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## DETERMINANTS OF LIVESTOCK HERD SIZE IN MIXED CROPPING ZONE OF PUNJAB-PAKISTAN

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### ABSTRACT

Pakistan is considered as an agricultural country dominated by smallholder farmers. The size of the land, livestock, and labor force have paramount importance for the livelihood of resource-poor farmers. The present study was designed to determine the factors affecting the size of the livestock, i.e., the flock size of large ruminant buffaloes and cows. A cross-sectional data set collected randomly from 150 respondents from three districts of the mixed cropping zone of Central Punjab was used to address the study's objectives. Regression estimates revealed that family labor for attending animals, length of lactation, total healthcare expenditures, small land holding, and the geographic district factors significantly affected the herd size of buffaloes and cows. Based on the findings, the study recommends that the implementation of health care systems is one of the crucial factors in building the herd size, mainly through reducing mortality rates, improving the length of lactation, and other aspects of animal well-being. Similarly, the benefits of government livestock policies should reach the grassroot level to retain and use domestic family labor, not as a norm but to engage in the livestock sector for earning their incomes.

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### INTRODUCTION

In Pakistan, the agriculture sector makes up 20% of the country's national GDP, with a major share (58%) coming from the livestock sector. Total livestock of Punjab has reached 70.367 million numbers, wherein buffaloes and cattle are 29.07 million (39.4%). Furthermore, the population of cattle is highest than buffaloes in Punjab. Muzaffargarh district, followed by Bahawalpur, has the highest population of cattle, whereas Faisalabad, followed by Okara, is rich in Buffaloes (GoP, 2019). The importance of livestock can also be gauged from the fact that it is a traditional banking product that plays a dominant role in the livelihood of rural families by providing 35-40% of income to over 8 million rural families as well as providing them food security by supplementing high-value protein of animal origin. Almost 3.1% of exports of the country are fulfilled from the livestock sector (GoP, 2019). Lubungu et al. (2012) also report a similar type of benefits of livestock as livestock is closely linked to the social and cultural lives of smallholder farmers, for whom animal ownership is to ensure varying degrees of economic stability.

The relationship among family labor, livestock herd size, land size, and participation of the farmers in the market is very important for the economic growth of the livestock sector. According to Salem and Smith (2008), livestock numbers can invariably increase livestock production, which is of paramount

consideration towards food security for many livestock farmers in most developing countries. Similarly, structural shifts in the economic and demographic landscapes in developing countries are a blessing for livestock producers to participate in the economic growth from which they have largely been bereaved (Lubungu, 2017). As these structural shifts take place, people tend to use more of the foods of animal origin, and accordingly, livestock production and population have a great potential to act as the driver of economic growth. On the one hand, building a healthy herd size is the prime element to the growth of the sector and ensuring that farmers take full advantage of the growth of the sector, but on the other hand, frequent droughts, floods, and invariable localized inputs are also charging a heavy toll on the condition and numbers of livestock usually the breeding herd. Chattha et al. (2013) argue that non-price factors are critical in determining milk production, thereby affecting the livestock population. It is therefore imperative to examine the crucial role of non-price factors in determining livestock population. Ogunkoya (2014) also suggests that factors like age, education, experience, land ownership, availability of extension services, health facilities, and the agro-ecological conditions prevalent in the areas may affect the livestock population. Chand and Raju (2008), during the regression analysis, hypothesized that livestock output

(growth) might be affected by the quality of herd, infrastructure for output marketing, facilities of veterinary hospitals, fodder availability, membership of dairy cooperatives, and technology. Therefore, estimating the influencing factors is necessary because they portray the stability of the herd structures. Also, knowing about the population indicators of different livestock breeds is necessary as these vary across different livestock value chains. Moreover, determining herd size is a major factor influencing farmers' market participation and off-take levels, as a bigger herd size is an influencing determinant of owners in marketing (Sikhweni and Hassan, 2014). Knowing of factors impacting the decision of rural farmers to keep sheep and/or goats is crucial when designing technologies and making policies that support village-based livestock production. The information on such factors will also improve the estimation of impact evaluation strategies on the livelihoods of people (Dossa et al., 2008). Literature also indicates that livestock plays a considerable role in the growth of other agriculture sectors (Bakhsh et al., 2014). Thus, livestock not only influences socio-economic conditions of farmers it also contributes in the productivity of allied agricultural activities in the rural areas.

The need to re-consider the role of socio-economic factors of humans in managing farm resources and accordingly, the animal farms is increasingly being studied worldwide despite the fact that large flocks may significantly cause disease outbreaks and other complications (Loi et al., 2019). The need to study flock forming factors is also reinforced because many smallholder livestock farmers operate just at the lower end of production, where a small additional input leads to a substantial increase in productivity (FAO, 2009). Researchers have made different attempts to study the herd size of livestock by applying various empirical methodologies in accordance with the prevailing issues in their countries. For example, Engler et al. (2018) studied the socioeconomic characteristics of rural households in Nigeria in conjunction with stocking rate (the number of animals per hectare) derived from the herd size (cattle number) and farm size. Lubungu et al. (2012) studied the links between livestock and the social and cultural lives of smallholder farmers, for whom family labor is important for animal ownership as this helps them to reduce the cost of production. Mwangi and Kavoi (2013) added that socio-economic and environmental factors such as population growth, urbanization and economic development, changing livestock market demands, impacts of climate variability and science and technology trends contributed to the changes in livestock numbers. Dossa et al. (2008) applied logistic regression technique on determining socioeconomic factors affecting goat and sheep herd size in Benin, West Africa. The researchers reported that resource poor farmers were more likely to keep small ruminants confirming their role as saving or living banks.

The study recognizes that the farmers of the country mostly keep large animals (buffaloes and cows) for their livelihood and hence, acknowledges that both the larger herd size as well as productivity can handle the challenge of food security facing the country. The study give weightage to the fact that understanding of factors affecting decision of farmers to keep livestock will guide impact intervention strategies on the

livelihoods of rural people majority of whom (89%) are landless in Pakistan (GoP, 2019). The persistence stagnation in the production of livestock from last two decades while animal population is increasing (GoP, 2019) also motivates to address this deadlock in production. Therefore, it was imperative to identify factors affecting herd size of buffaloes and cows as mainly these animals are reared for livelihood in the country and a little empirical evidence exists on correlation between the number of buffaloes and cows and socioeconomic and geographic factors in the context of Pakistan. The study used three district-level cross-sectional data from mixed cropping zone of the Central Punjab with the objectives of understanding socio-economic and agro-ecological factors making and maintaining the herd size of buffaloes and cows. The study may be helpful in, for example, improving livestock production and addressing the farmers' constraints of low market participation (Lubungu, 2017). The study specifically addressed to find the socioeconomic and geographic factors influence the flock size of large ruminants and to improve the socioeconomic conditions of the farmers.

## **METHODOLOGY**

### **Data Sources, Description of Variables and Ethical Considerations**

This study used primary data collected through well designed questionnaire from livestock owners of mixed cropping zone of Central Punjab. Seré et al. (1995) defined Mixed farming systems while classifying world livestock systems as the systems wherein over 10 percent of the dry matter fed to animals comes from crop by-products and stubble, or more than 10 percent of the total value of production comes from non-livestock farming activities. The same characteristics are reflected in the mixed cropping zone of the Pakistan where more milk and meat production even can occur in its worst conditions. Three districts from mixed cropping zone of the Punjab Province, i.e., Faisalabad, Chiniot and Jhang districts were selected as a target population for this study because these districts have comparatively higher number of livestock population among other districts falling under mixed cropping zone. Other reasons of selection of these districts were abundance of households holding livestock, the close proximity of these districts but wide variation in the endowment of natural resources and natural disasters in selected districts. Therefore, the selected districts can represent socio-economic and demographic conditions of mixed cropping zone and best for study of factors determining herd size of buffaloes and cows.

Data were collected through random sampling from 50 households each from three districts. In this way, the competent scientific staff of Pakistan Agricultural Research Council interviewed total 150 livestock holder families during year 2018. This study included small and large buffaloes and cows as a response (dependent) variable depicting the number of buffaloes and cows owned by an individual livestock owner. Although many factors can contribute both positively and negatively to changes in livestock population like growth, increased incomes, a boost in demand for livestock products, developments in breeding, animal nutrition and health welfare, changing food choices as well as changes in climate

conditions (Mandleni et al., 2019) yet the response variable in present study was regressed upon the explanatory variables like family labor (for crops and livestock separately), the livestock holding experience, age, education level, land operational area, district, lactation time, and total health expenditures on animals. During survey, permission to collect data was obtained from the heads of the rural households, and suitable times and venues were arranged with the farmers. Data were collected with the use of a well-structured questionnaire which was written in English. The questionnaire used simple sentences to make it respondent-friendly, while local concepts were used for easy interpretation. The questionnaire had already been tested on 20 household heads to ensure that the questions would be well understood. Face-to-face interviews were conducted with the farmers who was 18 years old and above. Questions that seemed difficult to the respondents were explained in their local language (Punjabi).

### Econometric Model Specification for the Herd Size of Buffaloes and Cows

Currently several econometric models are available in the literature to study the dynamics of herd size. These models can be applied to determine factors (explanatory variables) influencing on certain desirable characteristics of a desired dependent variable. For example, Zahoor et al. (2013), and Andaleeb et al. (2017) applied the linear regression model to determine participation of women in livestock production in Pakistan. Sikhweni and Hassan (2014) used negative binomial model while determining livestock herd size in Limpopo, South Africa. Kapembwa et al. (2022) applied the probit model to find out factors affecting choice of marketing channel and ordinary least square (OLS) regression to determine factors affecting number of goats owned among smallholder farmers in Zambia as the Dossa et al. (2008) did in logistic regression technique on determining socioeconomic factors affecting goat and sheep herd size in Benin, West Africa. Similarly, Nabi et al. (2019) determined factors affecting mutton exports from Pakistan by applying ordinary least square (OLS) regression on secondary data. Maree (2007) states that on one hand, the OLS is a mathematical modeling approach that can be used to describe the relationship between a continuous dependent variable and several independent variables and on the other hand, OLS regression is particularly powerful tool as it is relatively easy to check model assumptions such as linearity, variance and the effect of outliers (Hutcheson and Sofroniou, 1999).

Therefore, present study also relied on the technique of OLS regression to model a continuous dependent variable of herd size of cows and buffaloes in Pakistan. In order to investigate the factors affecting numbers (herd size), double log regression model was specified because transforming variables logarithmically in a regression model is considered an easy

method to handle situations where a non-linear relationship exists between the regressors and the regressand. Therefore, instead of un-logged form, logged form develops the effective relationship non-linear, while preserving linearity in the model. In other words, the OLS estimates were: linear, unbiased, with minimum variance, consistent and normally distributed (Gujarati, 2003).

The extended form of general OLS equation was specified as:

$$\begin{aligned} \ln_{\text{buff\_cow}} = & \beta_0 + \beta_1 \ln_{\text{family\_lab}_{\text{crop}}} + \\ & \beta_2 \ln_{\text{experience}} + \beta_3 \ln_{\text{education}} + \beta_4 \ln_{\text{age}} + \\ & \beta_5 \ln_{\text{tot\_health\_expnd}} + \\ & \beta_6 \ln_{\text{family\_lab\_livest}} + \beta_7 \ln_{\text{lact\_aver}} + \\ & \beta_8 \text{opert\_dum1} + \beta_9 \text{opert\_dum2} + \beta_{10} \text{ddum1} + \\ & \beta_{11} \text{ddum2} + \varepsilon \end{aligned} \quad (1)$$

Where  $\ln_{\text{buff\_cow}}$  = log of number of buffaloes and cows at the time of survey;  $\ln_{\text{family\_lab\_crop}}$  = log of family labor engaged in growing of crops;  $\ln_{\text{experience}}$  = log of experience in livestock rearing in years;  $\ln_{\text{edu}}$  = log of education/schooling years of livestock owner;  $\ln_{\text{age}}$  = log of age of livestock owner;  $\ln_{\text{tot\_health\_expnd}}$  = log of total health related animal costs in Pakistani currency;  $\ln_{\text{family\_lab\_livest}}$  = log of family labor engaged in attending livestock herd;  $\ln_{\text{lact\_aver}}$  = log of average length of lactation in months;  $\text{opert\_dum1}$  = dummy for operational land area of less than 12.5 acres;  $\text{opert\_dum2}$  = dummy for operational land area between 12.5 - 25 acres;  $\text{ddum1}$  = dummy variable for district Jhang;  $\text{ddum2}$  = dummy variable for district Faisalabad and  $\varepsilon$  = error term.

### Research Hypotheses and Summary of Determinants of Herd Size of Buffaloes and Cows

To fulfill research objectives several hypotheses regarding factors determining herd size of buffaloes and cows were formulated as shown in Table 1 that depicts summary status of all the explanatory variables included in the model but in a tabular form. The expected signs of each of the explanatory variable are also mentioned.

### Methods

Based on the objectives of the paper, first we described data on important socio-economic and demographic variables by selected districts. Then, we applied regression technique to get reliable, unbiased and consistent estimates of the parameters. In order to check for the multicollinearity and heteroskedasticity problems in cross-sectional data, post regression tests like Variance Inflation Factor (or Tolerance), IM test, HET test (Breusch-Pagan/Cook-Weisberg test of heteroskedasticity) were run in line with Khan et al., (2016). In the end, to check whether the model was correctly specified or not, a Link Test was performed. The analysis was conducted in STATA version 12.

Table 1. Research hypotheses and summary of explanatory variables.

ID	Variable description	Expected sign	Basis of signs
1	Age of livestock owner (years)	Positive	Sikhweni and Hassan (2014) reported that according to Vink and Kirsten (2001), older and experienced livestock producers tend to have larger herds of cattle than younger livestock owners thus hypothesizing positive association between age and herd size.
2	Education (years)	Negative	Farmers who are educated they try to adopt new technological inventions relating to cattle production and are thus able to learn skills faster than farmers with no-education; this trend may yield to higher productivity, often resulting in larger herds (Musiguzi, 2000).
3	Experience in livestock (years)	Positive	Study by Ogunkoya (2014) held a positive association between herd size and experience in livestock.
4	Family labor for crops (Nos.)	Negative	There is a positive relationship between herd size and family size because family size can provide necessary labor force for farm i.e. for both crops and livestock husbandry (Ogunkoya, 2014) but more attention towards livestock will shift labor in opposite direction from crops to livestock.
5	Family labor for livestock (Nos.)	Positive	There is positive relationship between sizes of herd and family because family size can provide necessary labor force for farm i.e. for both crops and livestock husbandry (Ogunkoya, 2014).
6	Operational land area (acres) 1= less than 12.5, 2= 12.5 to 25, 3= more than 25 acres	Positive	According to a study by Rahman et al. (2001), a positive association exists between ownerships of livestock as well as land held by farmers in semi-arid area of Bangladesh. Ciamarra et al. (2011) quotes report of the Government of India (2006) that National Sample Survey shows positive association between farm size and ownership of large animals, small ruminants and poultry.
7	Lactation length (months)	Positive	Atashi et al. (2012) found that larger herd size was giving an average increase of 2.69 kg in 305-day milk per 50 cows per herd. Similarly, Singh et al., (2016) found that average lactation yield was significantly higher for large herd size farms due to the better management practices adopted at large dairy farms as compared to small dairy farms.
8	Total animal healthcare expenditures (Pak. Rs.)	Positive	Study by Ogunkoya (2014) suggested that if there is no problem in managing animal veterinary dosing/drugs then there may be more herd size. Therefore, positive association is hypothesized.
9	District 1=Jhang, 2= Faisalabad, 3 = Chiniot	Positive	According to Niamir (1990), livestock ownership is also dependent on ecological zones as ownership differs widely among ecological zones, agricultural production systems (subsistence or commercial scale) and social factors.

## RESULTS AND DISCUSSION

### Socio-Economic and Demographic Features

Table 2 shows that the average age of the livestock owner respondents was almost 44 years, while there was a significant difference in age across three districts at a 1% level of significance. The livestock owners of district Chinot were comparatively younger. The overall level of education (tertiary level) was according to previous studies in these areas, but the education level was almost the same across the three districts. The age and education level of Pakistani livestock holders is nearly similar to the South African livestock farmers as there majority of the respondents comprised of adult smallholder cattle and sheep farmers between the ages of 38 and 57, with the educational level of up to standard 6 (Mandleni et al., 2019). In the present study, the average experience of livestock holding of 21 years was significantly different at 1% across districts. Livestock owners of District Jhang were comparatively more experienced. The implication of age, education, and experience are that majority of the energetic respondents had substantial years of experience in livestock farming on account of their low education. The average number of family members was eight persons across all districts, as evident from insignificant stats. Overall, family members involved in raising crops (3.3 persons) were significantly different across the districts at 1% level of confidence.

Average number of family persons in crops was comparatively highest (3.9 persons) in district Faisalabad. Similarly, average family persons attending the animals were 1.75 and highest family labor engaged in livestock was reported in district Faisalabad and this may be one of the reasons of having lead population of buffaloes in Faisalabad as compared to all other districts of Punjab Province (GoP, 2019). Average operational land area was more than 25 acres implying that livestock owners were mainly large farm owners. Land operational area was comparatively more in district Jhang. Average total health care expenditures on animals in Pak. Rs.43514 were also significantly different across districts at 1% level of confidence. Highest and lowest animal health expenses for district Jhang and Chinot respectively were in accordance with respective populations of livestock in these districts. The average lactation length of these milking animals was 7 months (210 days). Average total number of herd size comprising only buffaloes and cows was 21 animals and there was wide variation in livestock numbers among selected districts. The district Jhang possessed highest strength of buffaloes and cows as evident from survey results. According to GoP (2018), the overall number of buffaloes and cows are much higher in mixed cropping zone as compared to other zones of Punjab-Pakistan. According to Bhutto et al., (2015) although the number of buffaloes and cows (8.33) are less than the present study results yet livestock numbers in Sindh, Pakistan depict enhanced numbers.

Table 2. Socio-economic and demographic features.

Characteristics	Jhang	Faisalabad	Chiniot	Overall	Sig.
Age (Years)	46.1	47.5	38.0	43.9	0.000*
Education (Years)	8.5	7.6	6.7	7.6	0.154
Experience (Years)	24.9	23.4	16.5	21.6	0.001*
Household size (Persons)	8.1	8.2	8.1	8.1	0.968
Family labor in crops (Nos.)	2.6	3.9	3.5	3.3	0.002*
Family labor in livestock (Nos.)	1.38	2.08	1.80	1.75	0.006*
Operational area (Acre)	63.5	10.3	7.7	27.2	0.000*
Total veterinary health expenditures (Rs./annum)	80300.0	35288.0	14956.0	43514.67	0.000*
Average lactation (Months)	6.7	7.6	6.8	7.0	0.000*
Total buffaloes and cows (Nos.)	34.0	17.0	13.5	21.5	0.000*

Note: \* represents significance level and luckily all the significant variables are highly significant at 1% level.

### Regression Results

Table 3 summarizes the estimated results of double log regression taking herd size of buffaloes and cows as dependent variable, regressed on explanatory variables. A total of 5 out of 9 variables were significantly affecting dependent variable, i.e., total number of buffaloes and cows. The estimated signs of coefficients were consistent with our priori expectation. Results show that relationship is positive and highly significant between total health care expenditures on animals and herd size with coefficient of 0.356 implying that as the health related costs increased by one percent, the herd size of buffaloes and cows increased by 0.35 percent. The higher t-ratio (5.67) in case of health related expenditures indicated that this variable was contributing more to herd size of buffaloes and cows. As the real expenditures related to animal health care increase, the herd size of animals is increased as the animals start living longer on account of provision of better health facilities. This finding is almost in accordance with Gieseke et al. (2018) who elaborated direct correlation between herd size with animal welfare (provision of better care of animals). Innovations in breeding, animal nutrition and facilities allied to animal health will continue to enhancing potential production, efficiency and genetic gains from livestock (Thornton, 2010; Bhutto et al., 2015). Similarly, provision of better nutrition facilities have positive effects on the animal estrous cycle (Khlil et al., 2017) which can promote the growth of both the herd size and animal offspring into mature breeding stock. On the other hand, half of the cattle population left the herd due to enormous deaths (Lubungu, 2017).

Family labor for attending herd has significant and positive impact on herd size of buffaloes and cows as evident from regression results. In subsistence herding, large number of livestock are associated with large numbers of members (Hudson and Neville, 1969). Average length of lactation has a positive and significant effect on herd size at 10% level of significance. Again increased lactation period means animals of better breed which is considered as sign of better high yielding offspring. The operational land area of less than 12.5 acres (small farm category) has comparatively lowest stock of buffaloes and cows as evident from negative sign with coefficient of land area. Similarly, there is no difference in total number of buffaloes and cows between medium and large sized farm categories (between 12.5 to 25 acres category

farms and reference category farms of greater than 25 acres). Whatever the operational land category was, Mudzielwana (2015) said that the having or no-having of land is one of the natural endowments determining the fodder availability and hence, found this factor significantly determining decision to own the cattle and determine the size of herd. Similarly, Kapembwa et al., (2022) also reported that land area has significant correlation with the herd size of small ruminants in Zambia. The district Jhang was significantly possessing more number of buffaloes and cows than reference category (district Chiniot) as the sign with coefficient is positive. The large livestock asset of district Jhang is probably justified on the grounds of availability of more grazing land as well as higher rural-urban population ratio of 77%:23% as compared to both Faisalabad and Chiniot where the same ratios are less (52%:48% and 70%:30%) respectively. District Jhang has been facing comparatively more natural disasters i.e. floods. Hence, herd owners seem to align their animal numbers to flood cycles. Accumulation of livestock has to some extent been proved empirically an effective strategy for lessening shocks of environmental hazards for short time spans (Naess and Bardsen, 2013). Results further revealed that district Faisalabad was not affecting the herd size as the influence was insignificant. In this way, there was insignificant difference in total number of buffaloes and cows in Faisalabad and Chiniot districts. These results are contrary to Ogunkoya (2014) who while studying socio-economic factors affecting livestock population in South Africa, concluded that district has a negative but significant effect on livestock numbers. Our finding on district impact on livestock herd is also in line with the findings of Sikhweni and Hassan (2014) that the livestock herd size differs widely among districts. Comparing the two regression results in both year 2008 and 2012, the independent variables that were found to significantly affect livestock numbers were district, household size in Free State Province of South Africa (Mandleni et al., 2019).

The model is a good fit as evident from value of F-statistics (probability > F=0.000). Under regression diagnostics, quality of model evaluations is done using such measures as AIC, BIC, (adjusted) R<sup>2</sup>, etc. but we followed (adjusted) R<sup>2</sup>. The value of R<sup>2</sup>=0.52 in the present study means that explanatory variables included in the model explains 52 percent of total variation in numbers of buffaloes and cows. Although the relationship between farm labours engaged in

growing of crops and herd size is statistically insignificant but its sign is expected (negative). The reason may be that the farm family is more interested in growing crops than rearing livestock; hence, labor is diverted to crops. Similarly, variables of the age, education, and experience of farmers have insignificant relationships with the herd size, but the signs of coefficients are positive and expected, as hypothesized in the study.

### Post Regression Tests

Post regression tests were run in order to test and validate the model estimates based on the assumptions of linearity, normality, homoscedasticity and independence of error term.

According to results in Table 4, the mean value of Variance Inflation Factor (VIF) is even less than 5 (start of moderate problem of multicollinearity) implying no problem of multicollinearity in the current data set in confirmation with the Engler et al. (2018). IM test results in Table 5-A show that heteroskedasticity value is insignificant and not enough to reject null hypothesis of homoscedasticity. The HET test (Breusch-Pagan test) for heteroskedasticity also proves that variance is constant (Homoskedastic) as explained by value of chi-square i.e.  $\text{Prob} > \chi^2 = 0.887$  which is not able to reject null hypothesis of homoscedasticity (Table 5-B) Hence, we conclude that cross-sectional data is free from the problems of multicollinearity and heteroskedasticity.

Table 3. Regression summary.

Variables	B	SE	t-ratios	p-value
Constant	-2.501309	1.459962	-1.71	0.089
Family labor in crops	-0.2204768	0.202788	-1.09	0.279
Experience	0.0067601	0.143608	0.05	0.963
Education	0.0929273	0.079704	1.17	0.246
Age	0.0372107	0.356071	0.1	0.917
Total animal healthcare expenditure	0.3558353	0.06277	5.67	0.000*
Family labor in livestock	0.4152485	0.200114	2.08	0.040**
Average lactation period	0.7666836	0.444763	1.72	0.087***
Land > 12.5 acre	-0.2207354	0.226592	-0.97	0.332
Land < 12.5 acre	-0.5210202	0.220594	-2.36	0.02**
Faisalabad district (dummy)	0.0150618	0.170818	0.09	0.93
Jhang district (dummy)	0.380257	0.218784	1.74	0.084***
Number of obs = 150	F(11, 138) = 13.85	Prob > F = 0.000	R2 = 0.5248	Adj R2 = 0.4869

\* significant at 1%, \*\*significant at 5%, \*\*\*significant at 10% .

Table 4. Multicollinearity test results.

Variable	VIF	1/VIF
Experience	3.23	0.309735
Land < 12.5 acre	3.17	0.314997
Age	3.14	0.318819
Jhang District	2.91	0.343865
Family labor in crops	2.78	0.360077
Family labor in livestock	2.73	0.366526
Land > 12.5 acre	2.25	0.445242
Total animal health care expense	1.79	0.559469
Faisalabad District	1.77	0.564096
Education	1.49	0.670155
Average lactation period	1.27	0.787305
Mean VIF	2.41	-

Table 5-A. Cameron & Trivedi's Decomposition of IM-test.

Source	Chi <sup>2</sup>	Df	P
Heteroskedasticity	78.8	71	0.2458
Skewness	13.48	11	0.2633
Kurtosis	3.88	1	0.0488
Total	96.17	83	0.153

Table 5-B. HET test

Breusch-Pagan/Cook-Weisberg test for Heteroskedasticity

Ho: Constant variance

Variables: fitted values of ln (buffaloe + cow)

Chi<sup>2</sup> (1) = 0.02

Prob > chi<sup>2</sup> = 0.8874

Table 6. Model specification test.

Ln (buffaloes + cow)	Coeff	SE	t-ratios	p-value
Hat	0.492265	0.5360167	0.92	0.360
Hat <sup>2</sup>	0.0916205	0.095688	0.96	0.340
Constant	0.6523393	0.716969	0.91	0.364

An equally important assumption of good econometric regression model is correct model specification by testing whether the necessary variables have been included in OLS equation or not? For single equation regression models, the link-test command is enough to check the models' correct specification. Link-test creates two new variables, the variable of prediction, "hat" and "hat-square". Normally, the hat-square

should not be significant for proper model specification. Results of model specification test in Table 6 indicate that coefficient of "hat<sup>2</sup>" (0.0916205) is not significant at corresponding p-value of 0.340 for t-ratio (0.96). Here probability of rejecting the assumption that the model is specified correctly; is diminished. In conclusion, regression equation is correctly specified containing necessary variables.

### CONCLUSIONS AND RECOMMENDATIONS

Livestock production is highly concentrated among the majority of landless rural households and can contribute to improving the earnings of this resource-poor farming community in Pakistan. The production of mainly meat and milk from animals presents an opportunity for poor rural masses to engage in large ruminant production. It was observed that households possess a bigger flock of cows and buffaloes. It is of paramount importance for the rural families to build and maintain a bigger herd size in the presence of abundant domestic labor to attend the agriculture. Since the herd size can be influenced by many other factors that are not included in the present study, we limited the discussion to a few important correlated factors rather than causal factors. The results show that family labor for attending animals, length of lactation, total healthcare expenditures, small landholding, and the geographic district factors are positively and significantly correlated with the herd size of buffaloes and cows given the existing data set. On the one hand, management practices such as deworming, vaccination, insemination, and adequate nutrition are a big challenge to the resource-poor livestock holders and a primary means of increasing herd size on the other hand. Thus the study, based on the findings, recommends that adopting improved health care systems is one of the crucial factors in building the herd size as better healthcare management strategies play a critical role in reducing mortality rates, increasing birth life, improving the length of lactation and thereby affecting well-being aspects of animal husbandry. Similarly, the Livestock and Dairy Development Department should provide productive breeding stock and animal dosing products on subsidy to further improve lactation, which may contribute to the growth of the flock. Similarly, the input distribution policies of the government ensuring benefits to reach the grassroots level should also come in place for encouraging and retaining farm family labor in livestock not as a cultural norm but for diversification of agriculture. Lastly, livestock farmers can be trained by animal health and nutrition professionals in the field of best animal husbandry practices, thereby contributing to increasing herd sizes.

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### Author Contributions

All the authors have equally contributed in the design, data collection and write up of this original research article. The final version was read and approved by all the authors.

### Conflict of Interest

The authors declare no conflict of interest.

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