et al.*, 2001).

Livestock production in Egypt varies among the Delta region and Upper Egypt, where the nature of the land, temperature, and the cultivated crops differ. A study by Fahim *et al.* (2018) assessed the difference between buffalo production in the Delta and Upper Egypt, finding that an average household in the Upper Egypt did not own more than three animals, while households in the Delta region owned ten animals on average. The researchers also found that buffaloes represented 66% of all ruminants in the Delta region, but only 44% in Upper Egypt. The low number of animals in both zones is attributed to the limited availability of feeding resources and infrastructure. Cattle represent the second highest ruminants in rank within all farms' herds, while sheep and goats formed 25% of herds raised in Upper Egypt compared to 13% in the Delta region. Their study also found that 94% of the buffalo farmers in Upper Egypt used some of their raw milk to produce dairy products (such as cheese, cream, and butter), while only 78% of the buffalo farmers in the Delta region produced dairy products. Basic processing methods were used in both regions. Some of the liquid milk and dairy products were consumed by family members and the rest was sold through village markets.

Transportation services, storage facilities, and grading dairy products are quite poor and not available at many regions. Recently, the animal-product sectors have received remarkable attention to meet growing requirements. However, there hasn't been any studies assessing the performance of livestock farms, nor the differences among productivity and TE between the Delta region and Upper Egypt. Therefore, this research is focused on an efficiency analysis in order to gain more information about the differences between Delta region and Upper Egypt livestock farms. This information is useful for economic agents (i.e., policy makers and regulatory authorities) to design suitable policies to improve the performance of livestock farms within Egypt. A measure of TE is applied to determine the deficiencies in input use that will need to be improved. TE is analyzed using a parametric Stochastic Frontier Analysis (SFA) and non-parametric Data Envelopment Analysis (DEA) approaches.

In agriculture research especially, SFA and DEA methods have been widely used by empirical studies to assess the TE of farm production entities. The SFA approach was introduced by Aigner *et al.* (1977) and Meeusen and van den Broeck (1977). The approach is based on an econometric regression model that parametrically evaluates the frontier by using a stochastic procedure, in which the residuals can be decomposed into error term and positive inefficient elements. In contrast, the DEA model initially introduced by Charnes *et al.* (1978) is a non-parametric approach which estimates the frontier over the distribution of the observations that lie on or below the frontier line. DEA methodology has been used to study the economic performance of Decision Making Units (DMUs), in which a set of peer entities utilize multiple inputs to be converted to multiple outputs. The SFA method assumes that the distributions deviated from an estimated frontier are inefficient and a certain form of frontier must then be defined, leading to a biased TE estimation. For this reason, most recent studies, especially agribusiness ones, prefer to apply the DEA approach instead of the SFA. To overcome the shortcomings of the SFA method, we used a DEA model in this paper to assess the TE of the livestock farms in Egypt and determine the differences in performances between farms in the Delta region and Upper Egypt.

This paper is organized as follows: In the next section, a literature review of TE analyses and the contribution of this work to previous literature are presented. In section three, livestock production industry in Egypt is described. In section four, the methodological approach is described; the fifth section is devoted to the empirical implementation of assessing TE using the DEA approach. The last section of this paper offers concluding remarks.

2. Literature review

Concerning the methodological approach, a number of techniques have been applied to assess the economic performance. Some of this literature estimate the economic performance of the farms by considering production components as benchmarks, such as a costs per unit produced. However, these techniques have been shown to incorporate some shortcomings by potentially ignoring the enhancement of farm-specific production performance as a whole within the benchmark group (Gelan and Muriithi, 2010; Stokes *et al.*, 2007; Fraser and Hone, 2001). To overcome these shortcomings, the literature has delivered methods to estimate the production efficiency that analyze the economic performance of the farms as whole. As described above, most of the literature on productive efficiency analysis for farming systems relies on two approaches: the SFA (Parametric and Stochastic Frontier Analysis) and the non-parametric DEA (Data Envelopment Analysis). Nevertheless, the literature on TE performance of livestock farms is still scarce, which may be due to the lack of data that is required for such analysis.

Li *et al.* (2017) analyze TE among the top agricultural-producing countries in Asia through an applied Zero Inefficiency Stochastic Frontier Model (ZISFM). Results reveal that the average TE score is over 0.9 for all samples, which indicates that there is still room for improving TE.

A study by Galluzzo (2018) relies on a DEA model to assess the economic performance of farms in Bulgaria after entering the European Union (EU). Results indicate that specialized farms, such as dairy and granivores farms, worked more efficiently than mixed farms and vineyard farms. Results also show that the TE of the farmers was highly affected by the financial subsidies provided by the Common Agricultural Policy that affected the socio-economic marginalization of Bulgarian rural areas.

Błażejczyk-Majka (2017) studied the agricultural production efficiency rankings of EU member states; a DEA model was applied for this purpose. Results show that the economic performance of agricultural production for 18 out of 28 EU states is running efficiently. The DEA approach shows the causes of inefficiency in the remaining ten states, allowing for the poor agricultural practices that reduce productivity to be identified. It also formulates a set of recommendations that may enhance production efficiency.

An article by O'Neill *et al.* (1999) summarizes the application of both a fixed effects panel model and a stochastic production frontier approach to a panel of 307 farms drawn from the Irish National Farm Survey over the 1984-1994 period. The results found that the performance of farms is positively affected by extension contact.

Gelan and Muriithi (2010) assess the TE among 371 dairy farms located in seventeen districts in east African countries by relying on a DEA approach to estimate TE scores. A fractional regression method was applied as well to identify the TE scores by linking them to a set of explanatory variables. Results indicate that 18% of the farms were fully productive, each with TE scores of unity, which implies that these farms lie on the production possibility frontier. On the other hand, 32% of the farms have TE scores below 0.25, indicating that these farms would need to increase dairy production by 75% from current levels without any increase in the level of inputs. Results also show a positive effect on the efficiency levels through adopting technology factors, zero-grazing systems, and selling milk to individual consumers or organizations instead of other market outlets. The membership of dairy cooperatives was not statistically significant.

Michaličková *et al.* (2013) analyze the TE of dairy cattle farms in Slovakia over the 2006-2010 period using a DEA approach. An average TE score of 0.96 was found, implying that 96% of the herds are technically efficient in producing milk, and reducing 4% of the inputs used to produce milk is recommended. The TE was statistically affected by feed costs, though not affected by the factor indicating inefficient utilization of feed.

Research by Spicka (2014) evaluates the production efficiency of mixed crop-livestock farming among 103 FADN EU regions. A DEA approach with variable returns to scale (VRS-DEA) has been used for this purpose. Results indicate that the significant factors affecting the production efficiency of the mixed farming system are crop output per hectare; livestock output per livestock unit; productivity of material; energy; capital; and contract work. The study also found that agricultural projects are extended in inefficient areas and produce public goods which benefit from the rural development subsidies.

Demircan *et al.* (2010) measure the TE of 132 dairy farms in Turkey using a DEA model. Their findings show a TE ranging from 28.6% to 100.0%, with an average of 64.2%. The inputs of forage feed and labor were not used efficiently. Moreover, results confirm the existence of a positive relationship between herd size and efficiency, and a negative relationship between forage feed, land size and production efficiency. The study also provides evidence that there is not a significant relationship between the provision of extension services and the production efficiency score.

Mohamed *et al.* (2008) find that milk products in Egypt are redirected to consumers through both official and unofficial milk supplies. The unofficial market involves direct delivery of raw milk by farmers to consumers in their neighborhood, or it might pass through the hands of a distributor in nearby cities. The unofficial market is characterized by not needing a license to do business, weak pricing process, high farmer prices compared to the formal market, and no systematic procedures. Permits are not a precondition, and activities are also not monitored. Egypt's dairy sector has an essential position in the food supply, representing about 47% of food and agribusiness. The dairy trade constitutes the production of fresh milk and dairy products, such as butter, cheese, and yogurt. Dairy marketing paths for smallholders are hindered and there is a lack of transparency. Egyptian consumers prefer fresh milk and milk products (cheese, butter, and yoghurt) because of their clear descriptions; buffalo milk is white in color, a high fat content (around 7%) and a desirable flavor (Abdel Aziz and Sadek, 1999). Cheese consumption in Egypt is evaluated by 10.4 kg per capita per year (CDIC, 2014).

Smallholders produce large amounts of milk that makes its way to the unofficial market. To date, the entire milk distributed to the Egyptian capital of Cairo on a daily basis has not been tracked or studied. An estimated 80% of the milk in demand is supplied by the unofficial market. The Egyptian government has recently started to pay special attention to regulating and tracking the distribution of milk in different regions and villages. Khalil and Ahmad (2013) studied mixed crop-livestock smallholders' milk supplies in three different Egyptian governorates: two in the Delta region (El-Beheira (B) and Kafer El-Sheik (K); buffalo-rice-based systems) and one in Upper Egypt (Qena (Q); buffalo-sugar-cane-based systems). Buffalo milk is essentially used fresh or produced into butter. Buffalo milk revenue in B was significantly higher ($P \leq 0.05$) than that in Q and K. This could be because total milk yield was higher in B than K. The amount of buffalo milk rations sold in B was the highest, followed by K and Q. This may be due to high milk costs which induce producers to give extra attention to milking buffalo. Request for buffalo milk in B was more than the milk produced. In K, two-thirds of buffalo milk was purveyed and the rest was used for house consuming. In Q, however, milk marketing and selling was very basic due to social traditions of farmers sharing milk between neighboring households, workers, and relatives. Farmers receive agreeable prices for milk sold directly to consumers in the three targeted governorates. Variations between farm prices and other prices might be because the volume of milk produced in K was higher than local demand. As a result, distributers bring the milk to larger towns that offer best prices. The ratio of market cost damages in Q was higher than in B. This might be due to the long distances between milk farmers and markets, or the weak productivity of cows' traders collect milk from, which costs more money. There is an apparent difference in milk marketing margins among farm prices and consumer prices because of the chunks of farm revenues that traders receive as commission. This implies that farmers could acquire additional milk revenue if producer associations or cooperatives are established to enhance farm milk value. Treating milk to extend its shelf life is a viable alternate that can warranty best market costs.

This paper contributes to the efficiency literature by comparing TE levels of Delta region and Upper Egyptian livestock farms. Performance differences between the two farm types are also analyzed by determining the maximum output using different inputs in the production process. To our knowledge, this is the first attempt to study TE for livestock farms in Egypt using the DEA method.

3. Livestock production industry in Egypt

The majority of the farms in Egypt are mixed crop/livestock farming system with buffalo, cattle, sheep, and goats. The farm size is mostly small (1.2-9.7 hectare) with high cropping intensity. In addition to growing grains and crops, ruminants are critical to local farming systems in Egypt. Seasonal sales of these products represent the main method used by rural families to access currency, to invest in agricultural inputs, and to improve their households. Crop residues (i.e. animal fodder, straw) are essential for these ruminants, providing nutritious feed during the summer season and ensuring the fattening of the animals. The key aspect of the system is currently under developed leading to an under production of several livestock by-products, such as milk and cheese. It is unable to breed stronger flocks by the rural communities, who are often unaware of the dietary benefits of different crops and types of straw partially for the recycling of nutrient to maintain soil fertility and provide additional income in the form of milk and/or meat. Feed quality strongly varies with season, with the best feed available in winter with the production of clover. The ruminants are responded to the variation in feed supply by adjusting milk production and fertility. The major problem to achieve significant development in the dairy sector is the small size of the farms, which is the result of the inheritance system.

In 2017, the live animals in Egypt were 181.6 million heads representing 5.6% of live animals in Africa and were imported around 2 million head. Cattlesand buffaloes represent 4.6% (8.4 million head) of the total live animals in Egypt, while sheep and goats represent 5.5% (10 million head), and poultry birds represent the majority of the live animals in Egypt which is 94.7%. That amount of live animals produced 2.2 million tons of meat and 4.6 million tons of milk (FAOSTAT, 2017).

The production of yellow corn in Egypt is not sufficient to meet the animal feed demand and covers less than 20% of its feed demand needs. In 2018, Egypt imports a total of around 9.1 million metric tons of yellow corn (USDA-FAS, 2019). Most of the yellow corn is imported from Argentina, Ukraine, Brazil and the United States by 2.7, 2.4, 2.1, and 1.8 million metric tons, respectively.

4. Methodology

Data Envelopment Analysis (DEA) is used to assess and compare TE levels between Delta region and Upper Egypt livestock farmers. While the DEA method has been widely used in agricultural economics literature (Wang *et al.*, 2018; Toma *et al.*, 2017; Baležentis, 2015; Vasiliev *et al.*, 2008), empirical studies that use DEA to assess TE among livestock farmers are scarce, even more so in developing economies. The DEA model is based on Charnes *et al.* (1978) and shows the performance of a DMU among certain famers or agricultural firms by determining the ranks of the entities. Thus, inefficiently used inputs that are identified, which is relevant for making appropriate management decisions and creating support schemes to enhance farm efficiency, leading to an improvement in production competitiveness. The DEA model converts the multiple inputs into multiple outputs to evaluate economic performance through estimating operational processes (Cooper, 2011; Toma *et al.*, 2015). This model could be either input-orientated (minimize inputs used to obtain the same level of output) or output-oriented (maximize outputs through using the same level of inputs) (Malana and Malano, 2006; Toma *et al.*, 2015). In the agricultural sector, output-oriented DEAs are preferred, as farms tend to maximize their outputs given the scarcity of the resources. For this purpose, the objective of this analysis is to estimate TE under a circumstance whereby the DMUs produce the maximum feasible outputs for a fixed level of inputs. Each DMU estimated has different input components to produce different levels of outputs, then each DMU efficiency score is compared with the most efficient DMU using the DEA approach (Toma *et al.*, 2015).

The first DEA model developed by Charnes, Cooper, and Rhodes (1978) assumed constant returns to scale (CRS), which became known as the 'CCR model' in the literature. Subsequently, Banker, Charnes, and Cooper (1984) extended the CCR model to account for variable returns to scale (VRS), which is known as the 'BCC model'.

Assuming there are N decision making units (DMUs), where each DMU uses K inputs to produce M outputs, the i^{th} DMU utilizes x_{ki} units of the k^{th} inputs to produce y_{mi} units of the m^{th} outputs.

According to the BCC model, the output-oriented VRS DEA model for the i^{th} farm unit can be expressed as follows:

$$\max_{\phi_j,\lambda_{ij}} \phi_j \qquad (1)$$

Subject to

$$\begin{aligned}
&\textstyle\sum_{i=1}^{N} \lambda_{ij} x_{ki} + s_{kj}^{-} = x_{kj} && \text{for } k=1,..,K \\
&\textstyle\sum_{i=1}^{N} \lambda_{ij} y_{mi} - s_{mj}^{+} = \phi_j y_{mj} && \text{for } m=1,..,M \\
&\textstyle\sum_{i=1}^{N} \lambda_{ij} = 1 && \text{for } j=1,2,...,N \\
&\lambda_{ij} \geq 0, && \text{for } i=1,2,...,N \\
&s_{kj}^{-} \geq 0, s_{mj}^{+} \geq 0, && \text{for } k=1,..,K \text{ and } m=1,...,M
\end{aligned}$$

where $1 \leq \phi \leq \infty$ and $\phi_i - 1$ is the proportional increase in outputs that could be achieved by the i^{th} farm with input quantities held constant; s_{kj}^{-} is the k^{th} input slack for the j^{th} farm; s_{mj}^{+} is the m^{th} output slack for the j^{th} farm; and λ_{ij} is the farm weight of the j^{th} farm unit. If the constraint is eliminated, this VRS DEA model will turn into an output-oriented CRS DEA model, also known as the output-oriented CCR model.

The output-oriented DEA frontier attempts to maximize the proportional increase in output levels while remaining within the envelopment space or efficiency frontier. The proportional increase in output is achieved when the output slack, s^{+}_{mj}, becomes zero. If $\phi_j = 1$, $\lambda_{ij} = 1$ for $i = j$, and $\lambda_{ij} = 0$ for $i \neq j$, the results indicate the j[th] farm unit is efficient and lies on the frontier. If $\phi_j > 1$, $\lambda_{ij} = 0$ for $i = j$, and $\lambda_{ij} = 0$ for $i \neq j$, the results indicate the j[th] farm unit is inefficient and lies outside the frontier.

The efficient output level for the j[th] farm unit, denoted by , is defined as:

$$y^{*}_{j} = \sum_{i=1}^{N} \lambda_{ij} y_j = \phi_j y_j \qquad (2)$$

Following Farrell (1957), the output-oriented TE score of the j[th] farm is defined as the ratio of observed output to the efficient output, which can be expressed as:

$$TE_j = \frac{y_j}{y^{*}_{j}} = \frac{y_j}{\phi_j y_j} = \frac{1}{\phi_j} \qquad (3)$$

Hence, $1/\phi_j$ defines an output-oriented TE scores of the j[th] farm, which varies between zero and one.

To investigate the nature of scale inefficiencies, whether the DMU is operating in an area of increasing or decreasing returns to scale (RTS),[1] an additional DEA problem with non-increasing returns to scale (NIRS) can be run. This can be done by altering the VRS DEA model by substituting the $\sum_{i=1}^{N} \lambda_{ij} = 1$ constraint with the $\sum_{i=1}^{N} \lambda_{ij} \leq 1$ constraint. Then, the nature of the scale inefficiencies for a particular farm can be determined by comparing whether the TE scores obtained from the NIRS frontier is equal to the TE scores from the VRS frontier. Equal scores imply that the firm is operating at decreasing RTS; conversely, unequal scores imply that the firm is operating at increasing RTS. The VRS hypothesis is based on that the unit size is fixed and focused on the short term. In our case of the mixed farming system with different scales, the farmers can control the sizes. Thus, the VRS DEA model has been applied.

In addition, this study employs a Tobit regression model (also known as truncated or censored regression model) to investigate factors influencing a farm's efficiency. Since the output-oriented TE scores obtained from the VRS DEA model have values at the interval $\langle 0,1 \rangle$, the use of classical regression may lead to distorted results as the condition of the least squares, which is used to estimate the parameters of the regression model, is not met. The type of regression for a limited dependent variable is used to determine the relationship between the TE scores and other factors.

The standard Tobit regression model is characterized as:

$$Y_i = \begin{Bmatrix} \beta' Z_i + \varepsilon_i \\ 0 \end{Bmatrix} \begin{matrix} , & \beta' Z_i + \varepsilon_i > 0 \\ , & \beta' Z_i + \varepsilon_i \geq 0 \end{matrix} \qquad (4)$$

where Y_i is the dependent variable representing the TE scores obtained from the VRS DEA model; Z_i is the environmental variable which could influence the farm's efficiency and is assumed not to be under the control of the farmer; β is the coefficient parameter for the Z_i variable indicating the expected proportionate change of the dependent variable with respect to one unit change in the environmental variable Z_i holding other factors constant; and $\varepsilon_i \sim N(0,\sigma^2)$.

5. Empirical application and results

This analysis is based on cross sectional data; the survey data was conducted via face-to-face interviews and questionnaires with smallholder farmers during the period from January to July 2015 in Egypt's Delta region (specifically from: El Menoufia, El Sharkia, Qaluibia, Kafr-Elshikh, and El Behira Governorates) and Upper Egypt (specifically from: El Fayum, Suhag, Assiut, El Minya, and Beni-Suef Governorates). The sample data used in this study consists of 838 dairy

[1] RTS is a commonly used measure to describe the long-run production where firms are able to adjust all inputs in respond to change the scale of production. RTS measures rate at which all output increase as all inputs are increased proportionally. During the production process, an increasing RTS can occur when the outputs increase more than an increase in inputs used. Similarly, a decreasing RTS can occur when the outputs increase less than an increase in inputs used whereas a constant RTS occurs when the outputs increase the same proportion as an increase in inputs used. For example, farm outputs increase more than double when all inputs are doubled. This implies that the farm has experienced an increasing RTS.

smallholder farmers (500 dairy farmers in the Delta region and 338 in Upper Egypt). The Delta region and Upper Egypt differ in terms of the soil types and the nature of the climate, as well as geographical characteristics that could affect dairy production. For these reasons, the TE analysis was conducted to compare smallholder livestock production in the two regions.

The survey data provided multiple inputs and outputs for each of the 838 dairy farms. The data set includes four outputs measured in kilograms (butter, cheese, milk and meat). The three inputs include land cultivated per feddan (0.42 hectares); animal input per head, including buffalo, cattle, sheep and goats; and total number of hired labor for animal production. The environmental variables that could influence the TE scores include the region (Delta or Upper); education classified into three subgroups (university or high school, read and write, or illiterate); graduation classified into three subgroups (agricultural certificate holder, another certificate holder, or other(s)); land size per feddan; and activity goal classified into two subgroups (farms with only milk production or farms having both milk production and calving activities).

Table 1 presents a summary of the descriptive statistics for the input and output variables of the 838 dairy farms in Egypt. The outputs (butter, milk, cheese, and meat) are expressed by the average of the outputs per kilogram of each farmer. It provides a general description of the input and output set of the livestock farms sampled in each region. The differences among livestock farms in our sample are reflected by the high standard deviations. Farms in the Delta region produce higher outputs, including butter, cheese, milk and meat, compared to farms in Upper Egypt.

Table 2 presents the average livestock farm output-oriented TE scores obtained from the DEA model for both regions. The value of the TE scores is bound between zero and unity. The value of output-oriented TE scores equal to one implies that livestock farmers can produce the maximum feasible outputs for a given level of inputs. The TE scores for all the surveyed livestock farms in Egypt range from 0.132 to 0.854, with an average of 0.354. These findings imply that the livestock farms in this study could have been producing 64.6% more farm products (i.e., butter, cheese, milk, and meat) on average for a given level of land, labor, and animal inputs. Turning to differences in the TE scores across the two regions, the findings show that farms in the Delta region have higher TE scores than those in the Upper region. The TE scores for farms in the Delta region range from 0.151 to 0.889, with an average of 0.344, while the TE scores for farms

Table 1 - A summary of descriptive statistics.

Variable	*Delta (500 farms)*				*Upper (338 farms)*			
	Mean	*SD*	*Min*	*Max*	*Mean*	*SD*	*Min*	*Max*
Butter	236.56	49.73	0.00	7320.00	165.52	73.27	0.00	1830.00
Cheese	541.24	111.83	0.00	1647.00	376.72	191.11	0.00	1117.50
Milk	9961.75	51.05	0.00	5612.00	1487.54	33.04	0.00	1508.00
Meat	162.77	33.54	0.00	494.10	114.11	31.91	0.00	223.53
Land	3.82	8.03	0.13	28.00	2.66	8.44	0.08	20.00
Animal input	15.21	29.11	5.00	270.00	7.47	12.95	4.00	152.00
Labor	2.26	2.84	2.00	15.00	2.12	2.63	1.00	12.00

Table 2 - Average farm output-oriented TE scores by each region.

Region	*Mean TE*	*SD*	*Min*	*Max*
Delta	0.364	0.166	0.151	0.889
Upper	0.307	0.189	0.104	0.801
Total	0.354	0.175	0.132	0.854

Table 3 - Frequency distributions of TE scores by each region.

TE	Delta		Upper	
	No. of farms	*% of farms*	*No. of farms*	*% of farms*
0.0-0.2	67	13.4	50	14.8
0.2-0.4	271	54.2	206	60.9
0.4-0.6	107	21.4	52	15.4
0.6-0.8	45	9.0	23	7.4
0.8-1.0	10	2.0	7	1.5
Total	500	100.0	338	100.0

Table 4 - Frequency distributions of returns to scale (RTS) by each region.

RTS	Delta		Upper	
	No. of farms	*% of farms*	*No. of farms*	*% of farms*
Constant RTS	71	14.2	46	13.6
Decreasing RTS	195	39.0	174	51.5
Increasing RTS	234	46.8	118	34.9
Total	500	100.0	338	100.0

in the Upper region range from 0.104 to 0.801, with an average of 0.307. These results suggest that farms in the Delta region could potentially produce 63.6% more butter, cheese, milk and meat, and farms in Upper Egypt could potentially produce 60.3% more farm products for a given level of their input uses.

There are a set of reasons that make farms in Upper Egypt are not working efficiently compare to the farms in the Delta region; they are: the high-temperature in Upper Egypt is affecting negatively the generation of the milk production and thus decreasing the TE. The illiteracy rate in Upper Egypt is higher than in the Delta region given that our results indicate that the illiteracy rate is affecting negatively the TE, the infrastructure in Upper Egypt is not suitable for supporting improve the production efficiency to marketing and selling livestock product in this region.

Table 3 reports the frequency distribution of the TE scores by farm in each region, indicating that more than 60% of all Egyptian livestock farms obtained TE scores of 40% or lower. Approximately 11% of farms in the Delta region obtained TE scores of 60% or higher, while only less than 10% of farms in Upper Egypt obtained TE scores of 60% or higher.

Table 4 also reports the frequency distribution of the returns to scale (RTS) by farm in both regions. The findings show that there are only 71 farms in the Delta region and 46 farms in the Upper region exhibiting a constant RTS, which makes up the smallest amount of total farms. Increasing RTS dominates most farms in the Delta region whereas most farms in the Upper region exhibit decreasing RTS. The findings show that more than 46% of farms in the Delta region exhibit increasing RTS and approximately 39% exhibit decreasing RTS. These results are consistent with those findings of Hjalmarsson *et al.* (1996). In contrast, more than 51% of farms in Upper Egypt exhibit decreasing RTS and only 39% exhibit increasing RTS. These results are consistent with those findings in Sharma *et al.* (1997) and Jaforullah and Whiteman (1999).

To examine the factors affecting TE scores of Egyptian dairy farms, five environmental variables are defined and analyzed in this study including region (Delta/Upper), land size, education, graduation, and activity goal. Table 5 presents the logistic regression estimation for these factors influencing the TE scores. All coefficient estimates are significant at the 99%, 95%, and 90% confidence intervals, respectively. The coefficient estimates of the 'Region', 'Edu1', 'Activity' and 'Grad2' variables are statistically significant at the 95% confidence interval. The coefficient estimates of the 'Size' variable

Table 5 - The results of Tobit regression for efficiencies.

Variable[a]	*Coefficients*	*P-value*
Constant	0.329***	0.000
Region	0.030**	0.013
Edu1	0.184**	0.025
Edu2	0.028*	0.056
Activity	0.032**	0.013
Grad1	0.154*	0.062
Grad2	0.176**	0.022
Size	-0.103***	0.002
R2	0.628	
F(9, 837)	12.685	

*Note: [a] Region (1=Delta, 0=Upper); Edu1 (1= university/high school, 0=other); Edu2 (1=read and write, 0=other); Activity (1=milk production, 0=milk and calve production); Grad1 (1= agricultural certificate holder, 0=other); Grad2 (1= another certificate holder, 0=other); Significance level: * significant at 10%; ** significant at 5%; *** significant at 1%*

are statistically significant at the 99% interval, and the coefficient estimates of the 'Edu2' and 'Grad1' variables are statistically significant at the 90% interval. The findings indicate that farms in the Delta region positively influence TE improvement. Higher education and holding a certificate have a positive influence on TE improvement. Dairy farms with only milk production also have a positive influence on TE improvement. However, farm size has a negative influence on TE improvement. These results are consistent with previous studies (Bravo-Ureta and Rieger, 1991; Binici *et al.*, 2006). The majority of the animal production farmers in Egypt are smallholders and lacking for the advantages of the large scale such as procuring the inputs with lower prices, producing a higher quantity of the animal products, utilizing specialized and modern machineries to reduce production costs, utilizing specialized labors to produce a larger output with better quality and promoting R&D that could lead to discover a good and cheaper process. Nevertheless, our finding indicates that small-scale farms are found to be more technically efficient compared to large-scale categories. It could be because of the difficulty of controlling the large-scale farms where the supervision becomes ineffective and wastage of inputs becomes more widely. The low levels of TE indicate that most farms are unable to catch up with the production frontier under the existing production technology, which could be because of that most of the animal production farmers are smallholders and depend on the unofficial markets to distribute their products with low price, while receiving low profit. Thus, the technology used and production efficiency cannot be further improved by those farmers.

The decreasing economic performance of livestock farms in Upper Egypt compared to the Delta region is because of a few reasons. The concept of milk marketing is still very customary and simple, with farmers using the milk from home consumption or giving it to neighbors and relatives for free. High feed costs are also one of the reasons for reduced farm efficiency in Upper Egypt, as well as the lack of equipment and administrative skills, which are common constraints within the milk and meat processing sector. Poor infrastructure is the main hindrance to marketing and selling livestock product in this region. Elbadawy (2014) found that illiteracy in Upper Egypt was especially high among young adults (30%), and 27% of the youth had not completed compulsory education. This certainly negatively affects the efficiency of livestock production.

6. Concluding remarks and recommendations

Measuring the TE of crop-livestock farming systems has drawn research attention to research in developing economies as more data becomes available. These analyses are of high political, social, and economic interest, especially in light of low-income levels and chronic poverty affecting these countries. Our analysis focuses on measuring the economic performance of mixed crop-livestock farming systems in the Upper and Delta regions of Egypt using farm-level data for 838 mixed crop-livestock farmers. This study applies a non-parametric, output-oriented VRS DEA model to estimate TE over the distribution that lies on or below the frontier line. Agricultural production technologies in this study are represented by four outputs and three inputs. Empirical results indicate that average TE scores for livestock farms in this study is 0.354, implying that these farms have the opportunity to increase outputs by 64.6% for a given level of input use. Results also show that the livestock production farmers in the Delta region have higher TE scores, on average, than Upper Egypt farms (0.344 and 0.307, respectively). Moreover, more than 60% of all farms used in the analyses obtained TE scores of 40% or lower; about 11% of the farms in the Delta region obtained TE scores of 60% or higher and 10% of farms in the Upper region obtained TE scores of 60% or higher. Results also indicate that more than 46% of farms in the Delta region exhibit increasing RTS and approximately 39% exhibit decreasing RTS. While more than 51% of farms in the Upper region exhibit decreasing RTS and only 39% exhibit increasing RTS. Five environmental variables used to assess the factors affecting the TE improvement include region, land size, education, graduation, and activity goal.

The results suggest that TE improvement of the livestock farms is positively influenced by the Delta region, higher education, holding a certificate, and farms with just milk production. TE improvement is negatively affected by farm size, implying that small-scale farms perform more efficiently than large-scale farms.

The relatively low levels of TE indicate that most farms are unable to catch up with the production frontier under the existing production technology. Since the inefficiencies are normally associated with motivation, information, and institutional environment problems, policy makers should pay more attention to various factor market reforms as a whole. Farmers' rights to land should be strengthened and extended so that land tenure is more secure. Possible policy measures could include complete land titling to grant full property rights to farmers and hence establish a foundation for the development of rural rental and credit markets where land could be used as collateral.

The presence of decreasing RTS also has important policy implications with respect to the government's recent policy focus on supporting the creation of large-scale farms. Adjusting the structure of farm production is needed in order to reach the optimal proportion of various input use. The progress of this adjustment will also rely on the successful reform of land and labour markets. This study also finds that higher education and holding a certificate are important to the improvement of agricultural efficiency. Given these results, there are a set of suggested recommendations geared towards improving the TE of livestock farms in Egypt. It is recommended the government should improve the quality of formal education and agricultural extension services for farmers. Our finding also allows for providing interesting policy implications such as the provision of technical assistance through cooperatives and extension services that could improve the performance of farmers and facilitating and improving the education levels, particularly in the Upper Egypt region which has the lowest literacy rate. In addition, The Egyptian government could establish a gathering point for animal products with cooperatives or non-governmental organizations (NGOs). This could help smallholder farmers, especially those in Upper Egypt, to easily market their animal products with higher prices, enabling farmers to enhance their productivity.

This research study could be extended by assessing the organic farming for animal-based products in Egypt using TE models that could be desirable for future studies. Further models could be supplemented by the present estimation results, such as the local maximum likelihood (LML) approach and Zero Inefficiency Stochastic Frontier Model (ZISFM).

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