Quantitative Perspective of Small Ruminant Production in Akwa Ibom State, Nigeria

Eduma E. Essien
Federal Polytechnic, Ukana, Essien Udim L.G.A., Akwa Ibom State, Nigeria.

Mirabel I. George
National Teachers' Institute (NTI), Uyo City Polytechnic Study Centre, Akwa Ibom State, Nigeria.
*Email: mercymichael78@gmail.com

ABSTRACT

This study applies quantitative modelling and econometric analysis to assess small ruminant production in selected Local Government Areas in Akwa Ibom State, Nigeria. Data were collected from 31 small ruminant producers, randomly selected from three Local Government Areas (LGAs) of Akwa Ibom State (Uyo, Abak, and Ikot Ekpene). Using the farm-level data from the small-scale goat producers, the study estimates a Cobb–Douglas production function to identify input elasticities, measure technical efficiency with stochastic frontier analysis, and identify key socio-economic and production characteristics of goat producers in the State. Based on the findings, the study recommends that policy interventions should focus on improving farmers' access to affordable feed resources, veterinary services, and extension support to enhance productivity and technical efficiency. In addition, capacity building in modern husbandry practices and targeted investment in value chain development are necessary to promote competitiveness and ensure the long-term sustainability of small ruminant production in Akwa Ibom State, and Nigeria at large.

Keywords: Quantitative modeling, econometric analysis, small ruminants, ruminant production, goat production, Akwa Ibom.

INTRODUCTION

Small ruminant production occupies a strategic role in Nigeria's agricultural sector, particularly among smallholders who dominate the rural economy. Goats and sheep account for a substantial proportion of the national livestock population, with goats alone estimated at over 76 million heads (FAO, 2021). In Akwa Ibom State, where land fragmentation, urbanization, and crop–livestock competition are pronounced, small ruminants are valued for their adaptability, short reproductive cycles, and ability to thrive on limited feed resources (Okoye *et al*., 2019).

Production is largely traditional, relying on extensive or semi-intensive systems. Households keep small herds ranging from 5–20 animals, managed primarily by women and youth as supplementary income sources (Akinmoladun *et al.*, 2019). Despite their importance, productivity remains low compared to potential yields, due to reliance on unimproved breeds, high disease prevalence, and low investment in improved feeding and housing (Lawal *et al.*, 2020).

Among small ruminants, goats are the most widely kept species in Akwa Ibom State due to their hardiness, prolific breeding, and strong market demand. Goat meat is considered culturally acceptable across ethnic and religious groups, unlike pork or beef which may face consumption restrictions. Goats also serve as a "liquid asset," easily sold in emergencies to meet household financial needs (Ojo *et al.*, 2021).

Despite their potential, small ruminant systems in Akwa Ibom State face persistent constraints. Feed scarcity, especially during the dry season, remains the most critical production bottleneck. Most farmers rely on crop residues, natural pastures, and household waste, which are often nutritionally inadequate (Oluwatayo & Oluwatayo, 2019). Diseases such as peste des petits ruminants (PPR), helminthiasis, and ectoparasites lead to significant mortality and productivity losses (Adedeji *et al.*, 2020). Institutional barriers also play a role. Access to credit for small ruminant farmers is limited, while veterinary and extension services are either absent or poorly funded. The lack of organized cooperatives and value-chain linkages restricts the bargaining power of producers, exposing them to exploitation by middlemen (Yusuf *et al.*, 2021).

In the context of modeling, given their importance, and wide-ranging applications, mathematical and econometric tools are indispensable in agricultural economics, as they provide rigorous means of analyzing complex relationships, quantifying resource use efficiency, evaluating policy impacts, and supporting evidence-based decision-making for sustainable agricultural development. For small ruminant production, such methods reveal which inputs deliver the greatest marginal returns, where extension or credit programs can reduce inefficiency, and how market frictions (transport costs, market concentration) influence prices received by producers and sellers. Econometric evidence, ranging from cross-section regressions of production determinants to stochastic frontier analysis (SFA), panel data approaches, and micro-simulation models, enables researchers and policymakers to move beyond descriptive accounts and estimate causal relationships, elasticity measures, and welfare implications under realistic assumptions. These insights are directly applicable to program design, such as targeting feed subsidies, improving vaccination coverage, or investing in market infrastructure, thereby aligning research findings with practical policy actions.

Small ruminants (principally sheep and goats) are a cornerstone of rural livelihoods in many low- and middle-income countries, providing meat, milk, cash income, savings, and socio-cultural value while requiring relatively low capital and land compared with large ruminants. In Nigeria, small ruminants contribute substantially to

household food security and rural incomes, and they provide a flexible asset for poor and resource-constrained farmers in the humid and sub-humid zones of the south. However, despite strong local demand and clear livelihood importance, production in Akwa Ibom State remains characterized by low productivity, fragmented markets, disease burdens, feed shortages, and weak access to finance and extension services, constraints that undermine the sector's capacity to contribute to sustainable livestock development and resilience.

This study examines the role of mathematical and econometric methods in understanding and promoting sustainable small ruminant production in Akwa Ibom State. Quantitative modeling and econometric analysis are indispensable for diagnosing these constraints, quantifying production responses, measuring technical and allocative efficiency, and assessing the potential impact of policy or technological interventions. By combining production theory, efficiency analysis, and market modeling, researchers can identify the most effective levers for increasing productivity while maintaining environmental and social sustainability. This study synthesizes recent empirical and modeling studies relevant to small ruminant production in Akwa Ibom State and comparable contexts.

Small ruminants, particularly sheep and goats, play a vital role in global livestock systems because of their ability to convert low-quality forages into high-value products such as milk, meat, and hides with relatively low capital and land investment. Among them, goats stand out for their adaptability, resilience, and socio-economic importance, especially in resource-poor regions. They are often considered "the poor man's cow" because of their affordability, small body size, and ability to thrive in marginal environments. According to the Food and Agriculture Organization (FAO, 2011), goats provide a crucial livelihood buffer by serving as a source of income, savings, and nutrition in households across Africa, Asia, and Latin America.

Goat production systems vary widely across regions. In developed countries, production is more specialized, with intensive dairy, meat, or fibre enterprises characterized by controlled breeding, high input use, and modern management practices. In contrast, smallholder mixed crop–livestock and pastoral systems dominate in developing regions, relying largely on extensive grazing and seasonal feed availability (Iñiguez, 2011). These systems often face constraints such as low input use, feed shortages, and limited access to veterinary services and markets, yet they remain vital for rural livelihoods.

Feeding and nutrition are central to goat productivity. Goetsch, Gipson, Askar, and Puchala (2010) emphasized that goats are highly adaptable feeders, capable of browsing a wide variety of shrubs and trees while also grazing on grasses. This dual feeding strategy enables them to thrive on rangelands where cattle or sheep might struggle. Zervas and Tsiplakou (2011) demonstrated that feeding systems not only affect productivity but also influence product characteristics such as milk composition and meat

quality. For instance, forage-based diets tend to enhance fatty acid profiles in milk, while strategic supplementation during critical periods, such as late pregnancy or early lactation, improves reproductive performance and kid growth.

Breeding strategies present both opportunities and risks. The use of exotic breeds such as Boer goats for meat production has been widely promoted to improve growth and carcass traits. However, Iñiguez (2011) cautioned that crossbreeding often fails under low-input systems, as imported genetics may not perform well in environments characterized by feed scarcity and disease pressure. In many cases, crossbreeding dilutes the adaptive traits of indigenous breeds, making them more vulnerable to stress and diseases. Instead, community-based breeding programs that emphasize the conservation and selective improvement of local breeds have shown more sustainable results.

Animal health remains a significant bottleneck in goat production. Gastrointestinal parasites, infectious diseases, and reproductive disorders are widespread. Webb (2014) noted that poor health management reduces kid survival and overall flock productivity, especially in smallholder systems where veterinary services are limited. Integrated approaches that combine improved housing, hygiene, vaccination, and targeted deworming programs have proven effective in reducing mortality rates. Farmer training and the use of community animal health workers can bridge gaps in veterinary service delivery.

The growing demand for goat products presents important opportunities. Goat meat is increasingly popular in both local and international markets due to its lower fat content and distinctive taste (Webb, 2014). However, smallholders often face barriers in accessing these markets. According to FAO (2011), poor infrastructure, lack of cold chains, and weak producer organizations hinder value-chain development. Strengthening cooperatives, improving market information systems, and investing in local processing facilities for goat milk and meat are necessary to enable producers to capture higher returns.

Goats are widely recognized for their adaptability to harsh environments. They require less water and feed compared to larger ruminants and can survive in arid and semi-arid regions where other livestock would fail (Iñiguez, 2011). However, climate change poses new challenges, such as increased drought frequency, feed scarcity, and heat stress. Adaptive strategies, including forage conservation, the use of drought-tolerant feed species, and selective breeding for heat tolerance, are crucial for sustaining production. At the same time, research has begun to examine the environmental footprint of goat production, particularly in terms of methane emissions, with an aim to identify mitigation options.

Looking forward, several priorities emerge for research and policy. First, affordable feeding technologies adapted to smallholder conditions are essential to boost productivity. Second, breeding programs must balance productivity gains with the conservation of adaptive traits in indigenous goats (Goetsch et al., 2010). Third, scalable

health interventions—including vaccination campaigns and parasite control programs—should be expanded to rural communities. Finally, improved value-chain infrastructure and farmer organizations are needed to link smallholders more effectively to markets (FAO, 2011). Coordinated investment in these areas would harness the comparative advantages of goats as a pathway to poverty reduction and food security.

Goat production is uniquely positioned to contribute to sustainable livelihoods and nutritional security, particularly in resource-poor environments. As Goetsch et al. (2010) and Webb (2014) highlight, goats' versatility in feeding and adaptability to harsh climates make them a strategic livestock species for the future. However, realizing their potential requires addressing persistent challenges in nutrition, health, breeding, and market access. With targeted interventions that prioritize smallholder realities, goat production can evolve into a more productive, profitable, and resilient enterprise.

Objectives of the Study
1. Identify key socio-economic and production characteristics of goat producers in Akwa Ibom State.
2. Estimate a Cobb–Douglas production function for goat output, quantify input elasticities, and identify key socioeconomic determinants influencing goat production efficiency.
3. Identify covariates with the largest and smallest effects on production
4. Provide policy implications and recommendations to improve productivity and enhance sustainable small ruminant livestock production in Akwa Ibom State.

Theoretical Framework

Production function and input–output relationships
At the core of production analysis is the production function linking outputs (e.g., weight gain, number of animals sold) to inputs (labor, feed, veterinary services, breeding stock, land, capital). A widely used functional form is the Cobb–Douglas (CD) production function:

$$Y_i = A \prod X_{ij}^{\beta_j} e^{\varepsilon_i} \text{ or in log form: } \ln Y_i = \ln A + \Sigma \beta_j \ln X_{ij} + \varepsilon_i \qquad (1)$$

Technical efficiency and stochastic frontier analysis (SFA)
Observed output differences among similar farms reflect not only input endowments but also differences in technical efficiency (TE). The stochastic frontier model decomposes the error term into random noise and inefficiency:

$$\ln Y_i = f(X_i; \beta) + v_i - u_i \qquad (2)$$

METHOD

This study employed quantitative and econometric modeling dimensions to examine small ruminant production in selected Local Government Areas (LGAs) of Akwa Ibom State. Primary farm-level data were collected from 31 small-scale goat producers randomly selected from the three LGAs (Uyo, Abak, and Ikot Ekpene).

To ensure adequate spatial coverage and representativeness, a multistage sampling approach was adopted. In the first stage, the three LGAs were purposively selected based on their prominence in small ruminant production and accessibility. In the second stage, goat farming locations within each LGA were identified with the support of local field assistants. A list of active small-scale goat producers was then compiled for each LGA, from which respondents were randomly selected in proportion to the size of the producer population. Data were collected through structured questionnaires administered via face-to-face interviews, allowing for clarification of responses and minimizing non-response errors. The questionnaire captured information on socio-economic and production characteristics, herd size, input use, management practices, costs, and output levels, thereby providing consistent farm-level data suitable for econometric analysis.

Two basic econometric models were specified and estimated:

Model 1: Cobb–Douglas Production Function (Log–Linear Form)

The Cobb–Douglas production function was estimated in logarithmic form to capture the elasticity of output with respect to key inputs such as labour, feed, veterinary services, breeding stock, and capital. The coefficients represent input elasticities, indicating the percentage change in output associated with a one percent change in each input. The sum of the elasticities was used to assess returns to scale (increasing, constant, or decreasing).

Model 2: Technical Efficiency (Stochastic Frontier Analysis, SFA)

Technical efficiency was estimated using a stochastic frontier production function, decomposing the error term into random noise and a non-negative inefficiency component. Efficiency scores, ranging from 0 to 1, were obtained for each farm. These scores were subsequently regressed on farmer and household characteristics (e.g., education, access to extension services, and credit) to identify socio-economic factors influencing inefficiency.

Collectively, these models provided insights into the drivers of productivity, and sources of inefficiency, thereby informing evidence-based strategies for sustainable small ruminant development in Akwa Ibom State.

All models were estimated using maximum likelihood and regression-based techniques implemented in STATA 17 and R (version 4.3). Descriptive statistics were first generated to summarize household and production characteristics, followed by log–

linear regression for the Cobb–Douglas production function, maximum likelihood estimation for the stochastic frontier model, and generalized linear models (Poisson/Negative Binomial) and binary choice models (logit/probit) for market behaviour analysis. Robust standard errors and 95% confidence intervals were reported to ensure statistical reliability.

OLS Model specifications

Table 1: Definition of Variables Used in Production

Label	Description
Y	Output (farm-level annual goat output measured as kg of meat-equivalent sold or number of goats sold aggregated to output measure).
L	Labour input (labour-days used in goat production per year).
F	Feed input (feed quantity or feed expenditure; units depend on measurement convention).
V	Veterinary expenditure (money spent on veterinary services and medicines per year).
B	Breeding stock (number of breeding does/bucks or value of breeding herd).
K	Capital (value of fixed capital: housing, equipment, pens — monetary units).
P	Price per goat (Naira).
Q	Quantity sold by seller m (number of goats sold in the observation period).
transport	Transport cost (Naira per marketing trip or per unit).
market_type	Market classification indicator (0 = local/rural; 1 = urban).
const	Intercept (model constant).
TE	Technical Efficiency (score between 0 and 1 obtained from SFA).

RESULTS AND DISCUSSION

Descriptive Statistics of Goat Producers

Table 2 presents summary statistics of the goat producers surveyed across three cities in Uyo, Abak, and Ikot Ekpene Local government areas of Akwa Ibom State.

Table 2: Descriptive Statistics of key socio-economic and production characteristics of goat producers in Akwa Ibom State (N = 31)

Variable	Mean	Std. Dev.	Min	25%	Median	75%	Max
Output (kg)	143.96	26.64	92.60	131.96	142.98	160.35	197.38
Labour (hours)	38.81	9.14	20.40	33.02	38.84	44.78	58.52
Feed (units)	80.91	19.88	27.61	69.52	81.84	96.34	111.29
Veterinary services (visits)	14.82	4.82	5.41	12.97	14.83	16.49	27.32
Breeding stock (number)	11.78	2.79	7.18	9.45	12.55	13.23	18.57
Capital (₦ '000)	107.35	29.38	64.26	77.98	110.23	124.14	181.61
Herd size (number)	7.61	5.10	0.00	3.50	7.00	12.50	15.00
Veterinary access (dummy)	0.52	0.51	0.00	0.00	1.00	1.00	1.00
Market participation (dummy)	0.61	0.50	0.00	0.00	1.00	1.00	1.00
Age (years)	50.23	5.88	40.00	45.00	50.00	55.00	59.00
Gender (1 = Male, 0 = Female)	0.68	0.47	0.00	0.00	1.00	1.00	1.00
Education (0 = None, 1 = Primary, 2 = Secondary, 3 = Tertiary)	1.87	0.98	0.00	1.00	2.00	3.00	3.00
Extension access (dummy)	0.13	0.34	0.00	0.00	0.00	0.00	1.00

Notes: Gender coded as Male = 1, Female = 0 (68% male farmers), Education coded as None = 0, Primary = 1, Secondary = 2, Tertiary = 3 (spread across all levels; majority had some formal education), Extension access coded as Yes = 1, No = 0 (very limited and almost negligible access among farmers), Age clustered between 40 and 60 years, with mean ≈ 50 years; Output measured in kilograms; Labour measured in hours; Feed in standardized units; Veterinary services as number of visits; Breeding stock and Herd size as number of animals; Capital expressed in ₦ '000.

The descriptive statistics in Table 2 for 31 goat producers reveal notable patterns in production characteristics, resource use, and socio-demographic factors. On average, producers recorded an output of ≈144 kg of goat meat or its value equivalent, with wide variation (93–197 kg). This spread underscores heterogeneous production capacity, where some farmers operate efficiently while others remain constrained by limited inputs, poor management, or weak market integration.

Labour use (≈39 hours) and feed inputs (≈81 units or ₦80,000 equivalent) show moderate dispersion, with relatively tight interquartile ranges, suggesting that goat farmers rely on household or hired labour in consistent patterns and treat feed as a standardized but essential input. However, the presence of a few farmers investing substantially higher amounts in labour and feed indicates a shift toward commercial orientation among select producers. Veterinary expenditures (mean ≈14.8) and capital

(mean ≈107.4) are right-skewed, with long upper tails, reflecting a small subset of farms with disproportionately high investments. This validates the need for log-transformation in econometric modeling to address heteroscedasticity and yield interpretable elasticities. Herd size averaged 7.6 goats, ranging from zero to 15, further pointing to a dual production structure: some households maintain only very small flocks, while others manage larger herds that provide economies of scale and higher market leverage. Market participation and veterinary access, with means of ≈0.61 and ≈0.52 respectively, suggest that slightly over half of the producers sell goats or benefit from animal health services, leaving a significant proportion excluded from formal input-output linkages that could improve productivity.

Socio-demographic indicators provide additional context. The sample is male-dominated (68%), reflecting gender asymmetry in goat farming, though women also participate meaningfully. Education levels are distributed across all tiers, with most farmers having some formal education, implying a potential for knowledge adoption if supported by extension systems. However, extension access is almost negligible, reinforcing a structural weakness that limits the uptake of improved practices and technologies. Age distribution is clustered between 40 and 60 years (mean ≈50), indicating that goat production is concentrated among middle-aged farmers, whose experience may be an asset but whose succession prospects could be uncertain if youth engagement remains low.

In sum, the statistics highlight a production system characterized by high variability, skewed input allocation, dual farm structures, and significant gaps in veterinary, extension, and market access. These features justify econometric analysis to disentangle efficiency drivers and to guide targeted policy interventions that promote inclusive productivity growth in goat farming.

Overall, the descriptive results suggest that goat production in the study area is characterized by moderate productivity but substantial heterogeneity in herd sizes, input use, and market integration. This justifies the application of econometric techniques such as the Cobb–Douglas production function and stochastic frontier models to capture efficiency differences, while binary and count models help to explain variations in market behaviour. These findings also have direct policy implications; including improving access to veterinary care, promoting feed innovation, and encouraging market participation could reduce disparities, increase productivity, and enhance the livelihoods of goat producers.

Cobb–Douglas Production Function
The Cobb–Douglas regression examined the relationship between output (Y) and inputs (labor, feed, veterinary expenditure, breeding stock, and capital). The results (Table 3) reveal that while the overall explanatory power of the model is low, the coefficients suggest that capital (housing and equipment) had the most positive contribution to output,

followed by feed. Labor and breeding stock showed weak elasticities, while veterinary expenditure was negative. This outcome highlights inefficiencies in input use, possibly due to underinvestment in feed quality, limited extension access, and disease management challenges.

Table 3: Model Summary Statistics for Goat Output Equation

Statistic	Value
Dep. Variable	Y
R-squared	0.057
Adj. R-squared	-0.132
Method	Least Squares
F-statistic	0.3018
Prob (F-statistic)	0.907
No. Observations	31
Df Residuals	25
Df Model	5
Log-Likelihood	9.1190

The estimated Cobb–Douglas production model (dependent variable: **Y**, farm-level goat output; n = 31) displays very limited explanatory power. The R-squared of 0.057 and adjusted R-squared of −0.132 indicate that the included input measures account for only about 5.7% of the variation in observed output and that, after penalizing for model complexity, the model explains less variation than a simple mean-only model. The F-statistic (0.3018) with Prob(F) = 0.907 shows that, jointly, the regressors are not statistically significant predictors of output at conventional significance levels.

The log-likelihood (9.1190) confirms a modest fit to the data but must be interpreted in the context of sample size and model specification. With only 31 observations and five regressors (Df residuals = 25; Df model = 5), statistical power is low; therefore coefficient (coef.) estimates are likely to be imprecise and confidence intervals wide. Practical reasons that likely contribute to the weak fit include measurement error (for example, feed quality recorded as quantity or expenditure), omitted variables that matter for goat productivity (breed genetics, disease incidence, feed quality, management practices), and possible multicollinearity among inputs.

Policy and methodological implications follow directly. First, substantive inferences about individual input elasticities should be made cautiously. Second, for this sample it is advisable to adopt parsimonious specifications (fewer parameters), to standardize or combine collinear predictors (e.g., an input-index), and to report robust or bootstrap standard errors. Third, complementing OLS with techniques tailored to production analysis — such as Stochastic Frontier Analysis (to separate inefficiency from

noise) and instrumental-variable methods (to tackle input endogeneity) — would strengthen causal interpretation. Finally, expanding the sample and improving data on feed quality, disease burden, and breed would materially improve the model's ability to inform policies aimed at sustainable small ruminant development in Akwa Ibom State.

Table 4: Cobb–Douglas Production Function Estimates for Goat Output

Variable	Coef.	Std err.	T	P>/t/	[0.025]	[0.975]
const	4.3950	1.250	3.515	0.002	1.820	6.970
L	0.0163	0.157	0.104	0.918	-0.307	0.339
F	0.0387	0.131	0.296	0.770	-0.231	0.308
V	-0.0652	0.113	-0.577	0.569	-0.298	0.168
B	-0.0454	0.159	-0.286	0.777	-0.372	0.281
K	0.1320	0.145	0.909	0.372	-0.167	0.431

Notes: Omnibus: 0.007; Durbin-Watson: 1.823; Prob(Omnibus): 0.997; Jarque-Bera (JB): 0.178; Skew: -0.012; Prob(JB): 0.915; Kurtosis: 2.630.

The result in Table 4 *indicates r*esidual diagnostics (Omnibus p = 0.997; Jarque–Bera p = 0.915; skew ≈ −0.012; kurtosis ≈ 2.63) indicate no significant departure from normality, supporting the use of OLS inference in this cross-sectional sample. The Durbin–Watson statistic (≈1.82) shows no evidence of first-order autocorrelation of residuals. However, the condition number of the design matrix is high (≈288), suggesting the presence of multicollinearity or numerical ill-conditioning among the regressors. To address this, variance inflation factors (VIFs) were examined; more parsimonious model specifications were re-estimated; continuous regressors were standardized; and robust as well as bootstrap standard errors were reported to enhance the stability and reliability of the estimates.

The **k**ey diagnostics show very low explanatory power: R-squared = 0.057 and adjusted R-squared = −0.132. The F-statistic (0.3018, p = 0.907) indicates the regressors jointly do not explain a significant share of variation in log-output at standard levels. Model residual diagnostics (Omnibus, Jarque-Bera) do not reject normality; the Durbin–Watson statistic ≈ 1.82 suggests no pronounced first-order autocorrelation.

The estimated coefficients (elasticities) from the logged mode, indicate as follows: The const (intercept) = 4.3950 (p = 0.002). In level terms, exp(4.3950) ≈ 81.0. Interpreted loosely as the baseline output level (in the units of Y) when all logged inputs equal zero. The intercept is statistically significant, indicating a positive baseline productivity term that is not explained by the included inputs. L (labour) coef = 0.0163 (p = 0.918). Interpreted as an elasticity: a 1% increase in labour is associated with a 0.016% increase in output. This effect is effectively zero and statistically insignificant. Practical implication: within the observed range, additional labour days do not translate

into measurable output gains—likely because labour quality, task allocation, or managerial capacity vary and were not captured. F (feed) coef = 0.0387 (p = 0.770). A 1% increase in feed corresponds to a 0.039% increase in output, but this effect is not significant. This small and insignificant elasticity may reflect variation in feed quality (not captured by quantity/expenditure measures) or inefficient use of feed (poor feeding regimes). V (veterinary) coef = −0.0652 (p = 0.569). A negative, insignificant coefficient. This counter-intuitive sign often occurs when veterinary spending is largely reactive (incurred after disease outbreaks), so higher vet bills correlate with lower output. This is a measurement/interpretation issue rather than evidence that veterinary services harm production. B (breeding stock) coef = −0.0454 (p = 0.777). Negative and insignificant; likely driven by heterogeneity in breeding stock quality (unimproved vs. improved breeds) and unobserved management differences. K (capital) coef = 0.1320 (p = 0.372). Positive (largest magnitude among inputs) but statistically insignificant. Suggests investments in housing and equipment are associated with higher output—intuitively plausible because better capital can reduce mortality and stress, although the evidence in this regard is weak.

Returns to scale: the sum of estimated elasticities ≈ 0.0764. This sum is well below one, which if taken at face value—indicates decreasing returns to scale. However, because coefficients are imprecisely estimated and mostly insignificant, the returns-to-scale conclusion should be treated cautiously; omitted-variable bias could downward-bias the sum.

Key substantive interpretation for the study: measured inputs as reported do not explain much of the observed variation in goat output among producers in Akwa Ibom State. The implication is that managerial factors, disease incidence, feed quality, breed genetics, and unobserved shocks likely play dominant roles. For policies seeking sustainable productivity gains, this points to interventions that improve feed quality, animal health prevention, breeding/genetics, and farmer management skills rather than sole reliance on increasing input quantities.

To highlight the variables exerting the strongest and weakest influences on production and, the analysis reports key large-magnitude and small-magnitude coefficients, along with their 95% confidence intervals. These results are presented in Figures 1 and 2, respectively, to emphasize both effect size and statistical precision. Figure 1, indicating "key small-magnitude coefficients" plots coefficient estimates (L, F, V, B, K, transport) that are numerically small (close to zero) with 95% confidence intervals. These come from the Cobb–Douglas production model (producers) and the transport coefficient from the sellers model.Figure 2 indicating "key large-magnitude coefficients"plots the large-magnitude market coefficients (Q = quantity sold; market_type) with their 95% CIs (units = Naira for price regressions).
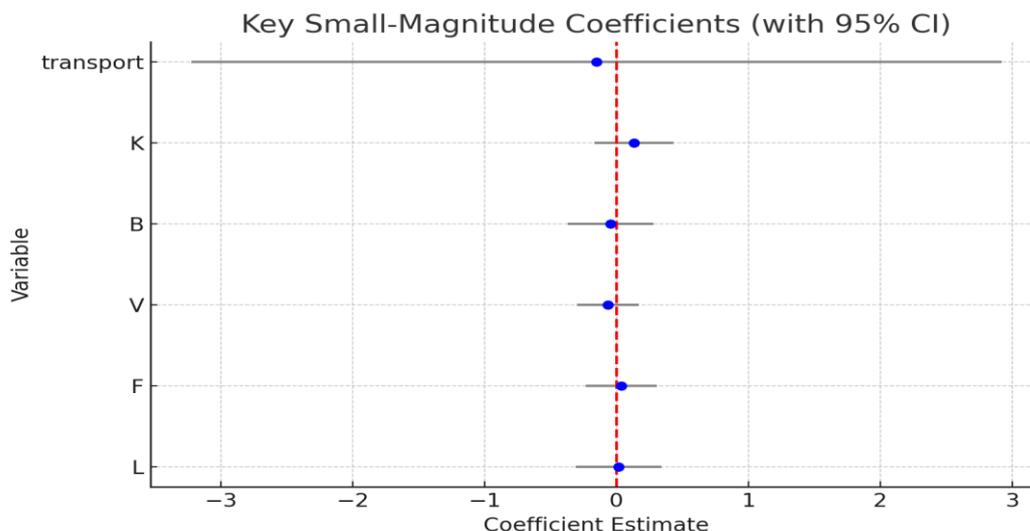
Figure 1. **Key Small-Magnitude Coefficients (with 95% CI)**

Figure 1 indicates the key small-magnitude coefficient estimates and 95% confidence intervals from the Cobb–Douglas production model (labour = L, feed = F, veterinary = V, breeding = B, capital = K) and the transport coefficient from the sellers' price model. Vertical dashed line at zero shows no-effect threshold. Sample: 31 producers (production model). The result further indicates the following inferences:

Coefficients cluster around zero: Labour (L), Feed (F), Veterinary expenditure (V), Breeding stock (B), Capital (K) and Transport have point estimates very close to zero.
Confidence intervals include zero: The 95% CIs for all these variables cross the vertical zero line. Statistically, this means none of these estimates are different from zero at the 5% level in the present sample — i.e., we cannot reject the null hypothesis of no effect.

Practical implication: For the production model, the plotted coefficients indicate that measured increases in input *quantities/expenditure* (as recorded) are not associated with reliably higher output in this sample. For transport, the negligible coefficient indicates transport cost variation (as measured) did not explain price differences across sellers.
These statistical effects may be attributable to small sample size, measurement error (especially feed quality vs feed quantity), endogeneity (inputs chosen in response to unobserved productivity), and omitted variables (disease incidence, breed quality, management practices).

Summary of Policy implications for Sustainable Small Ruminant Development in Akwa Ibom State

Although input elasticities are imprecise in this sample, the patterns point to two linked priorities for sustainable small ruminant development in Akwa Ibom State:

1. On-farm productivity requires investment in improving feed quality (forage technologies, feed blocks), preventive animal health (vaccination campaigns and community vets), and improved genetics; interventions likely to increase marginal returns more reliably than simply increasing input quantities.

2. Institutional and market support: Indicating the need for the government and other stakeholders interested in improving livestock production and food security, should strengthen extension services, farmer training, and access to credit and input/output markets to reduce production inefficiencies, improve technology adoption, and ensure that productivity gains translate into stable incomes and long-term sustainability.

CONCLUSION

The Cobb–Douglas analysis indicates that measured production inputs have **small elasticities** with respect to goat output: estimated coefficients are low in magnitude and their 95% confidence intervals are narrow enough to suggest limited responsiveness of output to incremental changes in those inputs. The model explains only a modest portion of the observed variation in farm-level goat output (moderate-to-low R^2 and diagnostic statistics), and the small sample (N = 31) limits statistical power and precision. Taken together, the results imply that (a) current input levels and conventional input adjustments are unlikely, on their own, to generate large immediate gains in output for the farms studied; (b) unmeasured factors; such as breed genetics, seasonal feed shortages, disease burden, management skill, and market/institutional constraints, may be important determinants of productivity but were not fully captured by the estimated model; and (c) targeted, context-specific interventions and improved measurement are required to unlock higher productivity gains.

Recommendations

1. **Prioritize low-cost, high-impact management interventions:** Small elasticities suggest marginal increases in conventional inputs may yield limited returns unless basic constraints are addressed. Target interventions that tackle binding constraints identified from descriptive data (e.g., feed scarcity, kid mortality, or poor housing). Practical measures include strategic supplementation during dry spells and late gestation, simple improvements to housing/hygiene to reduce kid

mortality, and targeted deworming and vaccination schedules. Pilot these measures with on-farm trials and measure productivity and profitability impacts before scaling.

2. **Strengthen institutional and market support:** Structural and institutional barriers (limited extension, poor access to credit/markets, weak producer organization) often limit the translation of input use into higher output and income. Thus, the important to facilitate farmer group formation or strengthen existing cooperatives for bulk purchase of inputs and collective marketing; improve access to tailored microcredit or input-financing schemes focused on small ruminant enterprises; and enhance extension delivery through community animal health workers or mobile-extension platforms that provide actionable, timely technical advice.

3. **Adopt participatory genetics and health strategies:** Because productivity gains from incremental feed/labor increases were modest, improving the biological potential and resilience of flocks may offer larger, sustainable returns. Thus, the need to develop community-based breeding programs that conserve adaptive local traits while selectively introducing productivity-improving genetics where appropriate. Combine breeding efforts with systematic health management (parasite control protocols, vaccination campaigns) and monitor animal-level performance metrics (growth rates, kidding rate, mortality). Use farmer-participatory trials to ensure adopted practices are feasible under local management and resource constraints.

4. **Improve data breadth and model specification in further studies**: With N = 31 and small-magnitude coefficients, statistical power is limited and omitted variables may bias estimates. Hence, the recommendation to expand the sample size in follow-up studies to increase precision and allow subgroup analysis (e.g., by production system or breed). It is also, important to enrich the model with additional explanatory variables likely to affect output, for example, breed type/age structure, seasonal feed availability, parasite/disease incidence, quality of extension contact, and market access indicators, while also considering non-linearities or interaction terms. More so, where possible, panel or repeated-measures data may be collected to control for unobserved heterogeneity and to estimate short- versus long-run effects.

REFERENCES

Adedeji, T. O., Fadiyimu, A. A., & Saka, J. O. (2020). Disease prevalence and productivity losses in small ruminant flocks in Nigeria. *Tropical Animal Health and Production, 52*(5), 2369–2379.

Akinmoladun, F. O., Farinu, G. O., & Ojo, V. O. (2019). Role of small ruminants in household food security in Nigeria. *Journal of Agriculture and Rural Development, 19*(3), 45–56.

Alabi, R. A., Awoyemi, T. T., & Bello, A. (2023). Consumption dynamics of goat meat in peri-urban Nigeria. *Nigerian Journal of Agricultural Economics, 13*(1), 55–70.

Anim-Jnr, A. S., et al. (2023). Sustainable Small Ruminant Production in Low-Income Countries: Challenges and Opportunities. Sustainability, 15(21), 15326.

Ayanwale, A., Adepoju, A. O., & Fakoya, O. E. (2021). Market performance and constraints of small ruminant trade in Southwest Nigeria. *African Journal of Livestock Economics, 5*(2), 77–89.

Bilotto, F., et al. (2024). Towards resilient, inclusive, sustainable livestock farming. Agricultural Systems

Food and Agriculture Organization of the United Nations (FAO). (2021). *FAOSTAT: Livestock primary*. https://www.fao.org/faostat

FAO. (2021). Nigeria: Agriculture at a glance. FAO Nigeria.

FAO (2011). *World Livestock 2011: Livestock in food security*. Food and Agriculture Organization of the United Nations.

Goetsch, A. L., Gipson, T. A., Askar, A. R., & Puchala, R. (2010). Feeding behavior of goats: A review. *Journal of Animal Science*, 88, 361–373.

Ike, P. C., & Oti, P. N. (2022). Structure and performance of goat markets in South-South Nigeria. *Journal of Agribusiness and Development Economics, 12*(4), 201–213.

ILRI. (n.d.). Market niches for increased small ruminant production in Southern Nigeria. International Livestock Research Institute.

Iñiguez, L. (2011). The challenges of research and development of small ruminant production in dry areas. *Small Ruminant Research*, 98, 12–20.

Lawal, R. B., Yusuf, S. A., & Oladimeji, Y. U. (2020). Productivity differentials in small ruminant systems across agro-ecological zones in Nigeria. *Nigerian Journal of Animal Production, 47*(2), 28–39.

Obi, C. N., Okonkwo, C. I., & Ekong, E. E. (2021). Community-based approaches to goat health management in Nigeria. *Journal of Veterinary Extension, 10*(1), 15–27.

Okonkwo, C., Udoh, E. J., & Eze, C. A. (2022). Price formation and integration in small ruminant markets in Nigeria. *African Review of Agricultural Economics, 14*(3), 150–169.

Okoye, C., Udo, E. S., & Sunday, V. (2019). Livelihood importance of goats in rural Nigeria. *International Journal of Livestock Research, 9*(8), 34–47.

Oladejo, J. A., Ojo, O., & Omotayo, A. (2022). ICT adoption in livestock marketing: Evidence from goat traders in Nigeria. *Information Technology for Development, 28*(4), 687–705.

Oluwatayo, I. B., & Oluwatayo, T. B. (2019). Constraints and opportunities in small ruminant feeding systems in Nigeria. *Tropical Grasslands–Forrajes Tropicales, 7*(2), 189–198.

Yusuf, S. A., Adeoti, A. I., & Akinwumi, J. A. (2021). Determinants of market participation among goat farmers in Nigeria. *Journal of Development and Agricultural Economics, 13*(5), 303–314.

Nwobodo, C. E., et al. (2022). Determinants of Ruminant Farmers' Use of Sustainable Practices. Frontiers in Veterinary Science.

Webb, E. C. (2014). Goat meat production, composition, and quality. *Animal Frontiers*, 4(4), 33–37.

Zervas, G., & Tsiplakou, E. (2011). The effect of feeding systems on the characteristics of products from small ruminants. *Small Ruminant Research*, 101, 140–149.