PRODUCTIVITY AND EFFICIENCY OF U.S. MEAT GOAT FARMS

Berdikul Qushim, Jeffrey Gillespie, and Kenneth McMillin

Prepared for the
Southern Association of Agricultural Economists
2014 Annual Conference
February 1-4, 2014
Dallas, Texas

Key Words:

Meat goat, performance measures, scale efficiency, technical efficiency, simulation

January 7, 2014

Berdikul Qushim is a graduate student and Jeffrey Gillespie is Martin D. Woodin Endowed Professor in the Department of Agricultural Economics and Agribusiness, Louisiana State University Agricultural Center; Kenneth McMillin is Professor in the School of Animal Sciences, Louisiana State University Agricultural Center

E-mail: bqushi1@lsu.edu, jgillespie@agcenter.lsu.edu, kmcmillin@agcenter.lsu.edu

Abstract

This study determines scale and technical efficiencies, productivity, other economic performance measures, and efficiency drivers for U.S. meat goat operations. We estimate an input distance function (IDF) using stochastic production frontier techniques (SPF). Empirical Monte Carlo (MC) simulation techniques are used to show the consistency of small-sample properties for the IDF.

1. Introduction

Since 1992, the U.S. has developed a strong interest in meat goat production (Spencer, 2008). The southeast region has proportionately more meat goat farms than all other regions together (Figure 1). From an economic viewpoint, goat production can complement other livestock production such as cattle, sheep, and others on marginal grazing pasture land. Goats efficiently convert low-quality forage including brush and other less desirable plants into quality lean meat and other products, requiring less of other feed sources such as corn and other processed feed (Singh-Knights et al., 2005). Moreover, meat goats can be produced with a small amount of grazing land and limited resources.

In recent decades, the meat goat industry has been one of the fastest growing livestock industries in the United States (USDA/APHIS, 2012). During the last decade, the U.S. immigrant population increased significantly. Fourteen million new immigrants came to America between 2000 and 2010 (American Community Survey, 2010). Most of those immigrants were from developing countries and regions such as the Middle East, Africa, Asia, and the Caribbean Islands, and consume lean goat meat. These factors have been major determinants in increasing goat meat production (Solaiman, 2007). Growth of the goat industry and demand for goat meat will likely continue with changes in ethnicity in the U.S. population. A small herd of meat goats can be produced on 10 to 15 acres of pastureland, so they can fit into more than 90 percent of U.S. farmsteads (Solaiman, 2007). Goats can also enhance small farm diversification and profitability (Solaiman, 2007). In addition, goat production can be handled easily by family farm members.

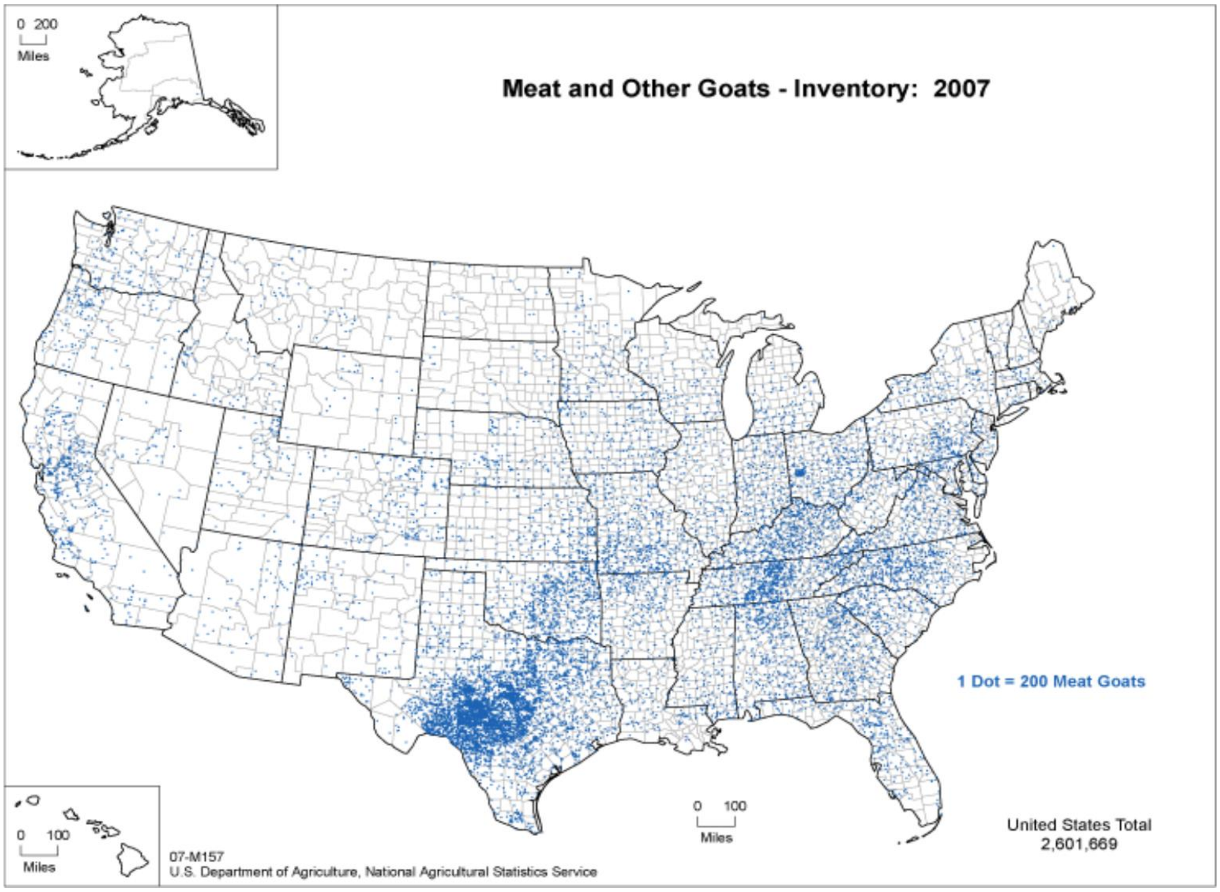

Figure 1 – Distribution of Meat and Other Goats in the United States
Source: USDA APHIS 2011

According to the 2007 USDA Census of Agriculture Report, average goat herd sizes were 27.7 and 21.7 per farm for 2002 and 2007, respectively. The number of all goat farms increased by about 52 percent from 2002 to 2007 (Table 1). The biggest percentage change has been in meat goats farms compared with milk goats and angora goats, 64.4 percent, 22.7 percent and 42.2 percent, respectively (Table 1). However, the average size of Angora goat operations declined by 32.1 percent versus 24.1 and 15.1 percent increases in numbers of meat goats and milk goats per farm, respectively (Table 1).

Table 1. Numbers of U.S. farms with goat products

Items	2002 Farms	2002 Numbers	2007 Farms	2007 Numbers	Percent Change in Farms	Percent Change in Operation Size
All farms	91,462	2,530,466	144,466	3,140,529	51.9	24.1
Angora goats	5,075	300,753	7,215	204,106	42.2	-32.1
Milk goats	22,389	290,789	27,481	334,754	22.7	15.1
Meat and other goats	74,980	1,938,924	123,278	2,601,669	64.4	34.2

Source: USDA, NASS, 2007 Census of Agriculture.

The first and only comprehensive study of the U.S. goat industry we are aware of was conducted by the USDA's National Animal Health Monitoring System in 2009. That study had the first nationally representative information on the animal health and management practices used in the goat industry. It found that the majority of U.S. operations with 10 or more goats raised goats for meat, with lower percentages raising goats for milk or fiber (USDA, Goat 2009). According to the 2007 USDA Census of Agriculture, about 76.6 percent and 82.8 percent of all goats in the United States were raised for meat in 2002 and 2007, respectively. The percentage of all goats raised for meat showed an increasing rate, but for angora, the percentage showed a slightly decreasing rate (Table 1). Therefore, meat goat production has become an attractive livestock industry in the U.S.

2. Literature

Few studies have investigated goat production efficiency and its productivity and profitability. Moreover, limited work has addressed meat goat production efficiency analysis in the United States. Rani Alex et al. (2013) conducted research on returns and determinants of technical efficiency in small-scale Malabari goat production farms in Kerala, India. They used a stochastic frontier production function to measure technical efficiency and its determinants for small-scale goat production units. One hundred goat farmers were selected using a multistage random sample for the study. The study found that feed cost was the major production cost. A mean value of technical efficiency was 0.88. Farm size and location were the important factors related to technical efficiency. The authors also suggested that there are still opportunities for increasing productivity and income of goat farmers by increasing efficiency.

Ogunniyi (2010) studied the economic efficiency of goat production in the Ogbomoso agricultural zone of Oyo State, Nigeria. The study used cross-sectional survey data sampled from 80 goat farmers. A log transformed Cobb-Douglas production frontier function was used to investigate goat production efficiency. The estimated parameters of labor and feed were statistically significant. The study found that feed frequency, years of establishment, education, and number of head were the main factors affecting the economic inefficiency of goat production. The mean economic efficiency was 0.60. The study concluded that there was scope for increasing goat production economic efficiency by about 40 percent.

Hidayat (2007) conducted an analysis of integrated goat farms in Banyumas, Indonesia. The research objectives were to determine the income generated from goat farming and its contribution to the farm business, the economic efficiency of goat farming with paddy and fish production, factors affecting level of production and income of different farming systems, and the best combination of farming generating maximum income. This research found that goat farming had a significant contribution in an integrated farming system (goat and paddy; goat and fish; and goat, paddy and fish), and these integrated production systems were economically efficient. The number of goats owned, land, urea application, manpower, feed, and breed were all factors affecting production level. The research concluded that goat farming could be an alternative solution to be developed in integrated farming operations and could be combined with other farming activities.

Zaibet et al. (2004) investigated socio-economic changes in the local community of Jabal Akhdar in Oman and assessed their impact on the economic performance of goat production using the concept of technical efficiency. They conducted research on economic performance of goat production for a sample of 43 farmers. Data were collected through a survey questionnaire from randomly chosen farmers in the Jabal Akhdar region. The study used data envelopment analysis (DEA) to derive technical efficiency measures. They found that feed cost and off-farm income were influential factors for the technical efficiency of goat farmers. However, they found that farm size, flock size, and family labor were not influential in predicting the output for technically efficient farmers. The study also found that goat production shows decreasing returns-to-scale. They summarized in the study that off-farm income was the major source of income for goat farms, and important inefficiencies existed in the use of resources.

Our study focuses on efficiency analyses of U.S. meat goat production. Results and conclusions derived from this research would be useful for improving efficiency and development of the U.S. meat goat industry. In addition to this, there are benefits to understanding efficiency drivers for potential goat meat producers when they are considering whether to enter the industry.

3. Data Sources and Methods

This study used a nationwide mail survey of U.S. meat goat producers which was conducted during Spring, 2013. Cost and returns data were collected from these farms. This survey was a follow-up to a first survey that focused on the marketing, technology, farmer attitudes, and farm and farmer characteristics of U.S. meat goat production. The reasons for the follow-up cost and returns survey were to estimate U.S. meat goat farm efficiency and to determine efficiency drivers. The study incorporated demographics and farm characteristics from the first meat goat survey.

Missing information occurs frequently in survey data, and this survey is not an exception. According to Rubin (1987), missing data may lead to biased estimates and reduce the efficiency of regression estimates. Various methods exist to handle missing data. However, the multiple imputation technique has gained popularity over the last two decades. Therefore, the multiple imputation method is used to handle the missing information in this study.

We use an input distance function (IDF) analysis to determine the economic performance of U.S. meat goat farms. To estimate this function, we apply stochastic production frontier analysis. The input distance function is specified as $D^I(X, Q, R)$ for this study, where X denotes a vector of inputs, Q denotes a vector of outputs, and R refers to a vector of farm efficiency determinants. For the meat goat farm analysis, two outputs are developed from the data collected in our survey: Q_{GOATV} = value of meat goat production including meat goat breeding stock and $Q_{VCROPLIVE}$= value of all other crop and livestock production.

Inputs are: X_{LND}= quality-adjusted land price[1]; X_{FEED}= feed expenses; X_{TFIXED}= total fixed expenses including depreciation, insurance expenses, interest and fees paid on debts, property taxes, and rental and lease payment expenses; X_{TVAR}= total variable expenses including marketing charges, seed and plant expenses, fertilizer and chemical expenses , purchased livestock expenses, bedding and litter expenses, medical supplies including veterinary and custom services, fuel and oil expenses, electricity expenses, all other utility expenses, farm supplies and marketing containers including hand tools, maintenance and repair including parts and accessories expenses, total labor expenses, machine hire and custom work expenses, other

[1] This study used state-level quality-adjusted values for the U.S. estimated in Ball et al. (2008) to account for land heterogeneity.

livestock related expenses, and other variable expenses. We also include farm-specific technical efficiency variables (R) from the goat production survey data. Farm characteristics include: production systems, percentage of annual net farm income from meat goat operations, regions, size of operations, whether farm production is organic or traditional, and whether farm sells goats for breeding stock, show, slaughter/ meat, and other purposes. Production systems consist of extensive-range or pasture/woods (not handled much), pastured but not rotated, pastured and rotated, and dry lot production systems. There are Southeast, Northeast, and West regions included in the study. The sizes of operations were divided into three groups: small farms (less than 20 meat goats in the operation), medium farm (greater than or equal to 20 and less than 100 meat goats in the operation), and large farms (greater than or equal to 100 meat goats in the operation). Operator characteristics include education level, gender, and whether the farmer holds an off-farm job.

A translog functional form is used to approximate the IDF for empirical implementation to limit a priori restrictions on the relationship among inputs. A translog functional form for the production technology can be specified as:

$$
\begin{aligned}
lnD_i^I(X,Q,R) = {} & \alpha_0 + \sum_m \alpha_m ln\, X_{mi} + \frac{1}{2}\sum_m\sum_n \alpha_{mn}\, lnX_{mi}lnX_{ni} + \sum_k \beta_k\, lnQ_{ki} \\
& + \frac{1}{2}\sum_k\sum_l \beta_{kl}\, lnQ_{ki}lnQ_{li} + \sum_q \delta_q\, R_{qi} + \frac{1}{2}\sum_q\sum_r \gamma_{qr}\, lnR_{qi}lnR_{ri} \\
& + \sum_k\sum_m \theta_{km}\, lnQ_{kit}lnX_{mi} + \sum_q\sum_m \varphi_{qm}\, lnR_{qit}lnX_{mi} + \sum_k\sum_q \tau_{kq}\, lnQ_{ki}lnR_{qi} \\
& + \upsilon_i = TL(X,Q,R) + \nu_i \qquad (1)
\end{aligned}
$$

Homogeneity of degree +1 in inputs implies the parametric restrictions:

$$\sum_m \alpha_m = 1 \qquad \sum_n \alpha_{mn} = 0 \qquad \sum_k \theta_{km} = 0 \quad \sum_q \varphi_{qm} = 0 \qquad (2)$$

By Young's theorem, the symmetry restrictions are:

$$\alpha_{mn} = \alpha_{nm}, \quad \beta_{kl} = \beta_{lk} \text{ and } \gamma_{qr} = \gamma_{rq} \quad \forall m, n, k, l, q, r \qquad (3)$$

Dividing all inputs and the distance term ($D_i^I(X, Q, R)$) by an input, quality-adjusted land, specified as $X_1 = X_{LAND}$ to be consistent with much of the literature on farm production, is the same as imposing the homogeneity restrictions. The function is specified on a per-acre basis as:

$$ln\frac{D_i^I(X,Q,R)}{X_{1,i}} = \alpha_0 + \sum_m \alpha_m ln\, X_{mi}^* + \frac{1}{2}\sum_m\sum_n \alpha_{mn}\, lnX_{mi}^* lnX_{ni}^* + \sum_k \beta_k\, lnQ_{ki}$$
$$+ \frac{1}{2}\sum_k\sum_l \beta_{kl}\, lnQ_{ki} lnQ_{li} + \sum_q \delta_q\, R_{qi} + \frac{1}{2}\sum_q\sum_r \gamma_{qr}\, lnR_{qi} lnR_{ri}$$
$$+ \sum_k\sum_m \theta_{km}\, lnQ_{ki} lnX_{mi}^* + \sum_q\sum_m \varphi_{qm}\, lnR_{qit} lnX_{mi}^* + \sum_k\sum_q \tau_{kq}\, lnQ_{ki} lnR_{qi}$$
$$+ v_i = TL(X^*, Q, R) + v_i \qquad (4)$$

Equation (4) can be written as

$$-\, ln\, X_{1,i} = TL(X^*, Q, R) + \nu_i - lnD_i^I(X, Q, R) = TL(X^*, Q, R) + \nu_i - u_i \quad (5)$$

where *i* denotes farms; *k* ,*l* the outputs; *m*, *n* the inputs; and *q*, *r* the farm characteristic variables. X_1 is land, specified as a normalization factor in inputs. $lnD_i^I(X, Q, R)$ is the distance from the frontier and it characterizes the technical inefficiency (TI) error, $-u_i$. TI is a function of farm- and farmer-specific characteristics. Technical efficiency (TE) can be obtained as the expectation of the term $-u_i$ conditional on the composed error term $\varepsilon_i = \nu_i - u_i$ (Jondrow et al., 1982). TE can be measured as:

$$TE = exp^{-u_i} \qquad (6)$$

We use single-step maximum likelihood (ML) methods (Battese and Coelli, 1995) to estimate (5) as an error components model, and the parameters of the IDF and the TI are estimated jointly using SPF techniques. The random error component v_{it} is independently and identically distributed, $N(0, \sigma_v^2)$. The one-sided error component of $u_i \geq 0$ is a random variable independently distributed with truncation at zero of the $N(\mu_i, \sigma_u^2)$ distribution, where $\mu_i = \sum_n \Phi_n \tau$, Φ_n is a vector of whole-farm efficiency determinants, and τ are unknown parameters.

This study has 124 U.S. meat goat farms which represent the population of United States meat goat farms. According to the 2007 USDA Census of Agriculture, there were 123,278 meat goat operations in the U.S. Thus, there is a concern of consistency of estimation of the sample size. As we know, an estimator is consistent if increases in the sample size estimating parameter converge to the true value of the population parameter. Therefore, this study uses empirical Monte Carlo simulation models to show consistency that as the sample size increases the sampling distribution of the estimator becomes increasingly concentrated at the true parameter value. This empirical simulation model is designed to show the consistency of small-sample properties of the survey data.

4. Stochastic Production Frontier Results

The ML parameter estimates for the IDF are presented in Table 2. The input variable parameters are statistically significant. These input contributions are somewhat different. The contributions of feed (lnX_2^*) and the fixed expenses (lnX_4^*) are the biggest and the smallest in magnitude, respectively. The contribution of variable expenses (lnX_3^*) is almost three times that of the fixed expenses, but increased variable expense increased the productive contribution of the land. The cross-input variable parameters are statistically non- significant but except for the variable and fixed expenses ($lnX_3^* lnX_4^*$). This interaction is statistically significant and positive, meaning these variables are complementary.

The output variable parameters have the expected signs, but only one is statistically significant (Table 2). The statistically significant all other crop and livestock production (lnY_2) means that increases in all other crop and livestock increase the productive contribution of the land. The output interaction between meat goat production and all other crop and livestock production ($lnY_1 lnY_2$) is statistically non-significant. Contributions of medium-sized (R_{mf}) and large-sized (R_{lf}) meat goat operations are statistically significant relative to small-sized operations (R_{sf}). The R_{lf} estimate also confirms that large meat goat farms require the greatest land input share or contribution, with medium-sized farm second, comparing to the base level.

Table 2. The IDF Estimates for U.S. Meat Goat Farms

Variables	Coeff.	t-test	Variables	Coeff.	t-test
constant	10.06***	3.64	$lnY_1 lnX_3^*$	-0.12***	-2.93
Y_1^d	-0.53	-0.28	$lnY_1 lnX_4^*$	0.01	0.96
Y_2^d	-3.07*	-1.76	$lnY_2 lnX_2^*$	0.01**	2.45
X_2^d	-3.62***	-2.93	$lnY_2 lnX_3^*$	-0.02*	-1.68
X_4^d	-1.40**	-1.97	$lnY_2 lnX_4^*$	0.00	0.06
lnX_2^*	-1.02***	-4.73	R_{mf}	0.62***	4.10
lnX_3^*	0.91***	2.97	R_{lf}	1.28***	4.47
lnX_4^*	-0.31***	-2.65	Inefficiency model		
lnX_{2sq}^*	0.05	1.44	constant	4.05***	2.62
lnX_{3sq}^*	-0.12***	-2.63	Education	-3.41***	-3.69
lnX_{4sq}^*	-0.001	-0.03	Goat Income	-0.63***	-2.95
$lnX_2^* lnX_3^*$	0.01	0.25	Southeast	-1.48**	-2.15
$lnX_2^* lnX_4^*$	-0.04	-1.25	Northeast	0.18	0.18
$lnX_3^* lnX_4^*$	0.08**	2.41	Extensive-range	-0.97	-1.01
lnY_1	0.27	0.55	Dry Lot	1.53*	1.95
lnY_2	0.86**	2.14	Breeding Stock and Show	-2.38*	-1.79
lnY_{1sq}	0.08	1.23	Operator Off-farm Job	-1.97***	-2.68
lnY_{2sq}	0.13***	2.82	Organic Production	-0.14	-0.14
$lnY_1 lnY_2$	0.02	0.17	Gender (female)	-1.68*	-1.85
$lnY_1 lnX_2^*$	0.08***	3.17	Experience	-25.97***	-3.12

***Notes*:** * 10% level of significance, ** 5% level of significance, *** 1% level of significance.

Estimated inefficiency model parameters estimates are also are presented in Table 2. The study found operator education level, percentage of annual net farm income from goat operations, southeast region, percentage of goat sales for breeding stock and show, operator off-farm job, gender (female), and experience as the efficiency drivers for U.S. meat goat farmers. These meat goat farm and farmer characteristics are statistically significant and increase meat goat production technical efficiency. The Dry lot production system, where goats are kept in a dry lot with no growing forage and are fed using purchased feeds and or/hay, was statistically significant but decreased goat farm technical efficiency. The results of the region dummies show that Southeast region meat goat farmers were more technically efficient than Western region farms.

The distribution of the estimated input-oriented technical efficiency scores is presented in Table 3. The results show an average efficiency of 0.84. This implies that the average U.S. meat goat farm could reduce about 16% in inputs to produce the same output as an efficient farm on the production frontier. The table also shows that approximately 73% of the farmers achieved technical efficiency levels of 80% or higher.

Table 3. Distribution of Technical Efficiency (TE)

Range of TE	Freq.	% of farms in TE interval	Mean	Std. Dev.
TE <= 0.30	2	1.61		
0.30 < TE <= 0.40	2	1.61		
0.40 < TE <= 0.50	7	5.65		
0.50 < TE <= 0.60	3	2.42		
0.60 < TE <= 0.70	6	4.84		
0.70 < TE <= 0.80	14	5.36		
0.80 < TE <= 0.90	26	20.97		
0.90 < TE <= 1.00	64	51.61		
Total	124	100.00		
Technical Efficiency			0.84	0.17

The marginal productive contributions (MPCs) of outputs and inputs can be estimated from the IDF respectively as $MPC_k = -\varepsilon_{D^I Q_k} = -\partial lnD^I(X,Q,R)/\partial lnQ_k = \varepsilon_{X_1 Q_k}$, and $MPC_m = -\varepsilon_{D^I X_m^*} = -\partial lnD^I(X,Q,R)/\partial lnX_m^* = \varepsilon_{X_1 X_m^*}$.

All MPCs have the correct signs, negative for inputs and positive for outputs, as shown in Table 4. All of the MPC measures are statistically significant. The largest MPC in absolute value for inputs is feed expense, followed by land, variable, and fixed expenses. The largest input share goes to meat goat production output (lnY_1) MPC – about 69 percent on average.

Table 4. Marginal productive contributions (MPCs) for inputs and outputs

MPCs	Coeff.	t-test	MPCs	Coeff.	t-test
$ln\ X_1$	-0.272***	-4.54	lnY_1	0.690**	2.04
lnX_2^*	-0.388***	-6.16	lnY_2	0.168**	2.40
lnX_3^*	-0.215***	-3.91			
lnX_4^*	-0.125***	-2.80			

Notes: **, *** Significances at the 5% and 1% levels, respectively.

The U.S. meat goat production overall economic performance indicators are presented in Table 5. The estimated RTS parameter for the U.S. meat goat farms showed that a one percent increase in all outputs increases overall input use by 0.86 percent. Therefore, an increasing RTS economy exists in U.S. meat goat production. A measure of scope economies was estimated from the IDF by taking the second cross partial output derivatives, but it was not statistically significant

Scale efficiency is the potential productivity gain from the optimal size of a farm. Scale efficiency measure can be estimated from the IDF. The method for estimating scale efficiency was introduced by Ray (1998), Balk (2001), and Ray (2003) from single-output multi-input and multi-output multi-input distance functions. Recently, Nahm et al. (2013) introduced a slightly modified method for estimating scale efficiency from a multiple-input and multiple-output parametric hyperbolic distance function. Following Ray (2003), scale efficiency for U.S. meat goat production can be estimated from the IDF as

$SEF(X,Q,R) = \exp((-(1-\sum_k \partial lnD^I(X,Q,R)/\partial lnQ_k))^2/2\sum_k\sum_l \beta_{kl})$. The scale efficiency is an economic performance indicator representing improvement in average productivity of the U.S. meat goat farms through a change in the scale of the meat goat production. This study found that U.S. meat goat farms, on average, are scale efficient if the farms' scale of production is greater than 54 goats or greater than 30 breeding does per operation.

Table 5. Return to scale (RTS), scope economies and scale efficiency

Measurements	Coeff.	t-test
Return to scale	0.86***	2.59
Scale efficiency	1.00***	10.70

Notes: *** Significance at the 1% level.

The study used hypothetical and empirical Monte Carlo (MC) simulation techniques to illustrate the consistency of small-sample properties for IDF analysis. We report only the empirical MC simulation results. For the empirical MC simulation technique, the IDF was specified as a normal-exponential stochastic production including heteroskedasticity problem. We introduced the following data generation process (DGP)

$$-x_{1,i} = \alpha_0 + 2y_{1,i}^d + y_{2,i}^d + 2x_{2,i}^d + 3x_{4,i}^d + 2x_{2,i}^* + 3x_{3,i}^* + 4x_{4,i}^* + x_{2sq,i}^* + 2x_{3sq,i}^*$$
$$+ 4x_{4sq,i}^* + 2x_{2,i}^*x_{3,i}^* + 3x_{2,i}^*x_{4,i}^* + x_{3,i}^*x_{4,i}^* + 2y_{1,i} + 3y_{2,i} + y_{1sq,i} + 2y_{2sq,i}$$
$$+3y_{1,i}y_{2,i} + 4y_{1,i}x_{2,i}^* + y_{1,i}x_{3,i}^* + 4y_{1,i}x_{4,i}^* + 3y_{2,i}x_{2,i}^* + 2y_{2,i}x_{3,i}^* + 3y_{2,i}x_{4,i}^* + r_{mf,i}$$
$$+ 2r_{lf,i} + v_i - u_i \quad (7)$$

where $v_i \sim N(0, \sigma_{vi})$, $u_i \sim rgamma(1, \sigma_{ui})$, and $\sigma_{vi} = \exp(0.5zv_i)$ and $\sigma_{ui} = \exp(0.5(1 + 0.5zu_i))$, and both idiosyncratic and inefficiency error scale parameters were a function of a constant term and of an exogenous covariate $(zv_i \; and \; zu_i)$ drawn from a standard normal random $(rnormal\ (0,1))$ variable. The MC simulation results are presented in Table 6. The empirical MC simulation results for the estimated parameters and the rejection rates show that there is no significant bias and that the asymptotic distribution approximated the finite-sample distribution well for the DGP with sample of size 250, 500, and 1000 replications. We reported only 250 MC simulation replications (Table 6).

Table 6. Empirical MC Simulation Results for 250 Replications

Parameters	Mean	Parameters	Mean	Parameters	Mean	Parameters	Mean
$\varphi_1 = 2$	0.236	$\beta_1 = 2$	1.845	reject_φ_1_y^d1	0.044	reject_β_1_y1	0.112
$\varphi_2 = 1$	2.569	$\beta_2 = 3$	3.405	reject_φ_2_y^d2	0.040	reject_β_2_y2	0.072
$\varphi_3 = 2$	3.895	$\beta_3 = 1$	1.036	reject_φ_3_x^d2	0.012	reject_β_3_y1sq	0.088
$\varphi_4 = 3$	2.706	$\beta_4 = 2$	1.939	reject_φ_4_x^d4	0.004	reject_β_4_y2sq	0.056
$\alpha_2 = 2$	1.604	$\beta_5 = 3$	3.011	reject_α_2_x2	0.008	reject_β_5_y1y2	0.008
$\alpha_3 = 3$	3.690	$\theta_1 = 4$	4.049	reject_α_3_x3	0.016	reject_θ_1_y1x2	0.028
$\alpha_4 = 4$	3.826	$\theta_2 = 3$	2.988	reject_α_4_x4	0.012	reject_θ_2_y1x3	0.024
$\alpha_5 = 1$	0.895	$\theta_3 = 1$	0.924	reject_α_5_x2sq	0.052	reject_θ_3_y1x4	0.004
$\alpha_6 = 2$	1.838	$\theta_4 = 2$	1.997	reject_α_6_x3sq	0.016	reject_θ_4_y2x2	0.020
$\alpha_7 = 4$	3.933	$\theta_5 = 4$	4.002	reject_α_7_x4sq	0.024	reject_θ_5_y2x3	0.020
$\alpha_8 = 2$	2.045	$\theta_6 = 3$	3.010	reject_α_8_x2x3	0.028	reject_θ_6_y2x4	0.012
$\alpha_9 = 3$	3.038	$\delta_1 = 1$	2.114	reject_α_9_x2x4	0.016	reject_δ_1_mf	0.052
$\alpha_{10} = 1$	1.073	$\delta_2 = 2$	4.136	reject_α_{10}_x3x4	0.028	reject_δ_2_lf	0.036

5. Conclusions

The study measures the economic performance of U.S. meat goat farms, focusing on technical efficiency, scale economies, and output or input substitution or complementary effects. This study employed the survey data on cost and returns of U.S. meat goat operations in 2011. The results show that all input variables were significant inputs for U.S. meat goat farms. We also found complementary effects between the variable and fixed expenses. The measures of marginal productive contributions had correct signs for inputs and outputs, and they were significant. We also found increasing return to scale for U.S. meat goat farms. The meat goat farms can be scale efficient at 54 total goats or greater than 30 breeding does in their operations. The results also show that there is an opportunity to decrease input use to produce output at the production frontier level. The results of empirical MC simulation based on the survey data showed the consistency of small-sample properties for the IDF.

References

Alex, R., R. Kuniyoor Cheemani, N. Thomas (2013). "Returns and determinants of technical efficiency in small-scale Malabari goat production units in Kerala, India." *Tropical Animal Health and Production* DOI 10.1007/s 11250-013-0411-6. May 2013.

Balk B.M. (2001). "Scale efficiency and productivity change." *Journal of Production Analysis* 15, 159-183.

Battese, G.E. and T.J. Coelli (1995). "A model for technical inefficiency effects in a stochastic frontier production function for panel data." *Empirical Economics* 20, 325-332.

Hidayat, N. N. (2007). "Analysis of goat farming on integrated farming in Banyumas." *Journal of Animal Production* 9, 105-110.

Jondrow, J., Lovell, C.A.K., Materov, I., Schmidt, P. (1982). "On the estimation of technical inefficiency in the stochastic frontier production model." *Journal of Econometrics* 19, 223–238.

Ogunniyi, L. T. (2010). "Factors influencing the economic efficiency of goat production in Ogbomoso agricultural zone, Oyo state, Nigeria." *Animal Research International* 7, 1129-1133.

Nahm, Daehoom and Ha Thu Vu (2013). "Measuring scale efficiency from a parametric hyperbolic distance function." *Journal of Production Analysis* 39, 83-88.

Nehring, R., C. Barnard, D. Banker and V. Breneman (2006). "Urban influence on cost of production in the Corn Belt." *American Journal of Agricultural Economics* 88, 4, 930-946.

Ray S.C. (1998). "Measuring scale efficiency from a translog production function." *Journal of Production Analysis* 11, 183-194.

Ray S.C. (2003). "Measure scale efficiency from the translog multi-input, multi-output distance function." Economic working paper-200325, Department of Economics, University of Connecticut

Rubin, D.B. 1987. Multiple Imputation for Nonresponse in Survey, New York: John Wiley and Sons.

Singh-Knights D. and Knights M. (2005). "Feasibility of goat production in West Virginia." A Handbook for Beginners. West Virginia Agricultural and Forestry Experimental Station and Davis College of Agriculture, Forestry, and Consumer Sciences. Bulletin 728. West Virginia University, 2005.

Solaiman, S. G. (2007). "Assessment of the meat goat industry and future outlook for U.S. small farms." Tuskegee University, Tuskegee, AL, August 2007.

Spencer, R. (2008). "Overview of the United States meat goat industry." Alabama A&M University, UNP-104, Dec. 2008. http://www.aces.edu/pubs/docs/U/UNP-0104/

United States Census Bureau (USCB), American Community Survey (2010). http://www.census.gov/acs/

USDA/APHIS, VS, NAHMS (2011). "Small-scale U.S. cow-calf operations." http://www.aphis.usda.gov/animal_health/nahms/smallscale/

USDA, APHIS, VS, Center for Epidemiology and Animal Health, Info Sheet, 2012. http://www.aphis.usda.gov/animal_health/nahms/goats/downloads/goat09/Goat09_is_MeatGoatOps.pdf.

U.S. Department of Agriculture, National Agricultural Statistics Service (USDA, NASS). 2007. Census of Agriculture

USDA, APHIS, VS, NAHMS. Goat 2009. "Part I: Reference of Goat Management Practices in the United States, 2009."

Zaibet, L., P.S. Dharmapala, H. Boughanmi, O. Mahgoub, and A. Al-Marshudi (2004). "Social changes, economic performance and development: the case of goat production in Oman." Small Ruminant Research 54, 131-140.