Efficiency Analysis of Southeastern U.S. Meat Goat Production

Berdikul Qushim
Research Associate
Department of Agricultural Economics and Agribusiness
Louisiana State University Agricultural Center
101 Martin D. Woodin Hall
Baton Rouge, LA 70803
Phone: (225) 578-3282
E-mail: BQushim@agcenter.lsu.edu

Jeffrey Gillespie
Martin D. Woodin Endowed Professor
Department of Agricultural Economics and Agribusiness
Louisiana State University Agricultural Center
101 Martin D. Woodin Hall
Baton Rouge, LA 70803
Phone: (225) 578-2759
E-mail: JGillespie@agcenter.lsu.edu

Kenneth McMillin
Mr. and Mrs. Herman E. McFatter Endowed Professor
School of Animal Sciences
Louisiana State University Agricultural Center
116c Francioni Hall South Campus Drive
Baton Rouge, LA 70803
Phone: (225) 578-3438
Email: KMcmillin@agcenter.lsu.edu

Selected Paper prepared for presentation at the Southern Agricultural Economics Association's 2015 Annual Meeting, Atlanta, Georgia, January 31 - February 3, 2015

Efficiency Analysis of Southeastern U.S. Meat Goat Production

Abstract

Technical efficiency, scale and scope economies, marginal productive contributions for inputs and outputs, and efficiency drivers were determined for the Southeastern U.S meat goat enterprise. The average technical efficiency was 0.88. We find increasing returns to scale and scope economies for Southeastern U.S. meat goat enterprises.

Key words: Meat goat; SPF; IDF; Technical efficiency; Scale and scope economies; Returns to scale

Introduction

Meat goat production is important throughout the world, especially in developing countries, and goat meat is the most heavily consumed red meat in the world (Meat Goat Production, 2000). Moreover, much of the rural population in developing countries depends on meat goat production as an important income source and food. Developing countries produced approximately 97 percent of the world's total goat meat in 2008 (FAOSTAT, 2008). The meat goat industry is not, however, limited to developing countries. The industry has rapidly expanded in the U.S. since the formation of the American Meat Goat Association in 1992 and the American Boer Goat Association in 1993; repealing of the Wool Act of 1954 in 1993; and financial settlements of the U.S. tobacco industry. These events provided an incentive for fiber/hair and tobacco producers to switch to meat goat production. Furthermore, diversification of U.S. population demographics with immigration has led to increased demand for goat meat.

The majority of U.S. meat goat production is scattered throughout the Southeastern U.S., with Texas dominating the production of meat goats among all U.S. states. The strong interest of Texas in meat goat production has been largely due to its dry climate and suitable forage species (Shurley and Craddock, 2005). The Southeast region is well suited to producing goats because of extended grazing periods for meat goat production. This extended grazing period gives southeastern meat goat producers the opportunity to pasture goats year-round, decreasing dependence on concentrated feedstuffs and adding value to goats with less expensive inputs compared to other regions. In some meat goat production regions or states, it is not possible to graze year-round. These regions depend on the use of conserved or stockpiled forages during a few months of the year. The Southeastern U.S. meat goat production advantage is its more amenable weather, considerably longer grazing season, lower need for supplemental feed, and simpler and cheaper goat housing (Singh-Knights et al., 2005).

As a comparably new and nascent industry in the U.S., the meat goat industry has not been studied extensively compared with other livestock industries such as beef cattle or swine. Therefore, comparatively little information exists regarding U.S. meat goat production, specifically economic measures and factors that can positively impact meat goat production efficiency. Much of the more recent research has focused on goat meat marketing and consumer preferences for goat meat (Worley *et al*., 2004; Knight *et al*., 2006; Ibrahim, 2011). Papers have largely neglected efficiency and productivity issues associated with U.S. meat goat farming. Studies on goat farm production efficiency, productivity, and profitability are limited; those which have focused on production efficiency have addressed the industry in other countries (Zaibet *et al*., 2004; Ogunniyi, 2010; Alex *et al*., 2013).

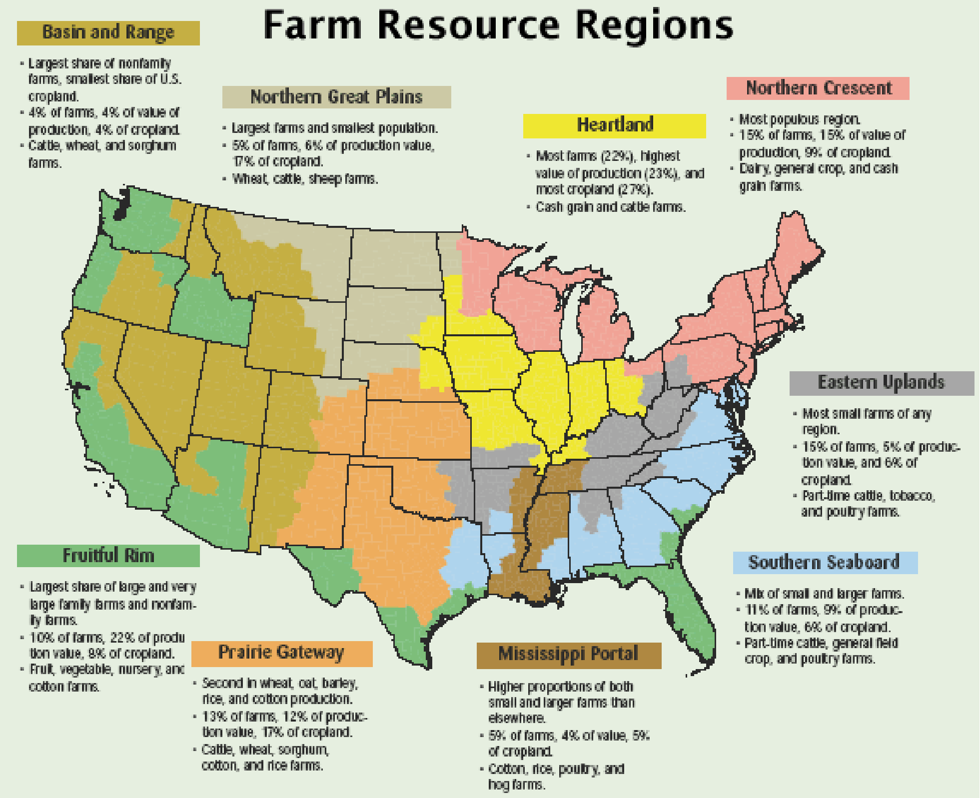
The USDA-NASS's 2012 Census of Agriculture estimated that about 76.6% and 78.3% of all goats in the United States were raised for meat in 2002 and 2012, respectively. Meat goat farms and operation size increased, respectively, by 34.6% and 5.9% from 2002 to 2012, showing increased meat goat production.

The objectives of this study are to determine the important factors influencing meat goat production technical efficiency (TE) and to quantify scale and scope economies for meat goat production in the Southeastern U.S. We estimate an input distance function (IDF) using stochastic production frontier (SPF) techniques for Southeastern U.S. meat goat production. We also use empirical Monte Carlo (MC) simulation techniques to show the consistency of small-sample properties for the IDF analysis.

Data and Methodology

We conducted a nationwide mail survey of U.S. commercial meat goat producers during Spring, 2013, and collected costs and returns data from those farms for 2011. The costs and returns survey was a follow-up to an earlier mail survey of late Summer, 2012, which addressed U.S. commercial meat goat production technology, marketing, farmer attitudes, and farm and farmer characteristics. The earlier survey was sent to 1,600 meat goat producers who advertised their meat goat product online or were members of meat goat associations. Addresses of these producers were selected from an extensive Internet search. Dillman's (2007) Tailored Design Method was used to design the survey. We received a total of 584 completed responses from the first survey for a response rate of 43% after adjusting for those who did not produce meat goats in 2011 and undelivered surveys. At the end of the first survey, meat goat producers were asked if they would be willing to fill out a follow-up survey on costs and returns of meat goat production. A total of 435 meat goat producers indicated their willingness to fill out the follow-up questionnaire. For meat goat production analysis, we received a total of 124 completed responses. After adjusting for undeliverable surveys, producers who did not produce meat goats, and incomplete surveys, the effective return rate was 30%.

This study has 69 farms as a sub-sample population for Southeastern U.S. meat goat production efficiency. The Southeast includes parts of the following farm resource regions as designated by USDA-ERS (Figure 1): Eastern Uplands, Fruitful Rim, Mississippi Portal, and Southern Seaboard. Southeastern states include AL, AR, FL, GA, KY, LA, MS, NC, OK, SC, TN, TX, VA, and WV. Parts of Oklahoma and Texas are included, divided on a line corresponding to north-south Interstate 35, with the eastern halves of these states being included in the Southeast region.



Basin and Range

- Largest share of nonfamily farms, smallest share of U.S. cropland.
- 4% of farms, 4% of value of production, 4% of cropland.
- Cattle, wheat, and sorghum farms.

Northern Great Plains

- Largest farms and smallest population.
- 5% of farms, 6% of production value, 17% of cropland.
- Wheat, cattle, sheep farms.

Heartland

- Most farms (22%), highest value of production (23%), and most cropland (27%).
- Cash grain and cattle farms.

Northern Crescent

- Most populous region.
- 15% of farms, 15% of value of production, 9% of cropland.
- Dairy, general crop, and cash grain farms.

Eastern Uplands

- Most small farms of any region.
- 15% of farms, 5% of production value, and 6% of cropland.
- Part-time cattle, tobacco, and poultry farms.

Southern Seaboard

- Mix of small and larger farms.
- 11% of farms, 9% of production value, 6% of cropland.
- Part-time cattle, general field crop, and poultry farms.

Fruitful Rim

- Largest share of large and very large family farms and nonfamily farms.
- 10% of farms, 22% of produ tion value, 8% of cropland.
- Fruit, vegetable, nursery, and cotton farms.

Prairie Gateway

- Second in wheat, oat, barley, rice, and cotton production.
- 13% of farms, 12% of production value, 17% of cropland.
- Cattle, wheat, sorghum, cotton, and rice farms.

Mississippi Portal

- Higher proportions of both small and larger farms than elsewhere.
- 5% of farms, 4% of value, 5% of cropland.
- Cotton, rice, poultry, and hog farms.

Figure 1. U.S. Farm Resource Regions; Source: USDA ERS

Missing information is a common issue for survey data, and missing data cause biased estimates and reduce regression estimates efficiency (Rubin, 1987). Various methods exist to handle missing data issues. We use the multiple imputation method (Rubin, 1987) to handle missing data in this study.

To estimate the efficiency of Southeastern U.S. meat goat production, a parametric SPF technique is used, which reveals the nature of the production technology, tests various hypotheses and statistical inferences, and measures the firm-specific efficiency characteristics. In general, the SPF model is specified as:

$$ln\,y \;= lnf(x) + \; v - u, \tag{1}$$

where y is the production level, x is a vector of inputs, v is a vector of unobserved farmers' heterogeneities, and u is the vector representing technical inefficiencies. The random error v is independently and identically distributed as $N(0, \sigma_v^2)$ and is independent of u; u is non-negative random variables and identically distributed as half-normal, $u \sim |N(0, \sigma^2 u)|$.

We use IDF analysis to determine the economic performance of Southeastern U.S. meat goat farms. To estimate this function, we apply SPF analysis. The IDF 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.

A translog functional form is used to approximate the IDF for empirical implementation to limit a priori restrictions on the relationship among inputs. After applying homogeneity of degree 1 in inputs and the symmetry restrictions of the parameters, the IDF can be specified as:

$$ln \frac{D_i^I(X,Q,R)}{X_{1,i}} = \alpha_0 + \sum_m \alpha_m ln\, X_{mi}^* + \frac{1}{2} \sum_m \sum_n \alpha_{mn}\, lnX_{mi}^* lnX_{ni}^* + \sum_k \beta_k\, lnQ_{ki}$$

$$+ \frac{1}{2} \sum_k \sum_l \beta_{kl}\, lnQ_{ki} lnQ_{li} + \sum_q \delta_q\, R_{qi} + \frac{1}{2} \sum_q \sum_r \gamma_{qr}\, lnR_{qi} lnR_{ri} + \sum_k \sum_m \theta_{km}\, lnQ_{ki} lnX_{mi}^* +$$

$$\sum_q \sum_m \varphi_{qm}\, lnR_{qit} lnX_{mi}^* + \sum_k \sum_q \tau_{kq}\, lnQ_{ki} lnR_{qi} + v_i = TL(X^*, Q, R) + v_i. \qquad (2)$$

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 IDF is specified on a per-acre basis. Equation (2) can be rewritten as

$$-\, ln\, X_{1,i} = TL(X^*, Q, R) + v_i - lnD_i^I(X, Q, R) = TL(X^*, Q, R) + v_i - u_i \qquad (3)$$

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 error, $-u_i$. Technical inefficiency is a function of farm- and farmer-specific characteristics. Technical efficiency can be obtained as the expectation of the term $-u_i$ conditional on the composed error term $\varepsilon_i = v_i - u_i$ (Jondrow et al., 1982), and can be measured as $TE = exp^{-u_i}$.

We use single-step maximum likelihood methods to estimate the parameters of the IDF and the technical inefficiency jointly using SPF techniques. The random error component ν_{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 farm efficiency determinants, and τ are unknown parameters.

The input and output variables are defined (Table 1) as: Y_{Mgoat} = value of meat goat production for slaughter and/or goat meat and $Y_{Gbstock}$ = value of meat goat production for breeding stock. Inputs are: X_{Land} = quality-adjusted land price[1]; X_{Feed} = feed expenses; X_{Fixed} = total fixed expenses including depreciation, insurance, interest and fees paid on debts, property taxes, and rental and lease payment expenses; X_{Var} = 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 livestock related expenses, and other variable expenses.

The Southeastern U.S. meat goat enterprise efficiency variables (Table 1) include: $\Phi_{College}$, a dummy variable indicating the farmer held a bachelor's degree or higher (the base category is a less than college degree). Φ_{Female} is a dummy variable indication the meat goat operator who is

Table 1. Summary statistics and variable definitions for Southeastern USA meat goat enterprises

---

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

Variable	Definition	Mean	SD
Mgoat	Meat goat production for slaughter and/or goat meat, $	2,579.62	7,343.45
Gbstock	Meat goat production for breeding stock, $	2,877.07	6,085.64
Land	Quality-adjusted total land value, service flow, $	4,444.70	9,204.08
Feed	Total farm feed expenses, $	3,333.53	5,940.89
Var	Total other variable expenses, $	9,092.61	12,000.53
Fixed	Total fixed expenses, $	4,607.35	11,535.85
College	Dummy variable for producer holding 4-years college degree	0.51	0.50
Female	1 female; 0 male	0.42	0.50
Age	Operator age: 1: ≤30; 2: 31-45; 3: 46-60; 4: 61-75; 5: ≥76	2.90	0.93
Smallfarm	Dummy variable for total number of meat goats < 20	0.48	0.50
Mediumfarm	Dummy variable for total number of meat goats ≥20, <100	0.46	0.50
Largefarm	Dummy variable for total number of meat goats ≥100	0.06	0.24
%Goatincome	% of annual net farm income from goat operations: 1: ≤19%; 2: 20–39%; 3: 40–59%; 4: 60–79%; 5: 80–100%	2.87	1.77
Offfarmjob	1 if farm operator has off-farm job; 0 otherwise	0.62	0.49
EU	1 if in Eastern Upland farm resource region; 0 otherwise	0.29	0.46
FR	1 if in Fruitful Rim farm resource region; 0 otherwise	0.10	0.30
MP	1 if in Mississippi Portal farm resource region; 0 otherwise	0.07	0.26
SS	1 if in Southern Seaboard farm resource region; 0 otherwise	0.54	0.50
Extrangpast	Number of breeding-aged goats in extensive-range and pastured but not rotated production systems	16.97	29.82
Pastrot	Number of breeding-aged goats in pastured, rotated production system	19.58	37.13
Drylot	Number of breeding-aged goats in dry lot production system	2.23	6.21
Breedshow	% of goat sales for breeding stock and show	50.33	37.11
Slaughterother	% of goat sales for slaughter and other purposes	44.58	36.82

Notes: ^{1}Southernmost counties of MO; ^{2}Eastern halves of OK and TX; ^{3}Western halves of OK and TX.

a female (the base category is a male operator). Φ_{Age} is a continuous variable in years indicating the age of the farmer. $\Phi_{Mediumfarm}$ and $\Phi_{Largefarm}$ are dummy variables for operation sizes with 20 to 100 and >100 meat goats, respectively (a small operation with <20 meat goats is the base). $\Phi_{\%Goatincome}$ is the percentage of annual net farm income from the meat goat enterprise, a measure of farm specialization. $\Phi_{Offfarmjob}$ is a dummy variable for the operator holding an off-farm job. Φ_{FR}, Φ_{MP}, and Φ_{SS} are sub-regional dummy variables for the Mississippi Portal, Fruitful Rim, and Southern Seaboard farm resource regions, respectively, as defined by USDA-ERS ($\Phi_{EU}$is the Eastern Uplands farm resource region considered as the base level). $\Phi_{Extrangpast}$ is the percentage of breeding-aged goats in extensive-range or pasture/woods and pastured but not rotated production systems. Φ_{Drylot} is the percentage of breeding aged goats in a dry-lot production system. The variable $\Phi_{Breedshow}$ refers to the percentage of goat sales for breeding stock or show, with the percentage of goat sales for slaughter/other purposes being the base.

Output and input variables may have zero values in the data. The zero value observations lead to biased estimation of the parameters of the translog function. Therefore, it is problematic for the production function (Battese, 1997). However, the coefficients of the variables with zero values can be estimated using dummy variables to avoid biased estimation (Battese, 1997)

An MC simulation model is used to investigate small-sample properties of the data given that our sample size is not large. A small sample size may result in a lack of statistical representation of the population, resulting in concern over consistency of estimates. Therefore, we conducted hypothetical[2] (based on artificial data) and empirical[3] (based on our data) MC simulations to determine consistency that the sampling distributions of the estimators approach very closely to their true parameter values as the sample size increases. The results of both MC simulation techniques show that there was no significant bias, and the asymptotic distribution approximated the small-sample distribution well for the data generation process (DGP) with samples of sizes 250, 500, and 1000.

Results

Since the data for this study were from two different survey questionnaires, there was concern of whether there were differences between these survey sample means. We conducted t-tests to determine statistically significant differences in means between the surveys. Results of

---

[2] The hypothetical MC simulation results are available upon request from the corresponding author.
[3] The empirical MC simulation results are available upon request from the corresponding author.

the t-tests suggest failure to reject the null hypothesis, concluding that there is not sufficient evidence to suggest the first survey and the follow-up survey population means differ at $P \leq 0.10$ levels. Table 2 shows t-test and p-values for selected variable means for both the first and the second survey samples.

Table 2. T-test results for the first and follow-up survey variable means

Variables	*T*-test value	*P* - value
Herd size	1.31	0.19
Number of breeding goats	1.24	0.21
% of farm income from goat operations	-1.06	0.29
% of sales for breeding stock and show	-0.30	0.76
Total farm land acres	1.52	0.12
Years farming	1.45	0.15

We conducted a number of tests on the structural form of the translog model by incorporating restrictions on the parameters. The likelihood ratio test was used to test the restrictions on the parameters using the test statistic given by $LR = \left(-2\ln\left[\frac{L(H_0)}{L(H_A)}\right]\right)$, where $\ln[L(H_0)]$ and $\ln[L(H_A)]$ are the values of the likelihood function under the null and alternative hypotheses, respectively. The likelihood ratio test has a χ^2 distribution with the degrees of freedom given by the number of restrictions imposed in the translog model. Results of the test statistics are given in Table 3 for Southeastern U.S. meat goat enterprises. We tested whether the explanatory variables in the enterprise model for inefficiency effects contributed significantly to the explanation of technical inefficiency effects. Test results show that the explanatory variables in the inefficiency models contribute significantly to the explanation of technical inefficiency effects. We also tested

Table 3. Likelihood Ratio Test Results for the Southeastern U.S. Meat Goat Enterprise Model

H_0 Restrictions	$\text{Ln}[L(H_0)]$	$\text{Ln}[L(H_A)]$	LR	Critical χ^2	Number of Restrictions
No inefficiency ($\tau_0 = \tau_1 = \tau_2 = \cdots = \tau_{12} = \tau_{13}$)	-105.95	-92.01	27.89	19.68	14
Cobb-Douglas production function ($\alpha_5 = \alpha_6 = \cdots = \alpha_{10} = \beta_3 = \cdots = \beta_5 = \theta_1 = \theta_2 = \cdots = \theta_6$)	-46.95	-17.34	59.22	.00	15

Notes: The test results at 5% level of significance.

whether the translog functional form described better the underlining production technology of Southeastern U.S. meat goat enterprises relative to the alternative Cobb-Douglas production functional form. Results show that the translog model is the more appropriate functional form for the model (Table 3).

The ML parameter estimates for the IDF are presented in Table 4. The parameter estimates of both outputs and two inputs are statistically significant. Of the inputs, the contributions of total other variable expenses (lnX^*_{Var}) is the largest in magnitude compared to feed expenses (lnX^*_{Feed}).

Table 4. The input distance function estimates for Southeastern U.S. meat goat enterprises

Variables	Coeff.	*t*-test	Variables	Coeff.	*t*-test
Constant	8.93***	6.14	$lnY_{Mgoat}lnX^*_{Var}$	0.04	1.33
Y^d_{Mgoat}	3.32**	2.10	$lnY_{Mgoat}lnX^*_{Fixed}$	-0.02*	-1.92
$Y^d_{Gbstock}$	-3.89***	-3.52	$lnY_{Gbstock}lnX^*_{Feed}$	0.01	1.29
X^d_{Feed}	-2.40*	-1.78	$lnY_{Gbstock}lnX^*_{Var}$	0.01	0.70
X^d_{Var}	0.15	0.08	$lnY_{Gbstock}lnX^*_{Fixed}$	-0.03***	-3.39
X^d_{Fixed}	-1.76***	-3.68			
lnX^*_{Feed}	-0.24***	-3.32	*Inefficiency*	*Model*	
lnX^*_{Var}	-0.36*	-1.87	*Constant*	-12.32***	-2.91
lnX^*_{Fixed}	-0.12	-1.25	*College*	-3.50**	-2.03
lnX^*_{Feedsq}	0.01	0.15	*Female*	-3.98***	-3.31
lnX^*_{Varsq}	-0.09***	-2.90	*Age*	-1.95***	-3.77
$lnX^*_{Fixedsq}$	0.05*	1.94	*Medium farm*	-3.54*	-1.77
$lnX^*_{Feed}lnX^*_{Var}$	0.09**	2.04	*Large farm*	-3.73***	-2.86
$lnX^*_{Feed}lnX^*_{Fixed}$	0.02	0.43	*%Goat income*	-2.27***	-2.64
$lnX^*_{Var}lnX^*_{Fixed}$	-0.10	-1.51	*Off-farm job*	-8.40***	-4.15
lnY_{Mgoat}	0.70**	2.02	*FR*	1.17	0.69
$lnY_{Gbstock}$	1.17***	3.50	*MP*	-22.21	-1.15
$lnY_{Mgoatsq}$	0.08	1.64	*SS*	-2.88**	-2.14
$lnY_{Gbstocksq}$	0.16***	3.50	*Pastrot*	-3.42*	-1.81
$lnY_{Mgoat}lnY_{Gbstock}$	0.03***	3.25	*Dry lot*	5.92	1.46
$lnY_{Mgoat}lnX^*_{Feed}$	-0.03***	-4.35	*Breedshow*	-3.40**	-2.47

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

The cross-input variable parameters are statistically non- significant except for the feed and total other variable expenses ($lnX^*_{Var}lnX^*_{Fixed}$). This interaction is statistically significant and positive, meaning these inputs are complementary. The output variable parameters have the expected signs and are statistically significant. The statistically significant meat goat production (lnY_{Mgoat}) and meat goat breeding stock production ($lnY_{Gbstock}$) variables suggest that increases in slaughter meat goat and meat goat breeding stock production increase the productive contribution of the land. The output interaction of slaughter meat goat production and meat goat breeding stock production ($lnY_{Mgoat} lnY_{Gbstock}$) is positive and statistically significant, implying their complementarity in production. This also suggests that an increase in meat goat breeding stock enhanced the contribution of slaughter meat goat production in the meat goat enterprise. Interaction between outputs and inputs, or $\varepsilon_{XY_kX_m} = \frac{\partial \varepsilon_{X,Y_k}}{\partial lnX_m} < 0$, indicate the increase in Y_k from an increase in X_m or output-input jointness or complementarity is implied. The parameter estimates for the interactions between the value of meat goat production (lnY_{Mgoat}) and feed expense (lnX^*_{Feed}), the value of meat goat production (lnY_{Mgoat}) and total fixed expenses (lnX^*_{Fixed}), and value of meat goat breeding stock production ($lnY_{Gbstock}$) and total fixed expenses (lnX^*_{Fixed}) lead to decreased land usage expenses.

Estimated inefficiency model parameter estimates are also presented in Table 4. The study found that operation size, college education, percentage of annual net farm income from the goat operation, Southern Seaboard farm resource region, female operator, operator age, a pastured and rotated production system, percentage of goat sales for breeding stock or show, and operator off-farm job were all positive efficiency drivers for Southeastern U.S. meat goat production. These meat goat farm and farmer characteristics are statistically significant and increase meat goat production TE.

We have expected results for farm operator education. Meat goat farmers with college degrees were more technically efficient than farmers without college degrees. Large-sized and medium-sized meat goat operations were more technically efficient than small-sized operations. Southern Seaboard meat goat farmers were more technically efficient than Eastern Uplands meat goat farmers. Percentage of income from meat goat production or degree of specialization increased technical efficiency. We also have expected results for the operator holding an off-farm job. Meat goat farmers holding off-farm jobs were more technically efficient than farmers who did not hold off-farm jobs. Older farm operators were more technically efficient than younger operators. Female operators were more technically efficient than male farmers. Farms using pastured and rotated production systems were more technically efficient than those using extensive-range or pasture/woods and pastured but not rotated systems. Farms that sold higher percentages of meat goats for breeding stock or show were more technically efficient.

The distribution of the estimated input-oriented technical efficiency scores is presented in Table 5. The results show an average technical efficiency of 0.86. This implies that the average Southeastern U.S. meat goat enterprise could reduce about 14% in inputs to produce the same output as an efficient farm on the production frontier. The table also shows that approximately 82% of the farmers achieved technical efficiency levels of 70% or higher.

Table 5. Distribution of technical efficiency

Range of TE	Freq.	% of farms in TE interval	Mean	SD
TE <= 0.30	2	2.90		
0.30 < TE <= 0.40	3	4.35		
0.40 < TE <= 0.50	1	1.45		
0.50 < TE <= 0.60	3	4.35		
0.60 < TE <= 0.70	3	4.35		
0.70 < TE <= 0.80	3	4.35		
0.80 < TE <= 0.90	6	8.70		
0.90 < TE <= 1.00	48	69.56		
Total	69	100.00		
Technical Efficiency			0.86	0.21

The marginal productive contributions (MPCs) of outputs and inputs can be estimated from the IDF, respectively, as $MPC_k = -\varepsilon_{D^I Y_k} = -\partial lnD^I(X,Y,R)/\partial lnY_k = \varepsilon_{X_1 Y_k}$, and $MPC_m = -\varepsilon_{D^I X_m^*} = -\partial lnD^I(X,Y,R)/\partial lnX_m^* = \varepsilon_{X_1 X_m^*}$. All MPCs have the hypothesized signs, negative for inputs and positive for outputs, as shown in Table 6. MPCs for outputs, lnY_{Mgoat} and $lnY_{CGbstock}$, indicate that an increase in all inputs results in an increase in output and should be positive, like an output elasticity or marginal cost. MPCs for inputs indicate the shadow values of inputs, lnX_{Feed}^*, lnX_{Fixed}^*, and lnX_{Var}^*, relative to land, X_{Land}, and should be negative, like the slope of a isoquant.

Table 6. Marginal productive contributions for inputs and outputs

MPCs	Coeff.	*t*-test	MPCs	Coeff.	*t*-test
$ln\ X_{Land}$	-0.324***	-3.32	lnY_{Mgoat}	0.193*	1.65
lnX_{Feed}^*	-0.294***	-4.50	$lnY_{Gbstock}$	0.636***	5.50
lnX_{Var}^*	-0.157**	-2.89			
lnX_{Fixed}^*	-0.226**	-2.97			

Notes: $^{**,\ ***}$ Significances at the 5% and 1% levels, respectively.

All of the MPC measures are statistically significant. The largest MPC in absolute value for inputs is land expense, followed by feed expense, total fixed expenses and total other variable expenses. The MPC for meat goat breeding stock production output, $lnY_{Gbstock}$, has the largest input share – about 64% on average.

Southeastern U.S. meat goat enterprise overall economic performance indicators are presented in Table 7. The estimated returns to scale (RTS) parameter for the Southeastern U.S. meat goat enterprises showed that a 1% increase in all outputs increased overall input use by 0.82%. This means an increasing RTS economy exists in Southeastern U.S. meat goat enterprise production. A measure of scope economies was estimated from the IDF by taking the second cross partial output derivatives, $\partial^2 lnD^I(X,Q,R)/\partial lnQ_k\, \partial lnQ_l > 0$. It was statistically significant, implying that scope economies existed in the Southeastern U.S. meat goat enterprise. A coefficient of 0.12 suggests that joint production of meat goat breeding stock and meat goat for slaughter and/or goat meat decreased average total cost by 12% relative to the separate production of these two outputs on Southeastern U.S. meat goat farms.

Table 7. Returns to scale, scope economies and scale efficiency

Measurements	Coeff.	*t*-test
Return to scale	0.82^{***}	6.23
Scale efficiency	1.00^{***}	10.58
Scope economy	0.12^{***}	3.08

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

Scale efficiency (SEF) is the potential productivity gain from moving to the optimal farm size (Table 7). A scale efficiency measure can be estimated from the IDF. The method for estimating scale efficiency was introduced by Balk (2001) and Ray (2003, 1998) for multi-output multi-input distance functions. Following Ray (2003), SEF for U.S. meat goat production was estimated from the IDF. SEF is an economic performance indicator representing the improvement in average productivity of the Southeastern U.S. meat goat enterprise through a change in the scale of meat goat production. This study found that Southeastern U.S. meat goat firms, on average, are scale efficient if the enterprise's scale of production is greater than 60 goats or greater than 40 breeding does per operation.

Conclusion

Our study revealed that the efficiency of the Southeastern U.S. meat goat production enterprise was impacted by factors such as meat goat operation size, percentage of income from meat goat production, production systems, education level, off-farm jobs, gender (female), age, percentage of goat sales for breeding stock or show, and region (location of farms). We found increasing returns to scale, scale efficiency, and scope economies, exposing insights into the growth potential for the Southeastern U.S. meat goat industry. For meat goat enterprise productivity growth, specialization and scope economy within the meat goat enterprise were found to be a potential factor to increase technical efficiency.

The effect of operation size on the technical efficiency and productivity of U.S. meat goat farms is significant. Large-sized and medium-sized meat goat enterprises were more technically efficient than small-sized operations. Small farms have the potential to enhance their competitiveness by increasing the scale of their operations. Increasing RTS on Southeastern U.S. meat goat enterprise suggests that producers can increase the size of their operations, resulting in less overall input usage per unit produced. Southeastern U.S. meat goat producers can benefit from significant economies of scale. Our results suggest that Southeastern U.S. meat goat enterprises can be scale efficient if their operation size is > 60 goats or operation size > 40 breeding does. The USA 2012 Census results suggest the average meat goat farm includes 20 goats, which is not scale efficient production size based on findings of this study.

Empirical MC simulations and obtained parameter estimates, standard errors, and rejection rates of the parameters for the t-tests of null hypotheses for 250, 500, and 1,000 replications show that the empirical MC simulations replications consistently estimated the parameters and enabled small-sample properties.

The U.S. meat goat industry efficiency will benefit from the extension educational efforts if those efforts focus on small-scale producers who are full-time farmers, those who are less specialized in meat goat production, and those who have lower education levels.

References

Alex, R., R. Kuniyoor Cheemani and 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.

Ball, V. E., W. A. Lindamood, R. Nehring and C. S. J. Mesonada (2008) Capital as a factor of production in OESD agriculture: measurement and data, *Applied Economics*, **40**, 1253-1277.

Battese, G. E. (1997) A note on the estimation of Cobb-Douglas production functions when some explanatory variables have zero values, *Journal of Agricultural Economics*, **48**, 250-252.

Dillman, Don A. (2007) *Mail and internet surveys: the tailored design method*, John Wiley & Sons, 2007.

FAOSTAT (2008) http://faostat.fao.org/default.aspx (accessed 2 July 2014).

Ibrahim, M. (2011) Consumer willingness to pay a premium for halal goat meat: a case from Atlanta, Georgia, *Journal of Food Distribution Research*, **42**, 73-76.

Knight, E., House, L., Nelson, M. C. and Degner, R. (2006) An evaluation of consumer preferences regarding goat meat in the South, *Journal of Food Distribution Research*, **37**, 88-96.

Meat Goat Production (2000) *Agricultural alternatives* series, College of Agricultural Sciences, Agricultural Research and Cooperative Extension, Pennsylvania State University. Available at http://extension.psu.edu/business/ag-alternatives/livestock/sheep-and-goats/meat-goat-production (accessed 2 July 2014).

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.

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 No. 200325, Department of Economics, University of Connecticut.

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

Shurley, M., and F. Craddock. 2005. “U.S. Meat Goat Industry: Past, Present, and Future.” Presentation at the Gathering of Goat Producers IV, Seguin, TX, July. Available at http://theikga.org/us_meat_goat_industry.html (accessed March 21, 2014).

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.

USDA-Economic Research Service, U.S. Farm Resource Regions.
Available at http://www.ers.usda.gov/media/926929/aib-760_002.pdf (accessed July 2, 2014).

USDA-National Agricultural Statistics Service (2012) 2012 Census of Agriculture – United States Data. Available at http://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_1_State_Level/Texas/st48_1_028_031.pdf (accessed July 2, 2014).

Worley, T., Ellerman, J., Mangione, D., West, T. and Yang, Y. (2004), Meat-goat market analysis: a pilot study of the Somali market in Columbus, OH, *Journal of Food Distribution Research*, **35**, 182-187.

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.