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Bayesian Analysis of Factors Influencing Milk Productivity of Small-hold Dairy Buffalo Farmers in South Luzon, Philippines

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Authors' contributions

This work was carried out in collaboration between both authors. Author TS designed the study, wrote the protocol, collected the data, reviewed the literature and wrote the manuscript. Author HT performed the statistical analyses, extensively managed literature research, wrote the manuscript, critically reviewed and approved the final manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

This study analyzed the factors influencing milk productivity of smallholder dairy buffalo farmers in South Luzon, Philippines. We used a cross-sectional data collected from 61 dairy buffalo farmers. This is the first local study to apply a Bayesian approach. The empirical results revealed that among the socio-economic, farm, and technology characteristics investigated, the household size have a positive effect, the number of lactating dairy buffalo negative effect, and the technology adoption of data recording a positive effect on milk productivity of dairy buffalo farmers rendering these factors significant in the analysis of productivity.

Keywords: Bayesian approach; milk productivity; dairy buffalo production; smallholder farmers.

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1. INTRODUCTION

The Philippines had an annual per capita milk consumption of 22 kg in 2017, and the national dairy consumption reached 2,486 MMT (LME). Meanwhile, domestic milk production was only at 22.76 MMT (LME), equivalent to a meager 1% of the Ready-To-Drink (RTD) milk in the market, leaving the country heavily dependent on import to meet the demand and most Filipino farmers in the rural communities belonging to the smallholder sector with the highest poverty incidence at 34.3% and having an average daily family income of less than US$ 7. Commonly carabaos bred here have a low genetic potential for milk production but are proven to be genetically improved using the dairy buffalo germplasm. Sustained upgrading in the villages produced upgraded carabaos or crossbred dairy buffaloes that, among many advantages, provide a better yield of premium buffalo milk. However, registered dairy buffaloes were only 0.64% out of 2.88 million total carabao population.

Small-scale milk production improves household producers' food security and helps create several employments throughout the dairy chain [1]. An adequately managed crossbred dairy buffalo can readily provide a Filipino family with an average of 5 kilograms of milk daily for about ten months, which can offer nourishment for the whole family. The excess can be an additional or alternative income source [2]. Since management for dairy buffalo is very different from raising carabaos for draft, the Philippine Carabao Center (PCC) generated several technologies for dairy buffalo production. PCC technology innovations are mainly categorized into animal management, data recording, forage production, and feeding management. These were promoted and introduced through extension programs and training, hoping to be adopted and help dairy buffalo farmers improve their farm economic efficiency and milk productivity. In dairy production, technology adoption grants higher milk yield and lower cost-to-produce [3]. The result of a local study by Palacpac et al. [4] showed that successful dairy buffalo farmers with positive net incomes are those that continuously adopt improved management technologies initiated by the PCC and that they also belong to the "earlier adopter "group. The same authors found that dairy buffalo farmers who have more communication or linkages with agencies and institutions for technical information adopt improved feeding practices [5]. However, no studies have shown the impact of adopting these technologies on milk productivity.

Scant local literature makes this a critical study that aims to analyze the socio-economic characteristics, farm characteristics and technology characteristics influencing milk productivity in smallholder dairy buffalo farmers in South Luzon, Philippines where majority of dairy buffalo farmers assisted by the Philippine Carabao Center and recipients of dairy buffalos are clustered. Identifying and understanding the different factors affecting milk productivity will help PCC in crafting and improving small-scale farmers' milk productivity.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

This study was conducted for smallholder dairy farmers breeding less than thirteen buffalos in two distinct areas, General Trias City (Cavite) and Rosario (Batangas), both located in Region 4A CALABARZON in South Luzon, Philippines. General Trias is a first-class city in the province of Cavite. This city has a total population of 314,303 people, according to the 2015 census, and is the 6th legislative district of Cavite and the lone district. The city has a total land area of 81.46 km2, with 33 barangays. This city is situated at the northern part of Cavite province and is located 14°23′ latitude and 121°53′ longitude and 35 kilometers southwest of Manila. Rosario is also a first-class municipality established in 1687 and is located in Batangas' fourth district. The town is known as the "Rice Granary of Batangas". It has a population of 116,764 people, according to the 2015 census. The town has 48 barangays and has a total land area of 226.88 km2. It lies between 13°41'7" N and 13°52'31" N latitude and 121°9'54" E and 121°21'50" E longitude and approximately 93 kilometers from Metro Manila. The municipality of Rosario is generally level, with gently sloping to undulating topography. It is located in terrain with an elevation ranging from 100 to 200 meters above mean sea level.

2.2 Sampling Procedure and Data Collection

We used data collected in 2018 using a pre-tested semi-structured individual interview questionnaire taken at the household level. The respondents were dairy buffalo farmers having at least one lactating cow and selling the milk to the dairy processing plants. These dairy buffalo farmers belong to organized groups assisted by the PCC. Secondary data were gathered from routinely submitted reports from the dairy processing plants where all the farmers sell their milk. Data samples from 61 farmers, socio-economic information, farm information, and adopted technology information were collected.

2.3 Description of Factors and Hypotheses

Understanding the underlying socio-economic factors affecting milk production is essential to make sound management decisions to enhance milk production [6]. The pieces of literature reviewed focused on several socio-economic determinants of milk production in smallholder level provided several influencing factors to daily milk yield [7-15]. Technologies are also expected to have significant effects on milk production [4]; In this study, mainly based on previous studies, the factors hypothesized to affect daily milk yield were grouped into 1. Socio-economic characteristics, 2. Farm characteristics, and 3. Technologies characteristics.

2.3.1 Socio-economic characteristics

The characteristics in this study are age, gender, education and household size based on previous studies. Age gives information on the household's development in terms of years. There is always an assumption that an increase in age means gaining more knowledge and experience to increase productivity. However, [14] relayed that milk production was negatively influenced by the age of the farmer and according to [16] and [15], active young age suggests high-quality labor and may positively affect farm productivity. Gender roles in buffalo production is seen to have a positive effect on milk production. Activities such as the construction of the shed, cleaning, grazing and feeding, breeding, and veterinary health care are still traditionally done-either male or female alone and joint decisions on buffalo rearing, marketing, and buffalo production activities [17]. Gender roles are observed throughout the value chain and influenced by the existing production systems, but gender was found to have no significant impact on milk production [14]. Education was measured as the number of years in formal education and can be seen to have a positive effect on animal productivity since it can increase the farmers' capacity to acquire information and knowledge to increase animal productivity [18]. However, [14] and [7] stated that education was found to have no significant impact on milk production and not the criteria to reflect the lactation milk yield. Household size is essential as a source of labor and demand to increase milk production [11] and has a positive relationship on daily milk yield [12].

2.3.2 Farm characteristics

These characteristics are experience, number of lactating carabaos, and off-farm sources of income based on previous studies, and being a dairy buffalo recipient, milk price, and milk production cost. Experience in carabao raising is hypothesized to negatively influence milk production due to farmers' tendency to adopt the same management of working carabao to dairy buffalo. Experience in dairy production develops a farmer in order to face challenges and adjust accordingly. [12] stated that experience has a relationship with daily milk yield and positively influences milk production. However, [8] stated that producers' experiences did not reflect profitability and productivity results. Access to dairy training of the farm owner significantly and negatively affects milk yield [14]. The Number of lactating carabaos has a relationship with daily milk yield [12]. However, increasing carabaos increase farmer's work and, therefore, may negatively influence milk productivity. Having off-farm sources of income have a negative influence on milk yield [14]. Being a dairy buffalo recipient means the PCC loans the animal to the farmer under a contract to use it for milk production. The recipients of dairy buffalo are expected to influence animal productivity and milk yield positively. Usually, milk price sold and milk production cost can provide some incentive for farmers to raise their profits.

2.3.3 Technology characteristics

[4] stated that the PCC, as the lead agency in the diffusion of dairy buffalo innovations, is confident that adoption of technologies is a significant component for the improvement of production and found that the number of technologies adopted in a dairy farm had a positive correlation with milk yield. In this study, technologies are hypothesized to influence milk productivity positively and the number of technologies included. The total number of technologies is 24 in this study, as shown in Table 1. PCC instructs farmers to adopt 24 technologies for the four different purposes of improving farm management. Therefore, 24 technologies are categorized into four types, A). Technologies in animal management (animal shelter, ear tagging, provision of wallowing area, consultation with a

veterinarian, deworming, and artificial calf mgt), B). Technologies in data recording (individual animal record, animal health record, milk production and sales record, breeding and AI services record, and calving data), C). Technologies in forage production and feeding management (propagation of forage legumes, forage ensiling, hay stacking and feeding, provision of feeding trough, provision of drinking trough and water, feed concentrates, provision of forage, and provision of any other types of feed supplements), and D). Ttechnologies in milking production (starting milking day 0, bathing before milking, twice a day milking, daily milk quality checking, daily mastitis signs checking, and disinfection on teats right after milking).

2.4 Empirical Model

In this paper, we started with a multiple regression model to identify the factors influencing milk productivity as the first step. In the model, the dependent variable was daily milk productivity per head, and the independent variables were four socio-economic characteristics, eight farm characteristics, and four technology characteristics. As the second step, we applied random-intercept model as a type of Bayesian hierarchical model to specify the influence in detail of technologies identified through multiple regression analysis. As described, technology characteristics variables are expressed by numerical data reflecting the number of technology adoption. That is, these variables implicitly assume that each technology has the same size as the effect on milk productivity. To confirm the validity of this implicit assumption, Random-intercept model was used. Random-intercept allows us to estimate the effect of technology characteristics as the effect of the difference of group farmers belonging according to number of technologies. Thus, the effect of technology characteristics can be captured without giving meaning in advance to the magnitude of the number of technologies adopted.

Bayesian analysis was applied to estimate both steps. Data analysis using the Bayesian inferential method presents a logical framework to use all sources available in order to come up with a decision. The sources of information will not just include the currently collected field data but will also utilize experiential knowledge, technical expert opinion, or data from previous researches having similar methodology with the current data [19]. Bayesian statistics are not based on large samples and may produce reasonable results even with small to moderate sample sizes. [20,21] also stated as one of the other advantages, Bayesian analysis is in increased statistical power for data-limited studies, and many papers have shown the benefits of Bayesian statistics in the context of smaller datasets.

Bayesian multiple regression model with 16 independent variables used in the first step is presented as:

$$\mu_i = \beta_0 + X_i\beta \quad \text{for } i = 1, \ldots, N,$$
$$ln\,(y_i) = \text{Normal}\,(\mu_i, \sigma^2) \text{ for } i = 1, \ldots, N, \quad (2\text{-}1)$$

where β_0 is the intercept, β is the coefficient column vector, X_i is the explanatory variables row vector for sample i, y_i is milk productivity (l/day/head) for sample i, and ln (y_i) follows the normal distribution with mean μ_i and variance σ^2.

Bayesian random-intercept model used in the second step is presented as:

$$\mu'_i = \beta'_0 + X'_i\beta' + r_j \quad \text{for } i = 1, \ldots, N, \text{ and all } j$$
$$ln\,(y_i) = \text{Normal}\,(\mu'_i, \sigma'^2) \quad \text{for } i = 1, \ldots, N,$$
$$r_j = \text{Normal}\,(0, \sigma_{rj}^2) \quad \text{for } all\ j, \quad (2\text{-}2)$$

where β'_0 is the intercept, β' is the coefficient column vector, X'_i is the explanatory variables row vector for sample i and the selected variable sets which strongly influence the dependent variable through Step1 analysis, r_j is the random-intercept for group j identified through the difference of the number of technologies adopted by farmers, and ln (y_i) follows the normal distribution with mean μ'_i and variance σ'^2. Note that when several technologies were specified as variables that strongly influence the dependent variable through Step1, more random effect terms like r_j are added.

Bayesian inference of both models was implemented using the brms package. This package implements Bayesian multilevel models in R using the probabilistic language Stan [22]. It provides a procedure for estimating the posterior distribution of model parameters by implementing sampling procedures, no-U-turn sampler (NUTS) introduced by [23]. NUTS is an extension of Hamilton Monte Carlo (HMC) sampler. According to [22], using HMC leads to higher quality samples but takes more time per sample than other algorithms typically applied and needs to pre-specify at least two parameters, which are both critical for the performance of HMC. The NUTS sampler allows setting these parameters automatically, thus eliminating the need for any hand-tuning, while still being at least as efficient as a well-tuned HMC [23].

NUTS sampler produced four independent Monte Carlo Markov Chains (MCMC) samples for posterior distributions of our model parameters, with 1,000 iterations after 5000 warm-up iterations for each chain. Thus, the total post-warm-up samples for each parameter was 4,000.

Table 1. Description of technologies for dairy buffalo farmers

Technology	Description
A. Animal Management	
Animal shelter	Dairy buffaloes need protection from direct sunlight, heavy rains and extreme weather conditions to minimize environmetal stress
Ear tagging	Individual identification numbers are manually tagged on the ears of each animal for tracking and record purposes.
Provision of wallowing area	dairy buffaloes benefit from wallowing area to cool their bodies, manage environmental stress and minimize external parasite infestation.
Consultation with veterinarian	regular consultation with veterinarians to prevent occurrence of diseases, improve animal management and treat diseases.
Deworming	Periodic and regular administration of anthelmintic and flukicide drugs to each animal to prevent production losses.
Artificial calf management	Calves are kept in a separate pen right after they are born. They will be fed with colostrum for 5 days and milk replacer through feeding bottles or pails for 3 months.
B. Data Recording	
Individual animal record	Each dairy buffaloes are given an individual animal record where all pertinent data about the animal are written, including pedigree, marks, growth record, animal health, and subsequent breeding information.
Animal health	This is the animal's health history and can be found in the individual animal record or farmer's logbook . All preventive biologicals like, vitamins, anthelmintic medicines, flukicide, and treatment drugs are listed each time it is administered to the animal with the corresponding dosage. It also includes the clinical signs observed and the staff who administered the drugs.
Milk production and sales	This is the daily record of milk yield volume from each dairy buffaloes right after milking and the corresponding price sold to the cooperative dairy processing plant.
Breeding and AI services	record of estrus signs, ovarian activity through rectal palpation, form of breeding - natural or artificial insemination, identification of mating bull or frozen semen straws.
Calving data	This contains information on the date of calving (giving birth), including information on calf (sex, weight, and markings), and observations on calving process (signs of distocia or birthing difficulty)
C. Forage Production and Feeding Management	
Propagation of forage and legumes	Forage and legume production and propagation is the most basic requirement in dairy buffalo production to ensure the daily feed requirement of each animal.
Practice forage ensiling	Silage production of forages is the farm's safety net in times of severe weather condition such as typhoons or drought in dry season where there is minimal forage to harvest. This will ensure that no matter the weather condition, the animals will always have feeds.
Practice hay stacking & feeding	Hay stacking is another farm's method of securing feeds for the animals. Rice straws are usually free and widely

Technology	Description
	available in rice-producing areas. These are gathered, sun-dried, baled, and stored for future use in times of forage shortage. These are treated with urea and molasses mixture when fed to dairy buffaloes.
Provision of feeding trough	This is a special elevated area of the barn, pen, or shelter where food for the dairy buffaloes are placed. They do not eat trodden and dirty forage on the floor.
Provision of drinking trough and water	Dairy buffaloes have an unlimited requirement for clean drinking water anytime of the day.
Provision of feed concentrates	Feed concentrates are needed for a balanced feed ration according to the requirements of each animal in production. This is also a big factor in increasing milk yield of dairy buffaloes.
Provision of Forage	Fresh forage should always be available for the animal anytime of the day whether they are inside a barn or tethered in the pasture area.
Provision of other types of feed supplements	Feed supplements such as additional calcium and mineral blocks are always provided for each animal inside the shelter. These ensures that all the nutritional requirements of lactating animals are met.
D. Milk Production	
Start milking on day 0	Milk production starts on day or the calving date. The calf is separated from the dam and secured in a calf pen. The dam will be milked and the daily colostrum for 5 days and succeeding milk will be fed to the newborn calf using artificial feeding bottles or pail.
Bathing before Milking	Pre-milking shower relaxes and cools the animals before the actual milking time. It also removes most of the hair coat dirt that can drop and contaminate the newly collected milk.
Twice a day milking	Milking animals two times in a day increases the milk production to about 25-30% more.
Daily On-farm milk quality checking	Checking and recording the pooled milk quality right after collection is important to qualify and grade the milk in the farm before transit through milk collectors. Milk quality can deteriorate if not cooled down right after milk collection and while travelling to the processing area. Deteriorated milk can be rejected by the quality analyst and farmers will have no milk sales for that particular day.
Daily On-Farm Checking for Signs of Mastitis	Mastitis check and control is a preventive management tool to catch this condition in the early stage and prevent heavy losses in milk production and income. This will prevent mixing mastitic milk with the good ones and the chance of all milk being rejected in the dairy processing plant.
Application of iodine or any disinfectant on teats right after milking	Disinfectants directly applied on the teats soon after milking prevent mastitis.

3. RESULTS AND DISCUSSION

3.1 Multiple Regression Analysis Results

Table 2 presents the posterior means, standard deviations, and Bayesian 95% credible intervals as the multiple regression analysis results. Fig. 1. also presents the 95% credible intervals and the posterior means to provide a visible understanding of the results. In this figure, the bar shows the 95% credible intervals and the circle stands for the posterior means. Bayesian 95% credible intervals indicate the 0.025 and 0.975 quantiles of the posterior distribution for each characteristic. The characteristics that have the same signs in the 95% credible interval are interpreted as factors that influence milk productivity. The results showed that among the socio-economic characteristics, Household size (posterior mean 0.09) have a positive effect; among the farm characteristics, Number of lactating carabaos (posterior mean -0.23) have a negative effect, and among technology characteristics, Data recording score (posterior mean 0.20) have a positive effect on milk productivity. The characteristics that do not have same signs in the 95% credible interval are interpreted as factors that may influence milk productivity. The results showed the only factor as such is the Off-farm sources of income (posterior mean -0.25). The rest of the characteristics appears to have no or negligible effect on milk productivity. Therefore, the critical factors to be considered in the analysis of dairy buffalo milk productivity are Household size, Number of lactating carabaos and Data recording score. Hence, the random-intercept model presents these three variables as explanatory variables, and the random effects of each group having a different Data recording score are estimated.

3.2 Random-intercept Model Analysis Results

Table 3 presents the posterior means, standard deviations, and Bayesian 95% credible intervals as the random-intercept model analysis results. The results regarding Household size and Number of lactating carabaos reveal population-effects. While, the results regarding Data recording score reveal group-effects. The results demonstrated that Household size (posterior mean 0.08) could have a positive effect, and Number of lactating carabaos (posterior mean -0.22) could have a negative effect. These two results showed almost the same value compared to the results in the multiple regression analysis. The Random-intercept of Data recording score implicitly assume but not entirely support monotony where milk productivity increases with an increase in data recording scores.

3.3 Discussion

In Table 2, the household size positively affects milk productivity and can probably be explained by having additional family members who help and contribute to farm activities instead of hiring expensive farmworkers and laborers. Household size is important as source of labor and demand to increase milk production [15] and has a relationship on daily milk yield [17]. This fact is contrary to a result revealed by [24], who conducted an investigation in Nigeria on the influence of socio-economic characteristics of cooperative farmers on agricultural production. In their study, household size has an inverse relationship with agricultural production, indicating that as the household size increase by one person, farmers output levels decrease by 14.9kg, suggesting that other members of the household are not supportive of the household head in agricultural production, increases dependency and negatively affect production.

The result of our analysis also revealed that the Number of lactating carabaos has negative effect on milk productivity. This can probably be

Table 2. Posterior means, standard deviations and Bayesian 95% credible intervals of multiple regression analysis

Variables	Posterior mean	Standard deviation	95%credible interval	
Intercept	0.90	0.80	-0.67	2.53
Socio-economic characteristics				
Age (years)	0.00	0.01	-0.02	0.01
Gender male (male=1, female=0)	-0.11	0.22	-0.53	0.33
Education(years)	0.01	0.02	-0.04	0.06
Household Size(persons)	0.09	0.04	0.02	0.17
Farm characteristics				
Off farm source income (yes=1, no=0)	-0.25	0.14	-0.52	0.00
Recipient of PCC dairy buffalo	0.07	0.16	-0.23	0.39
Carabao raising experience(years)	0.00	0.01	-0.01	0.01
Dairy farming experience(years)	0.00	0.01	-0.02	0.01
Carabao production training	0.07	0.18	-0.28	0.42
Number of lactating carabaos(heads)	-0.23	0.04	-0.31	-0.14
Raw milk price(ppp//)	0.01	0.01	-0.01	0.02
Production cost(ppp/l)	0.00	0.00	0.00	0.00
Technology characteristics				
Animal management score	-0.06	0.07	-0.20	0.09
Data recording score	0.20	0.05	0.10	0.31
Forage production and Feeding management score	-0.01	0.04	-0.09	0.07
Milking production score	-0.06	0.14	-0.34	0.20

Table 3. Posterior means, standard deviations and Bayesian 95% credible intervals of random-intercept model analysis

Variables	Posterior mean	Standard deviation	95% credible interval	
Intercept	1.17	0.24	0.70	1.67
Socio-economic characteristics				
Household Size(persons)	0.08	0.03	0.02	0.13
Farm characteristics				
Number of lactating carabaos (heads)	-0.22	0.04	-0.30	-0.15
Technology characteristics				
Data recording score: Random intercept				
0	-0.36	0.23	-0.84	0.06
1	-0.13	0.23	-0.60	0.29
2	-0.05	0.22	-0.49	0.38
3	-0.12	0.22	-0.56	0.29
4	0.29	0.20	-0.10	0.71
5	0.32	0.22	-0.09	0.76

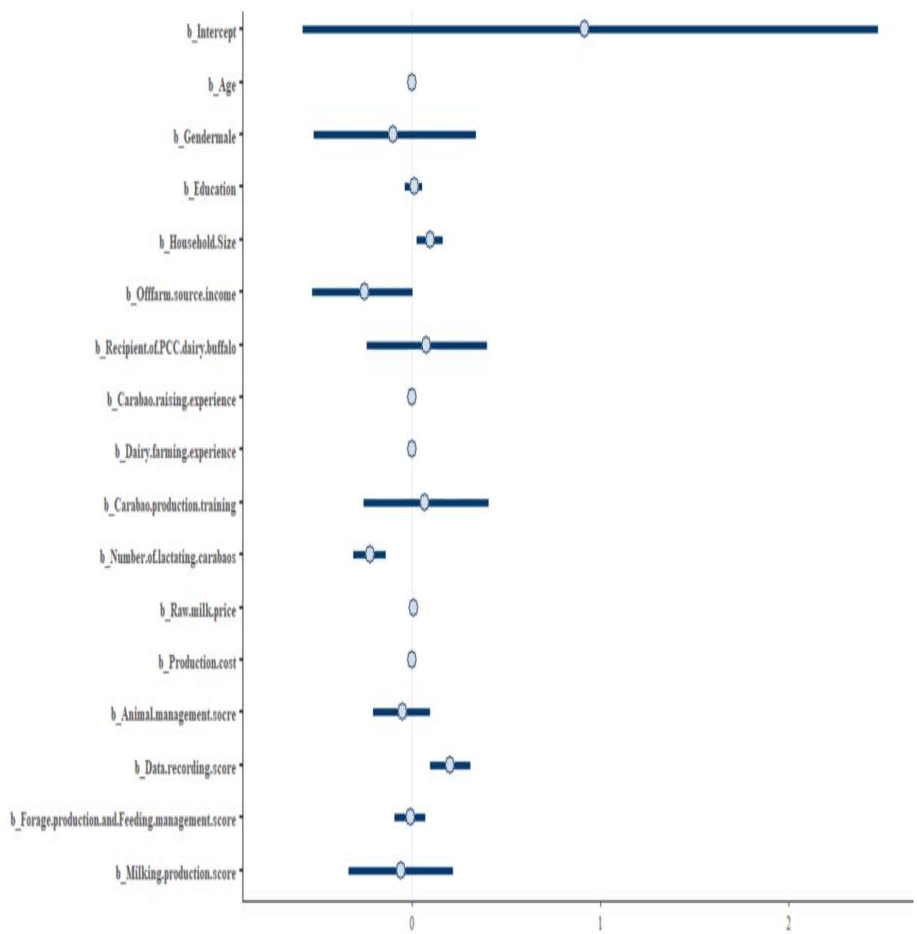

Fig. 1. Bayesian regression model results for 95% credible intervals associated with factors influencing milk productivity in small hold dairy buffalo production in South Luzon, Philippines

explained by the realization that having more animals means more heads to feed and increase in farm activities. Limited farm hands will result to undernourished animals and limited farm activities done eventually resulting to lower milk productivity. Opposite to this finding, a local study stated that the Number of dairy cows have positive linear correlation with the income derived from raising dairy buffalo [5]. In addition, [25] and [15] stated that farmers with more dairy cows have higher milk production. Furthermore, the results of this study demonstrated that data recording have a positive effect on milk productivity. Data records serve as information and guide for the farmer and the dairy herd.

The off-farm sources of income may have a negative influence on milk productivity. This is backed by the results of [14] stating that off-farm income had a negative influence on milk production. Another study concluded that households with large farm size and many off-farming activities have the lowest returns per hectare since they have devoted their time to other activities [26]. Meanwhile, [4] had an opposite finding stating that off-farm sources of income have positive linear correlation with dairy buffalo income.

4. CONCLUSION

We identified factors influencing milk productivity of smallholder dairy buffalo farmers. Our results revealed that from among the socio-economic, farm, and technology characteristics investigated, the household size and data recording have a positive effect, the number of lactating carabaos have a negative effect and off-farm sources of income may have a negative effect. The rest of the characteristics appears to have no or negligible effect on milk productivity. Therefore, the critical factors to be considered in the analysis of dairy buffalo milk productivity are household size, number of lactating carabaos, and data recording score. To address these critical factors for consideration, we recommend the following:1) regular conduct of training for smallholder farmers on dairy buffalo production and enterprise development. 2) We also recommend further studies on the effects of technology adoption, use of dairy handbook or manual, and conducting regular technical trainings on dairy buffalo farmers' milk productivity.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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