TECHNICAL EFFICIENCY OF DAIRY FARMS IN RURAL NIGERIA

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Abstract: *The study assessed the technical efficiency of Nigerian dairy farms. Information on 73 dairy farms was obtained from the General Household Survey (GHS Panel) for the year 2018-2019 wave, and the method of analysis employed include descriptive statistics and Data Envelopment Analysis Model. The findings show that not all the farms sampled are technically efficient, which means they can still utilize their input resources more effectively. The average level of technical efficiency of sampled farms was 83%; this suggests from the technical point of view that there exist an opportunity for expansion of milk production and revenue using the same level of inputs at present and putting to use effectively available technologies by 17%. Furthermore, results also show that farms that practice grazing systems, those located in the northern part of Nigeria and small farm sizes, have higher T.E. overall.*

Keywords: *Dairy farms, Nigeria, Technical Efficiency, DEA*
(JEL Classifications: Q12, Q1, R15)

INTRODUCTION

Dairy farming stands as one of the critical sectors in most countries' economies (Maina et al.,2018), and it is treated as one of the noblest activities, where it offers a regular and stable income as compared to other agricultural and allied activities (Jacob—Ambily, 2018). The sector provides employment and income sources for many, especially in developing countries. FAO (2010) evaluated households that lived on or within dairy farms and discovered that of the world's population, about 12-14 per cent falls into this category, accounting for 750-900 million people. The IFCN Country Profile collected for over 100 countries in 2015 shows that the growing size of farm and herds has fueled the growth in milk supply over the past decades. Dairy farms have been on the increase from 1996 to 2013, with a current number of about 118 million dairy farms across the world and each has an average of 3 cows and a mean yield of 2.2 tons of milk produced per cow annually (IFCN, 2015). Also, according to IDF 2013 report, the world altogether turned out approximately 621 million tons of milk from a cow in 2011 which was valued at 292 billion USD, this amounted to about 9 per cent of all agriculture products for that year. The World milk production for 2020 was projected to hit almost 860 million tons which is a 1.4 per cent increase from 2019 (FAO, 2020).

Nigeria, a developing and prominent country in Africa, is predominantly an agrarian country that provides a livelihood source for two-thirds of the populace and employs about 75 percent of the nation's workforce (IFAD, 2012). Nigeria has excellent opportunity based on its livestock population and large animal production capacity, with about 25 per cent of livestock herds leading livestock producers in Central and West Africa (Benard et al., 2010). The country's cattle herds are estimated to be 20 million heads in 2018; this stands for 1.36 per cent of the global total, putting Nigeria in the fourth position of largest cattle population in Africa after countries like Ethiopia, Sudan, and Tanzania, based on the U.N. Food and Agricultural Organization statistics. Out of the country's total herd, 11.5 per cent accounts for dairy, while about 88.5 per cent is consumed as meat. The country's meat consumption can be said to be low, this is especially true for pork meat, because pork meat has to face religious regulations (Vida – Szűcs, 2016), and customers' misbelieves (Vida, 2013).

In spite of all these substantial potentials, the Nigerian dairy sector is still far below expectation, the local milk production is less than 1 per cent of the total annual demand, estimated to be 1.45 billion litres (FAO, 2013). Exploiting the potentials needs higher level management and work organization solutions supported by strategic decisions (Felföldi, 2001). Nigeria's growing population is expected to expand swiftly in the next decades, with an anticipated population of almost 400 million by 2050. These would lead to high demand for livestock products and a projected per cent increase of 117, 253 and 577 in beef, poultry, and milk consumption, respectively (FAO, 2019). Dairy consumption in Nigeria is rising faster than the pace of production, leaving imports to fill the gap. The sector must be managed and organized to become effective and efficient (Apáti et al., 2005). The annual importation of food in Nigeria is accumulated to about 5 billion USD, and milk importation accounts for about 1.3 billion USD (NLTP, 2019). From the point of view of the quality food of the future, it is essential to develop and increase the efficiency of milk production (Kovács et al., 2021).

The national production of milk and dairy products in Nigeria presently stands at 0.5 million tons, just about 38% of the growing demand of about 1.3 million tons (FAO, 2019). This production is inadequate to satisfy the growing demand for the dairy product in Nigeria. The local production of dairy products is far below the annual demand making the Nigerian population's milk consumption less than 10 litres per head compared to the global average, which of about 40, 50 and 70 litres per head in South Africa, New Zealand, and the USA respectively, and in some African countries 28 liters per head (FAO, 2013). Indigenous cattle breeds represent over 90 per cent of the herd population in Nigeria, while the rest are cultured breeds imported from the Netherlands and other countries (Saleh et al., 2016).

Also, milk production in Nigeria is handled mainly by the pastoralist tribesmen called the Fulani who control over 90 per cent of the cattle population (Olafadehen—Adewumi, 2008), and the production is further hindered by the low level of cattle nutrition, poor milk yield and traditional method of processing milk products (Okeke et al., 2016). Despite the well-known fact that it has close relationship between cattle keeping and quality of milk (Nagy-Felföldi, 1999), production practices are grossly underdeveloped with many constraints affecting productivity, such as lack of modern dairy facilities and infrastructure, the poor genetic quality of local breeds limiting the potential for optimal milk production, high technology cost for cross-breeding of exotic cattle, the type of dairy system practised which is mostly pastoralism (Ugwu—Achike, 2010).

Consequently, this paper aims to explore the efficiency of Nigerian dairy production. More concretely, the study would seek to explain:

1. The profile of dairy farmers socio-economic characteristics in Nigeria
2. The technical efficiency level of dairy farms in rural Nigeria
3. Factors influencing the technical efficiency level of dairy farms

LITERATURE REVIEW

World milk production has been increasing, and it has been estimated that cow milk covers about 81 per cent of global milk and experienced a growth of about 1.3 per cent in 2019 to about 852 million tons (OECD/FAO, 2020). It was also estimated that global milk production in 2020 expanded by 1.4 per cent from 2019 and reached nearly 860 million tons; this reflected a positive production increase in crucial milk-producing countries like the USA, the E.U., Russia, Brazil, Pakistan, and India (FAO, 2020). India and Pakistan are essential milk producers worldwide, and they are estimated to supply over half of the global milk production growth in the next decade, accounting for over 30 per cent of global production by 2029 (OECD/FAO, 2020).

Table 1: Top 5 Milk producer countries in 2019

Country	Milk produced (' 000tons)
World	852,000
India	191,000
European Union	167,811
USA	99,057
Pakistan	47,297
Brazil	34,897

Source: FAO Dairy Market Review 2020

In the case of Nigeria, there is more than 20.6 million head of cattle which are primarily raised and controlled by the extensive system (FAO, 2018). The primary cattle production system existing in Nigeria, as seen in Table 2, is the intensive (modern), semi-intensive (agro-pastoral) and extensive (traditional) systems, which represent about 82% of the total population (UAA, 2011).

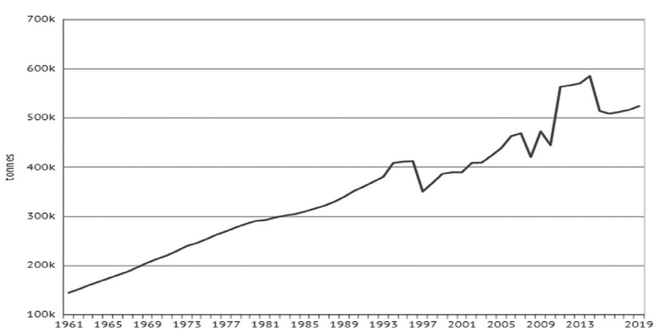
Table 2: Nigeria cattle production system as of 2017

Production systems	Number (heads)	Total population (%)
Extensive	15 111 309	82.1
Semi-intensive	3 089 804	16.8
Intensive	203 548	1.1

Source: Federal Ministry of Agriculture and Rural Development 2017.

In 2019, the milk production for Nigeria was 523,599, increasing from 213,000 tons in 1970 to 523,599 tons in 2019, growing at an annual rate of 2.01 per cent. About 5 per cent of local milk produced in Nigeria is from exotic breeds raised by commercial farmers such as Brown Swiss, Holstein Friesian, Jersey, and other crossbreeds, with an average milk production of 8 litres per cow per day (FAO, 2018). The current milk production in Nigeria does not meet the market demand of

Figure 1: Trend of Nigeria's Milk Production between 1960 and 2019



Source: Knoema 2020

about 1.45 billion litres annually (CSIRO Factsheet, 2018); dairy production is typically small-scale oriented, which is associated with low productivity: the average milk production annually is about 213 litres for a cow, this is below 1/10 the world milk production average (Makun, 2018).

Growth in agricultural productivity has been an effective way to maintain the sector as a significant source of economic growth (NPC, 2015); one way of increasing productivity is by improving the efficiency of production (Farrell, 1957). Measuring productive efficiency is an old concept pioneered by Farrell (1957), who showed how to decompose the economic efficiency of a farm into its technical and allocative efficiency components. Efficiency measures should be a priority area for dairy farmers to ensure that their farms produce to meet the competition efficiently for the national and, most significantly, international markets in a more sustainable way (Jafor, 2019). To measure efficiency is a difficult task, because efficiency can be measured in different ways, with different levels (partial, complex, social, corporate, regional and macro-economical) of indicators (NÁBRÁDI et al., 2008). To counteract the effects of urbanisation, it is necessary to maintain and develop those agricultural sectors that can provide an acceptable level of income for people living in rural areas on a relatively small area (Bittner-Kerékgyártó, 2012) Increasing the efficiency of these sectors is therefore an important aspect.

METHOD AND DATA

Nigeria lies between latitude 4o and 14o North and longitudes 2o and 15o East, covering a geographical space of 923,768 square kilometers. This study used secondary data obtained from the General Household Survey (GHS Panel) conducted in the 2018-2019 wave four by the Nigeria National Bureau of Statistics (NBS) Nigeria in collaboration with the World Bank Living Standard Measurement Study (LSMS) integrated surveys. For our research, information about agriculture was filtered and sorted out to obtain the desired sample population. 73 dairy farms with valid and complete information were selected for the sample data. The variables extracted from the main data set include the socio-demographic characteristics of dairy farmers, their geopolitical zones and most importantly, the production factors in dairy farming.

Efficiency always expresses the relationship between an output and input category (Nábrádi et al. 2009). Data Envelopment Analysis (DEA) was used to calculate the efficiency rate of dairy. This is the most important representative of the non-parametric methods for measuring efficiency, which use mathematical programming rather than regression (Oluwatayo—Adedeji, 2019). According to Charnes et al. (1978), the entities for which their efficiency scores were calculated was called Decision-Making Unit (DMU). They employed linear programming to obtain non-parametric, piece-wise frontier 'enveloping' all input-output combinations (production possibility set) for each DMU. DEA develops an empirical frontier function, which is determined by the most efficient producers of the observed dataset because efficiency is measured as the distance to this frontier; without considering statistical noise, DEA is a deterministic model. The significant advantage of this method is the flexibility due to its non-parametric nature, i.e., no assumption about the production function is required (Andor—Hesse, 2011).

The most applied and used model was done by Charnes et al. (1978); they proposed a model that had an input orientation and assumed constant returns to scale (CRS) to solve the following linear programming problem for each firm to obtain the efficiency score:

$$\begin{aligned} &\max_{u,v} && \mathbf{(u'yi / v'xi),} \\ &\text{constrains:} && \mathbf{u'yj / v'xj \leq 1,} \quad j = 1, 2, ..., N, \qquad (1) \\ & && \mathbf{u, v \geq 0} \end{aligned}$$

Based on Coelli et al. (2005), some notations are defined. Assuming there is data on K inputs and M outputs from N firms. For the i-th firm, these are represented by column vectors xi and yi, respectively. X represent the K*M input matrix, while Y explains the M*N output matrix for all N firms. To obtain the efficiency measure, there is a need to measure the ratio of all outputs over all inputs, such as u'yi / v'xi, where u represents the M*1 vector of output weights, and v represents the K*1 vector of input weights. The values for u and v must be found such that the efficiency measure for the N-th firm is maximized, subject to the constraints that all efficiency measures must be less than or equal to one. One problem exists with the formulation because the model has infinite solutions. Charnes et al. (1978) added another constrain v'xi = 1 to help solve the problem, which provides:

$$\begin{aligned} &\max_{\mu,v} && \mathbf{(\mu' yi),} \\ &\text{constraints:} && \mathbf{v'xi = 1} \\ & && \mathbf{\mu'yj - v'xj \leq 0,} \quad j= 1, 2……, N, \qquad (2) \\ & && \mathbf{\mu, v \geq 0,} \end{aligned}$$

The change of notation from u and v to μ and v implies that this is a different linear programming problem. The reformation in (2) is known as the multiplier form of data envelopment analysis. From the above multiplier formula (2), the envelopment form is as follows:

$$\begin{aligned} &\mathbf{\min_{\theta,\lambda} \theta,} && \\ &\text{constrains:} && \mathbf{-yj + Y\lambda \geq 0,} \qquad (3) \\ & && \mathbf{\theta xi - X\lambda \geq 0,} \\ & && \mathbf{\lambda \geq 0,} \end{aligned}$$

where λ represents the vector of peer weights. θ is a scalar whose value obtained will be the efficiency score for the i-th firm. It satisfies θ ≤1 when the value is 1 indicating a technically efficient firm. This linear programming problem must be solved N times, covering each firm in the sample. Each firm has its own θ value efficiency score (Coelli et al., 2005). The points at which firms are fully efficient to determine the fully efficient frontier line.

The assumption about the constant return to scale is only suitable if firms operate at optimal scale, which is often not so for firms with imperfect competition, government regulation, the constraint on budget, and many other factors. Banker et al. (1984) and other various authors suggested adjusting CRS model to account for variable returns to scale (VRS) situations. The VRS model is similar the CRS model but for convex¬ity constraint N1'λ = 1, which is added to the model. This VRS approach by Banker et al. (1984) presents an output-oriented model, where firms have a fixed quantity of input resources, i.e., capital, labour, live¬stock and land, and want to produce output such as, milk and calf as much as possible. This model is similar to the input-orientated model. The formula of an output-orientated VRS model is the following:

$$\max_{\phi,\lambda} \phi,$$
$$\text{constrains:} \quad \begin{aligned} &-\phi\, y_j + Y\lambda \geq 0, \\ &x_i - X\lambda \geq 0, \\ &N1'\lambda = 1 \\ &\lambda \geq 0, \end{aligned} \qquad (4)$$

where ϕ is a scalar, λ is a Nx1 vector of constants, and N1 is an N*1 vector of ones, $1 \leq \phi < \infty$ and ϕ–1 is the proportional increase in output that could be achieved by the i-th firm, with input quantities held constant. 1/ϕ determine the technical efficiency score, which lies between zero and one. For this study, output-oriented VRS DEA was used to determine how much output the farmers would produce within the given input level.

The study used one output variable as the output-orientated DEA model- milk production revenue (values expressed in naira) while for the farm model, five input variables were as follows:

1. *Dairy cows:* It referred to the total number of cow head owned by the dairy farmers during 2018/19 production season and held for milk production.
2. *Feed Cost:* this refers to the total cost of fodder, concentrates, supplements, and watering of the dairy farm. (Valued in naira).
3. *Labour input cost* is the total cost of labour working on the dairy farm; this is expressed in naira.
4. *Veterinary cost:* The cost of animal health care during the 2018/19 production season expressed in naira.
5. *Other costs:* It is the overhead cost involved in dairy production to cover other expenses like energy cost, facilities cost, and storage cost, which is expressed in naira.

RESULTS AND DISCUSSION

Before presenting the results of the DEA model, Table 3 contains the descriptive statistics of the production variables used on dairy farms. It reveals the minimum and maximum cost of production within the 2018/19 production season.

Table 3: Descriptive statistics of production variables (N=73)

Variables	Unit	Minimum	Maximum	Mean	Std. Deviation
Milk Revenue	Naira	500	8 500	2 276.71	1 608.357
Dairy Cows	Number	1	200	11.15	24.800
Cost of Veterinary	Naira	100	16 000	3 006.58	1 682.307
Cost of Feeds	Naira	1 500	160 000	21 164.38	19 780.752
Cost of Labor	Naira	400	5 000	1 490.41	921.565
Operating Expenses	Naira	1 000	15 000	5 736.99	1 768.514

Source: Own's calculation based on the GHS (2018/19) data.

The efficiency of sampled DMU's scores in this study were presented on a scale of 0-1.00, where farms with a 1.00 score show that they are fully efficient with the current level of inputs they put into use while those with 0.0 score are inefficient,, with their input use.

Table 4: Estimated Technical Efficiency of Sampled Dairy Farms

TE Range	Frequency	Percent (%)
0.00-0.39	0	0.0
0.40-0.50	2	2.7
0.51-0.60	3	4.1
0.61-0.70	12	16.4
0.71-0.80	21	28.8
0.81-0.90	6	8.2
0.90-1.00	29	39.7
Total	**73**	**100**
TE estimates		
Mean	0.83	
Min	0.46	
Max	1.00	
Standard deviation	0.15	

Source: Own calculation based on the GHS (2018/19) data.

The results in Table 4 show that under the VRS model with output orientation, the mean technical efficiency of the dairy farms sampled was 83%, with a standard deviation of 15%. This means that an average farm in the sample could increase its level of milk production and revenue, using the same current input quantities by 17% through the proper use of input at its disposal more effectively without introducing external inputs and practices. The minimum and maximum efficiency levels were about 46 and 100 %, respectively; this shows that there is wide disparity among the sampled dairy farms in their T.E. It indicates that there is room for improving the existing level of milk production through improvement in the farm's technical efficiency.

Relationship of Feeding System, Geographical Zone and Farm size on Farm Efficiency

Through DEA VRS model using the output orientation it is aimed to examine if the feeding system (grazing vs main feed), the zone or location of farming and the farm size affect the farm efficiency.

Feeding System: The proper management of feeds is essential in dairy farms to boost the productive of dairy cows (Derib, 2010) hence the importance of feed in efficiency measures. According to the result from Table 5, the majority of farms 73% made use of a grazing system, also known as pasture, to feed their cattle, while the other 27% kept their cattle in a closed system and fed them with mainly feeds like TMR (contains blends of feedstuffs in a balanced ration with required nutrient level).

Using the VRS model, it was discovered that farms that practice the grazing system have a higher mean technical efficiency score of 84%, while farms that confine their cattle to feed have a mean efficiency of 79%. This means that an average farm that gives their cattle only feeds could increase their milk production and revenue by 21% with the level of the current input, while on the other hand those who use grazing/pasture systems can increase theirs by 16%. This result is consistent with Shkodra et al. (2020) findings which explain that farms that practice grazing systems have a higher T.E., happy and healthier animals, and produce good quality milk with lower costs incurred. They also explained that farms that use grazing hardly record problems associated with cow lameness, commonly encountered in closed-system farms. To further buttress the grazing system, it is essential to explain that the majority of cattle raised in Nigeria are under the pastoral / extensive type whose feeds mainly through grazing and practice nomadic system.

Table 5: Mean of VRSTE for the sampled farms based on feeding system.

Feeding System	Percent (%)	Mean VRSTE	Std. deviation
Grazing	73	0.84	0.16
Mainly feeds	27	0.79	0.15

Source: Own's calculation based on the GHS (2018/19) data.

Geographical Zone: Based on the zone categories, about 81% of the sampled farmers are from northern Nigeria; this population is higher than the southern counterpart, where just about 19% are represented in the study. This result is further supported by the findings of UAA (2011), which explained that cattle rearing is dominant and commonly practised in the northern part of the country, mainly because it is their principal occupation and source of livelihood. The technical efficiency of the geopolitical zones was calculated, as seen in Table 6. There is a significant effect, with the most efficient region being the Northern part of Nigeria, with mean technical efficiency of 84%. This means that dairy farms in this region used their resources effectively compared to the southern part of the country; this could be because dairy farming is one of their primary and important income sources in the northern part of Nigeria as against the south. In addition, the high level of experience in practice is another crucial factor that gives them a superior advantage (UAA, 2011). It was also discovered that they could increase their milk output and revenue by 16% if their input was more efficient. On the other hand, the southern part of Nigeria has a mean T.E. of 78%, meaning there is about 22% opportunity for them to increase their output at the current level of input and technology available at their disposal and use.

Table 6: Means of VRSTE of the sampled farms based on zone.

Gender	Percent (%)	Mean VRSTE	Std. deviation
North	81	0.84	0.16
South	19	0.78	0.15

Source: Own's calculation based on the GHS (2018/19) data.

Farm Size: The farm size was grouped into three categories based on the number of cows owned. About 89 % of the dairy farms have herd sizes between 0 and 20, and this category has the largest number of farmers; this explains that most are small-scale dairy farmers. 6.8 % of the farms are medium size and have a herd size of between 21 and 49 cows, while just 4.1 % have a cattle size of over 50 in number, and this category represents the large farm size within the scope of the study.

According to Table 7, the mean of VRS technical efficiency of each farm size was presented. Results under the DEA VRS model revealed that farm size influences T.E. Small farms ranging from 0-20 have a mean score of 0.84, meaning they have a T.E. of 84%. The possible reason for this could be that farmers in these categories combined their resources more effectively. Also, the mid-size farm has a lower score of 0.78 which means a technical efficiency of 78%, while large farms have a mean efficiency of 54%. There was a decline in the mean technical efficiency from small farms (0.84), which has the highest efficiency, to large farms, the lowest (0.54). This is a testament that most farms in the sample size are small-scale and maximize their resources efficiently. Also, from the result, small farms have about 16% opportunity to increase their output by fully utilizing their inputs at the current level of resources and technology. This result was contrary to the findings of Kovacs—Szucs (2020), where they discovered that large farms in Hungary have higher efficiency levels, and Shkodra et al., 2020 in their findings also confirmed that larger farms have more assets and consequently could produce more than small farms.

Table 7: Means of VRSTE for each farm size.

Farm Size	Percent (%)	Mean VRSTE	Std. deviation
Small (0-20)	89	0.84	0.15
Medium (21-49)	6.8	0.78	0.15
Large (50 above)	4.1	0.54	0.18

Source: Own's calculation based on the GHS (2018/19) data

CONCLUSION

This paper evaluated the technical efficiency of a dairy farm in rural Nigeria using the Data Envelopment Analysis (DEA) model to estimate the overall technical efficiency of each sampled dairy farm in Nigeria using the variable return to scale (VRS) method. Different forms of input usage were presented based on production factors and the level of milk production.

The findings show that not all the farms sampled are technically efficient, which means they can still utilize their input resources more effectively. The average level of technical efficiency of farms sampled was 83%; this suggests from the technical point of view that there is an opportunity for expansion of milk production and revenue using the same level of inputs at present and using effectively available technologies by 17%. This result suggested that there can be an improvement in the productivity and efficiency of dairy farms in Nigeria if they practice their farming system more efficiently. Results also revealed that farms that use grazing systems scored better in technical efficiency than those that used feeds, small-size farms scored the highest level of efficiency under the VRS, and dairy farms located in northern Nigeria have higher technical efficiency scores than those in the south.

Conclusively, proper feed management should be encouraged, and farmers were seen to practice more of a grazing system to make this more efficient; they should seek to grow plants rich in proteins like soybean and incorporate ingredients that will aid cattle growth and milk production. Also, government and policymakers should establish working policies that would support grazing land availability to cattle owners, most especially in the Northern part of Nigeria, where cattle are reared and raised.

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