Unlocking Total Factor Productivity of Smallholder Dairy Farmers in Tanzania

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Abstract

Tanzania is endowed with a diversity of ecosystems, a huge number of cattle farming, and available arable land. However, the productivity per cow is still very low due various reasons. This study used data from the African Asian Dairy Genetic Gains (AADGG) database collected over a period of eight years from 2016 to 2023 and supplemented with mini-survey of cost of production done in twenty-four (24) Local Government Authorities (LGAs). The objective of this study was to determine factors that influence total factor productivity in small-scale dairy farms in high milk shade LGAs in Tanzania. Results show that despite of favourable conditions for dairy farming, productivity is still low (40%). The low productivity is exuberated by two factors: the high cost of feed and treatment (among other costs) within respective area of production. However, with improvements in management, the cost will be reduced by almost half (47%), hence an increase in productivity per cow. To increase productivity per animal, this study recommends proper choices of local available resources such as breed types, feeds and disease management regimes. It is also suggested that choice of resources should be practiced in combination with modernization and transformation of traditional systems of integrated farming that will enhance the use of livestock production resources efficiently.

Keywords: AADGG, dairy farmer, productivity, smallholder, Tanzania

Introduction

Tanzania is endowed with a diversity of ecosystems including humid highlands that receives a minimum of 800 mm of rainfall per annum, suitable for cropping and fodder production annually (Dawson Maleko, 2022). At the same time the land accommodates huge cattle population (33.9 million) kept by 1.7 million (about 37% of total) rural households (150 million households in the globe); out of this population, 71% keeps between 1 and 10 heads of cattle (average = 13 heads of cattle (Dawson Maleko, 2022). It is also reported that 90% of the amount of milk produced in Tanzania comes from cattle (Tanzania National Bureau of Statistics (NBS), 2021).

Cattle production in Tanzania most is done by smallholder farmer with different reasons and objectives, one of the reason/objectives is for prestige, which is reported more than 1.7 million rural households keep 1-10 head of cattle with no clear objective than saying people would praise them for having cattle (Rangi, 2018; Bundala *et al.,* 2020 & NBS, 2021). Second reason/objective is for income; this is majority of dairy farmers they expect to get milk, live calves, and meat which they sell them in the local market as formal and informal. The research reported that cattle produce 90% of milk in Tanzania (NBS, 2018). Live calves are also sold if not kept for replacement of cows, also the milking cow when are old (Lyatuu *et al.,* 2021), they slaughter them or sell them as live animals to the butcher as well as bulls are normally sold to butchers when they are 18 months or so. The third reason is to get manure, most farmers are doing integrated farming where during cropping season they grow cereals or beans and they may have garden for horticultural farming where manure is highly needed as fertilizer, therefore dairy cow produces enough manure to fertilizer the soil for cropping (Lupindu *et al.,* 2012 &

Rukiko *et al.,* 2018). Some farmers sell manure to their neighbours to earn income, although there is no formal market to do so.

Total Factor Productivity (TFP) in economics is defined as measured as the ratio of aggregate output to aggregate inputs (Wang *et al.,* 2015). Some studies use TFP and productivity interchangeably (Wang *et al.,* 2021), so does this study. Different studies show difficult in getting common factor that affect TFP (Haider *et al.,* 2020), especially in dairy (Alem 2023). However, most obvious Lipsey (2004) gave views on how TFP can be appreciated through efficient balancing of the resources available. Gelan & Muriithi (2010) mentioned two ways of improving productivity; input-oriented or output-oriented. Input-oriented efficiency is measured by reducing proportion (quantity)of inputs without affecting quantity of output produced. Similarly, output-oriented efficiency is measured by increasing quantity of output without changing of inputs quantities used. However, using existing resources in an efficient way and develop a society is increasing productivity (Oguz *et al.,* 2018). This is what make the term TFP being arch and extremely important in the increasing economic welfare. Olagunju *et al.,* (2022) concluded that, easy way to increase TFP in dairy farming is through proper use of available technology (e.g. artificial insemination, farm infrastructures).

Despite of larger population of cattle in Tanzania, productivity per cow is hampered with high input used compared to output, example, most milk produced is consumed by the household or sold through informal markets (Tanzania National Bureau of Statistics (NBS), 2021). It is imperative that improving TFP is widely recognised as a means to address challenges mentioned above, as it allows managers to allocate resources efficiently and sustainability within the farm (Olagunju *et al.,* 2022). The farm management realizes productivity gains depending on where the farm is in the technological adoption process (Mbelle, 2005), the slow diffusion of new genetic material or new variety of fodder that survives in their environment. Decision of management in the farms influences gains in the TFP at each stage (Dharmasiri, 2009).

However, TFP in the dairy farm influence profit only if available records are used by the farmer to change the inputs used in production. Many farms struggle to have more output and end up using too much input which in turn affect the productivity gains (Liang & Cabrera, 2015). However, proper choices of available resources such as breed type that's fit well in the farmer environment, use cheap available nutritious feeding and disease management programme (proper use of vaccination) may make the farm change within short time. Most research has mentioned low productivity per cow but what are the factors that affect TFP is not well understood (Beshir 2021). They mention that cows produce bellow production potential with an average 2-6 liters a day in the high milk shade areas. The reason for the low yield is mentioned to be in access to the proper breeds for their environment as well as and in access to the quantity and quality feed throughout the year (Beshir 2021). Few research mention production cost as major reasons for poor productivity but it is the major reason (Olagunju *et al.,* 2022). Failing to balance input output orientation is a major hiccup that has been affecting productivity (Lipsey 2004). However, the main essential to high productivity is mentioned to be appropriate breed of cow, access and application of knowledge and skills in dairy management and access and available feed & other inputs at reasonable cost (Olagunju *et al.,* 2022).

This paper intended to determine factors that influence TFP in the small-scale dairy farms in high milk shade in Local Government Authorities (LGAs) in Tanzania. This paper found that there are factors that affect TFP in dairy small-scale farms despite of the fact that the farms have eight years records of cattle performances. Moreover, farmers were trained through physical visits once each month by livestock extension officers and farmer received digital messages sent to their mobiles all these were geared at improve management and to make farm profitable business.

Methodology

Data Sources and Analysis Techniques

This paper is based on a qualitative and quantitative research approach, represented

on exploratory, explanatory, and descriptive, based on livestock data and development trend over a period of eight years from 2016 to 2023. The study used data from the African Asian Dairy Genetic Gains (AADGG) database that were captured in a period mentioned above. The nature of the data includes demographic, performance, health, assets, economics and environmental related data. The data and information gathered from twenty four LGAs (i.e. Arusha city, Arusha district, Meru district, Hai district, Siha district, Moshi district, Rombo district, Korogwe district, Korogwe town, Lushoto district, Bumbuli district, Muheza district, Tanga city, Iringa district, Iringa urban, Mafinga town, Mufindi district, Makambako town, Njombe town, Njombe district, Mbeya city, Mbeya district, Rungwe district and Mbozi district (Figure 1)) in more than 33,763 farmers and 86,269 animals with their records.

Although AADGG database have several records but not all farms have consistency data in eight years. Therefore, this study chose farms and cows with consistency data of eight consecutive years in each LGA to avoid biasness, therefore, 7,775 cow in 2,123 farms were used in this study. These farm owners were trained through physical visits once each month by livestock extension officers and farmer received digital messages sent to their mobiles, all these were geared at improve management and to make farm profitable business. The data and information from the AADGG database were supplemented with mini-survey conducted in August to September 2023 to update economic information available in study area. The mini-survey gathered information on economics though open data kit (ODK), specifically on cost of production and income earn. The primary data and information were used in triangulating the facts that relate dairy production value chain, and its connectivity to the determinant of TFP and productivity within fixed time. Input costs and income earned were gathered from selected farms with consistency data through extension officers assigned in their respective LGAs using Open Data Kit (ODK) and submitted to the main database. Results of data analysis were related with the techniques to see the relevant with previous studies suggestions and recommendation using ANCOVA and multivariate analysis to draw conclusion.

The Conceptual Model

The conceptual framework is based on research contribution by AADGG database. The model is composed of dependent variable that is considered important stage of dairy value chain production to determine TFP in the fixed time. To conceptualize the model, the study used policy, initiatives, and strategies/programme developed as one of the moderating variables which relates to economic value of production within dairy sector production but connected to respective farmers.

Empirical Model

The empirical model was regressed from general principal of production to get simplified equation;

$Y = a + b_1X_1 + b_2X_2 + ... + B_nX_n$

Describes as; Y = dependent variable (the predicted value) a = constant b = regression coefficient (the value increases or decreases) X_1, X_2= independent variable.

The equation regressed from total output (Y) as a function of total-factor productivity (P), capital inputs (K), labour input (L), and the two inputs' respective shares of output (α and β are the share of contribution for K and L respectively). Usually, the equation of this form suggests that an increase in either P, K or L will lead to an increase in output.

$Y = P\ x\ K\alpha\ x\ L\beta$

$$P = \frac{Y}{(K\alpha\ \ L\beta)}$$

Results and Discussion

Cost of production and income

Dairy farmers have different reasons of rearing cow, some farmer would like to get milk, others manure, calves and other keep dairy for prestige. These reasons are the one that trigger cost on production but also geographic area and land availability. Some area with vast land has little problem with fodder and feed while area with scarce land have difficult in accessing fodder and feed. Land use may be challenges as priority of land may be directed in producing food crops for human rather than animal feed.

This also goes to commercially oriented farmers who sell their produce in a market price which make it difficult for the livestock keeper to afford price as they compete with human feed. This research has looked cost of production and income earned based on the farmer objectives on output from dairy cow. The productivity shows to be increasing but with low pace given huge potential for milk production whereby the estimates show that over the projection period, about a third of the worldwide herd population is projected to be in Africa and to account for around 6% of world milk production(FAO, 2023). FAO, 2023 shows that when the world average milk production is 2,200 litres per cow per year compare to Tanzania which is very low 424 litres per years per cow. The data did not separate dairy from beef, therefore there is a need to have clear data for dairy only country wide.

This research found that (Table 1) Mufindi district council has very low productivity (1.21) compared to other district and compare to total average productivity of 4.05. The reason behind is the high cost of vaccination and treatments and fair amount of feed cost. Other LGAs recorded low were Lushoto district council and Meru district council; Lushoto district council recorded low because of the feed cost which raised so high. The LGA with high productivity are Njombe district council, Mafinga town council and Makambako town council with 9.43, 6.67, 6.18 respectively. The main reason for all were low cost of inputs compare to outputs. All three LGAs had very low cost of treatments and vaccination with fair amount of feed costs. The result on cluster effect on TFP show to be positive which encourage more training based on records on the cluster of farms as it was reported by Komwihangilo *et al.,* (2021) (Table 3).

Comparison of the Productivity between regions in two consecutive years

The productivity of 2020/2021 and 2022/2023 were calculated using similar conditions and results found that TPF has generally increased within one year in all the regions. The reason for increase contributed by slight increase in the price of milk by 29.6% and average milk production increased from 9.9 to 10.3 litres in the same period.

Table 2 and Figure 2 shows an increase in productivity especially in Njombe, Kilimanjaro and Tanga. The abrupt increase in productivity for Njombe is contributed with an increase in milk yield without increasing in the cost of production (Fig. 1). This means that farmers were able to maintain low cost of input but increase the output (milk yield). Kilimanjaro had different scenario where cost of production increased slightly while milk production increased abruptly which made the productivity to be high (Fig. 2). In Tanga output (milk yield) increased with decreasing rate while input (production cost) decreased slightly as well (Fig. 2).

Arusha had completely different results where the rate of an increase in the productivity in 2020/2021 has no significant different from the rate of an increase of productivity in 2022/2023 (Table 2). This was caused by costs of production being doubled in the same period (Fig. 2). The cost double due to feed cost which was caused by heavy drought that hit Arusha and it was unfortunately farmers did not have their own feed reserves or they did not have land for fodder production.

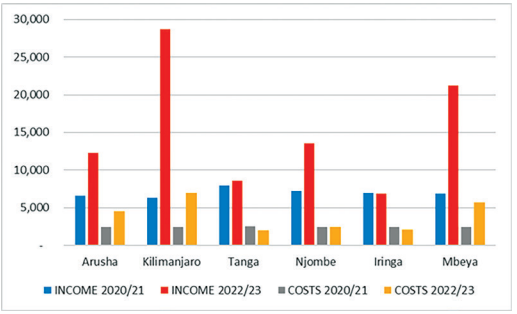

Figure 2: Comparison of TFP between 2020/2021 to 2022/2023 for seven regions that have high milk shade

Source of data: AADGG data base with authors own calculations

Empirical Analysis and Discussion

Although there was slight increase in milk price by 29.6% but farmer complained that there is no reliable market for their products (Table 4). They said their produces (milk and manure) are sold in formal and informal market. The formal

Table 1: Total Income, Costs, Productivity clustering per LGAs and per region in a day

Regions	LGAs	Total milk sold TZS	Amount of milk produced (litres)	Amount of manure sold TZS	Income (TZS)	Total costs (TZS)	TFP	Clusters			
								1	2	3	4
Arusha	Arusha CC	6,732,450	4,987	88,533	6,820,983	2,389,499	2.85	-	322	331	11
	Arusha DC	3,950,100	3,591	103,532	4,053,632	1,305,883	3.10	-	161	150	51
	Meru DC	1,350,375	1,385	64,000	1,414,375	804,715	1.76	-	29	195	-
	Sub total	12,032,925	9,963	256,065	12,288,990	4,500,097	2.73		512	676	62
Kilimanjaro	Hai DC	13,722,500	9,980	785,000	14,507,500	3,293,996	4.40	-	335	3	447
	Moshi DC	2,605,900	2,266	188,500	2,794,400	1,195,012	2.34	-	35	338	4
	Rombo DC	1,686,750	1,730	210,714	1,897,464	771,813	2.46	-	22	266	7
	Siha DC	9,330,000	4,665	165,880	9,495,880	1,719,602	5.52	580	-	-	-
	Sub total	27,345,150	18,641	1,350,094	28,695,244	6,980,422	4.11	580	392	607	458
Tanga	Korogwe TC	141,450	138	4,286	145,736	55,602	2.62	-	3	16	1
	Lushoto DC	400,800	501	22,250	423,050	224,603	1.88	-	2	94	-
	Tanga CC	2,097,700	1,907	35,700	2,133,400	553,273	3.86	-	106	127	5
	Muheza DC	5,727,700	5,588	167,616	5,895,316	1,189,279	4.96	-	244	322	16
	Sub total	8,367,650	8,134	229,852	8,597,502	2,022,756	4.25		355	559	22
Njombe	Njombe TC	4,682,086	4,622	622,214	5,304,300	1,240,054	4.28	-	239	320	3
	Makambako TC	5,781,672	6,177	450,000	6,231,672	1,008,087	6.18	-	411	32	7
	Njombe DC	1,872,200	2,024	145,000	2,017,200	213,881	9.43	-	143	2	-
	Sub total	12,335,958	12,823	1,217,214	13,553,172	2,462,023	5.50		793	354	10
Iringa	Mufindi DC	1,431,000	1,590	179,208	1,610,208	1,326,608	1.21	-	25	203	-
	Mafinga TC	4,846,500	3,590	427,500	5,274,000	790,368	6.67	-	244	322	16
	Sub total	6,277,500	5,180	606,708	6,884,208	2,116,975	3.25		269	525	16
Mbeya	Rungwe DC	5,783,220	6,498	414,000	6,197,220	1,633,149	3.79	-	289	9	116
	Mbozi DC	2,249,600	2,812	74,333	2,323,933	512,506	4.53	-	107	152	-
	Mbeya CC	4,685,200	5,512	591,606	5,276,806	1,349,706	3.91	-	239	119	56
	Mbeya DC	6,926,400	7,696	485,714	7,412,114	2,241,037	3.31	-	395	264	21
	Sub total	19,644,420	22,518	1,565,653	21,210,073	5,736,399	3.70		1030	544	193
	Grand Total	**86,003,603**	**77,259**	**5,203,587**	**91,207,190**	**22,527,403**	**4.05**	**580**	**3351**	**3265**	**761**

Source of data: AADGG data base with authors own calculations

Table 2: Comparison of TFP for two consecutive years (2020/2021 and 2022/2023 across the regions

Regions	TFP		Differences
	2020/21	2022/23	
Arusha	2.69	2.73	0.04
Kilimanjaro	2.58	4.11	1.53
Tanga	3.12	4.25	1.13
Njombe	2.92	5.50	2.59
Iringa	2.80	3.25	0.45
Mbeya	2.79	3.70	0.91
Total	2.77	4.05	1.28

Source of data: AADGG data base with authors own calculations

market is available during drought and the informal market always available but not sure that they can sell as supply normally is higher than demand during wet season (Blackmore *et al.,* 2022). Therefore, farmer struggle to find markets and end up consuming their produce within the household or marketed locally through informal value chains (Blackmore *et al.,* 2022).

Hence, the milk and manure sold has negative effect on the total factor productivity (TFP) (Table 3). For the case of vaccinations, feed, vitamin and minerals they have high cost hence raise the cost of input and created negative affect to the overall TFP (Table 3).

Table 3: Empirical results for productivity as independent variable vs other factors

Independent variable TFP (productivity)	Coef.	Std.	Err.	t	[95% conf. Intervals]	
Milk yield	0.092735	0.0064204	14.44	0.000**	0.801494	0.1053207
Milk price	0.0010012	0.0000693	14.45	0.000**	0.0008654	0.0011371
Milk sold	0.2018484	0.0521766	3.87	0.000**	0.0995682	0.3041285
Manure sold	0.2018105	0.0521823	3.87	0.000**	0.0995192	0.3041018
Income	0.2015671	0.0521767	3.86	0.000**	0.3038475	0.0992867
Vaccination cost	-0.000032	1.63E-06	-19.67	0.000*	-0.00003	-0.00002
Feed Cost	-0.0016719	0.000064	-26.1	0.000*	-0.0017975	-0.0015464
Vitamin and minerals costs	-0.0018754	0.0001244	-15.08	0.000*	-0.0021192	-0.0016316
Other costs	-0.0000718	0.0000652	-1.1	0.000*	-0.0001997	-0.000056
Clusters	0.160353	0.0090298	17.76	0.000*	0.1780538	0.1426521

Source of data: AADGG data base with authors own calculations

This research found that to get optimal TFP, the average milk production per cow has to increase by 40.9% without increasing input cost in ceteris paribus (Table 4). This was realized in Kilimanjaro region where the production of milk increase, although the cost increased but the milk produced surpass the cost of production hence made the productivity very high compared to the previous years. Similarly, research found that with improvements in management, the cost of production will be reduced by almost half (47%) (Table 4), hence an increase in productivity per cow. The study also found that to have substantial profit farmers has to invest in fodder production and cut cost of production by 0.81 (Table 4). This paper found that there are factors that affect TFP in dairy small-scale farms despite of the fact that the farms have eight years records of cattle performances. Generally, they are merged in two major factors that affect TFP; high cost of feed (including vitamins and minerals) and treatments.

This has been reported by several studies that efficiency in dairy management depends on balancing of output and input-orientation, if it is well balanced on their own environment then the productivity and factor affecting TFP can be eliminated through choices, however, farms should always maintain and use their records to balance orientation of input and output. Several studies including Lyatuu *et al.,* (2016) suggested quick ways of increasing productivity is by adoption of innovation and technology in a right time in right environment.

Table 4: Dairy Production Efficiency

Item	Value
Average milk yield (Y)	9.9
Average productivity (P)	4.05
Efficiency (P/Y)	0.409090909
Average Production costs (C)	3064
Average fodder costs (F)	2575.867337
other costs (T)	488
Fodder cost deficiency (T/F)	0.189459027
Efficiency if fodder available (1-(T/F)	0.810540973
Average cost	3064
Average vaccination costs (V)	6465.5
Management cost M=(V-C)	3402
Management efficiency ME=M/V	0.526117291
Improve in management needed (1-ME)	0.473882709
Average Price in 2022 (P1)	800.2131
Average Price in 2023 (P2)	1136.768845
Difference in prices D=(P2-P1)	336.7688449
% increase in price D/P2	0.296250945

Conclusion

The research proved that technology use in improving genetics, dairy management, recording system, accessing locally availability quality feed has tremendous contributed to the increase in total factor productivity (TFP) in ceteris paribus. On the other hand, TFP in the dairy farm can influence profit only and only

if available records kept in the farm is used by the farmer in the same farm to balance input output orientation. However, to have substantial profit farmers has to invest in fodder production and cut cost of production by 0.81, this will minimize the cost of feed that affect TFP.

It is important to mention that Tanzania has a huge potential for milk production whereby the estimates show that over the projection period, about a third of the worldwide herd population is projected to be in Africa and to account for around 6% of world milk production. The challenge is to increase the productivity in the traditional systems of integrated farming, so that dairy may increase the productivity per animal within limited resources. It would be beneficial to apply the technology which can easily reduce factors that affect TFP without affecting the output/input-orientation efficiency. Minimizing feed costs is the most important in animal husbandry, can be balance by selection of high nutritious food available in local vicinity while choosing the correct breed that survive better in local environment to cut cost of treatment.

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