PRODUCTIVITY AND EFFICIENCY OF SOUTHEASTERN U.S. MEAT GOAT FARMS

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Abstract

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

1. Introduction

In recent decades, U.S. meat goat production has increased substantially compared with other U.S. livestock industries. The majority of the meat goat population is located in the Southeast with Texas having the largest meat goat production (Appendix A). The Southeast region is well suited to producing goats because of extended grazing periods for livestock production. The Southeast 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). 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).

The meat goat industry has been one of the fastest growing livestock industries in the U.S. (USDA/APHIS, 2012). A significantly increased U.S. immigrant population has been the major factor impacting the growth of U.S. meat goat production. Fourteen million new immigrants came to America between 2000 and 2010 (American Community Survey, 2010) and most of those immigrants consume lean goat meat. Growth of the goat industry and demand for goat meat will likely continue with changes in ethnicity in the U.S. population.

The USDA's National Animal Health Monitoring System study on the U.S. goat industry 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 2012

U.S. Census of Agriculture, about 78 percent and 77 percent of all goats in the U.S. were raised for meat in 2012 and 2002, respectively (2012 Census of Agriculture).

The U.S. meat goat industry is a relative newcomer to the livestock industry. Therefore, there is relatively limited information available about U.S. meat goat production, specifically meat goat efficiency that can impact the goat industry.

2. Literature

Few studies have investigated meat goat production efficiency and its productivity. Alex et al. (2013) conducted research on the technical efficiency in small-scale Malabari goat production farms in Kerala, India. The important factors related to technical efficiency were farm size and location. They suggested that there are still opportunities for increasing productivity and income of goat farms by increasing efficiency. Ogunniyi (2010) studied the economic efficiency of goat production in the Ogbomoso agricultural zone of Oyo State, Nigeria. Feed frequency, years of establishment, education, and number of head were the main factors affecting the economic inefficiency of goat production. They concluded that there was scope for increasing goat production efficiency by about 40 percent.

Hidayat (2007) conducted research on integrated goat farms in Banyumas, Indonesia, 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 the level of production and income of different farming systems, and the combination of farming generating maximum income. Zaibet et al. (2004) investigated the impact of socio-economic changes on goat production in the local community of Jabal Akhdar, Oman. They found decreasing returns-to-scale for goat production. They concluded that off-farm income was the major source of income for goat farms, and important inefficiencies existed in the use of resources. Limited work has addressed meat goat production efficiency in the U.S. Our study focuses on the efficiency of Southeastern U.S. meat goat production.

3. Data Sources and Methods

For this study, we 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 an earlier survey that focused on the marketing, technology, farmer attitudes, and farm and farmer characteristics of U.S. meat goat production. The reasons for the cost and returns survey were to estimate U.S. meat goat farm efficiency and to determine efficiency drivers. The study used demographics and farm characteristics from the earlier survey.

Missing information occurs frequently in survey data, and missing data may lead to biased estimates and reduce the efficiency of regression estimates (Rubin, 1987). Various methods exist to handle missing data. The multiple imputation (MI) method was used to handle the missing data 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,

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

property taxes, and rental and lease payment expenses; and 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 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 the meat goat operation, regions, size of operation, whether farm production was certified organic or transitional, and whether the farm sold goats for breeding stock, show, slaughter/ meat, or 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. The Southeast includes parts of the following farm resource regions as designated by USDA-ERS (Appendix A): Eastern Uplands, Fruitful Rim, Mississippi Portal, and Southern Seaboard. The sizes of operations were divided into three groups: small farm (< 20 meat goats in the operation), medium farm (≥ 20 and < 100 meat goats in the operation), and large farm (≥ 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:

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

$$+\frac{1}{2}\sum_{k}\sum_{l}\beta_{kl}\, lnQ_{ki}lnQ_{li} + \sum_{q}\delta_q\, R_{qi} + \frac{1}{2}\sum_{q}\sum_{r}\gamma_{qr}\, lnR_{qi}lnR_{ri} + \sum_{k}\sum_{m}\theta_{km}\, lnQ_{kit}lnX_{mi}$$

$$+ \sum_{q}\sum_{m}\varphi_{qm}\, lnR_{qit}lnX_{mi} + \sum_{k}\sum_{q}\tau_{kq}\, lnQ_{ki}lnR_{qi} + v_i = TL(X,Q,R) + v_i \qquad (1)$$

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 rewritten as

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

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 $\varepsilon_i = v_i - u_i$ (Jondrow et al., 1982). TE can be measured as:

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

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 69 farms which represent the population of Southeastern U.S. meat goat farms that advertise via the internet. A thorough internet search of U.S. meat goat farms yielded just 1,600 that advertised via the internet, of which 69 were located in the Southeast. Thus, there is a concern of consistency of estimation of the sample size. An estimator is consistent if increases in the sample size estimating parameter converge to the true value of the population parameter. Therefore, we used empirical Monte Carlo (MC) 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 of the IDF for the Southeastern U.S. meat goat whole farm and enterprise are presented in Table 1. All input variable parameters for the Southeastern U.S. meat goat whole farm model were statistically significant. The contribution of total other variable (lnX_3^*) and feed (lnX_2^*) expenses were the largest inputs in magnitude, meaning that the increase in total other variable and feed expenses decreased the productive contribution of land ($ln\, X_{1,i}$). The total fixed expense (lnX_4^*) had the smallest contribution in magnitude. Two input variables, feed and total other variable expenses, were statistically significant in the Southeastern U.S. meat goat enterprise model.

Table 1. The IDF Estimates for Southeastern U.S. Meat Goat Farms

Whole farm			Enterprise		
Variables	Coeff.	t-test	Variables	Coeff.	t-test
constant	1.98	0.61	constant	7.70***	4.55
Y_1^d	4.24***	3.09	Y_1^d	3.47*	1.88
Y_2^d	-0.17	0.06	Y_2^d	-3.20**	-2.33
X_2^d	-5.83*	-1.86	X_2^d	1.89	-1.41
X_4^d	-1.73**	-2.33	X_3^d	-0.23	-0.15
lnX_2^*	-1.97***	-7.89	X_4^d	-0.75	-1.12
lnX_3^*	-2.41***	-4.24	lnX_2^*	- 0.19***	-2.99
lnX_4^*	-0.30*	-1.65	lnX_3^*	-0.34*	-1.89
lnX_{2sq}^*	0.06	0.63	lnX_4^*	0.11	1.10
lnX_{3sq}^*	-0.18**	-2.33	lnX_{2sq}^*	-0.002	-0.05
lnX_{4sq}^*	0.03	0.52	lnX_{3sq}^*	-0.05	-1.58
$lnX_2^* lnX_3^*$	0.18	1.04	lnX_{4sq}^*	0.01	0.28
$lnX_2^* lnX_4^*$	- 0.10*	-1.81	$lnX_2^* lnX_3^*$	0.04	0.96
$lnX_3^* lnX_4^*$	0.10	1.14	$lnX_2^* lnX_4^*$	0.01	0.35
lnY_1	0.94**	2.39	$lnX_3^* lnX_4^*$	-0.03	-0.41
lnY_2	0.48	0.68	lnY_1	0.61	1.33
lnY_{1sq}	0.07	1.31	lnY_2	1.13***	3.07
lnY_{2sq}	0.09	1.19	lnY_{1sq}	0.07	1.10
$lnY_1 lnY_2$	-0.04*	-1.81	lnY_{2sq}	0.16***	3.31
$lnY_1 lnX_2^*$	0.16***	5.07	$lnY_1 lnY_2$	-0.03***	-2.99
$lnY_2 lnX_2^*$	0.09***	4.00	$lnY_1 lnX_2^*$	-0.02***	-3.47
$lnY_1 lnX_3^*$	-0.29***	-3.97	$lnY_2 lnX_2^*$	0.00	0.07
$lnY_2 lnX_3^*$	-0.04**	-4.00	$lnY_1 lnX_3^*$	0.03	1.38
$lnY_1 lnX_4^*$	0.02	1.28	$lnY_2 lnX_3^*$	0.02	0.91
$lnY_2 lnX_4^*$	-0.02*	-1.77	$lnY_1 lnX_4^*$	-0.02**	-2.21
R_{mf}	0.62**	2.53	$lnY_2 lnX_4^*$	-0.03***	-3.49
R_{lf}	1.01**	2.35	R_{mf}	0.45**	2.55
			R_{lf}	0.89***	2.93
Inefficiency Model			Inefficiency Model		
constant	13.57***	3.75	constant	17.08***	5.65
Education	-2.00**	-2.71	Education	-2.85***	-3.36
Goat Income	-2.37***	-5.07	Goat Income	-1.90***	-4.45
Mississippi Portal	-2.40	-0.57	Mississippi Portal	-27.71***	-6.00
Fruitful Rim	-4.66***	-3.15	Fruitful Rim	-1.00	-0.89
Southern Seaboard	-3.59**	-2.25	Southern Seaboard	-4.47***	-3.17
Extensive-range	-5.90***	-3.02	Extensive-range	-2.54**	-2.02
Dry Lot	7.21***	5.30	Dry Lot	6.13***	3.13
Breeding Stock and Show	-2.49**	-2.23	Breeding Stock and Show	-6.60***	-4.70
Operator Off-farm Job	-4.68**	-2.48	Operator Off-farm Job	-7.91***	-4.94
Experience	-1.43*	-1.65	Age	-1.61***	-2.86
Gender (female)	-6.07***	-3.93	Gender (female)	-5.26***	-4.59
Sell Goat Meat	-1.97	-1.44			

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

Interaction of feed and total fixed expenses ($lnX_2^* lnX_4^*$) was statistically significant and indicates they are substitutes in the Southeastern U.S. meat goat whole-farm model analysis. This interaction suggests that an increase in feed expense led to a decreased total fixed expense contribution to productivity. Moreover, land use does not have to decrease as much to expand the feed expense if the total fixed expense level is high.

The statistically significant productive contribution of meat goat production (lnY_1) in the whole farm model suggests that increased meat goat production increased the productive share or contribution of the land. The statistically significant productive contribution of meat goat breeding stock production (lnY_2) in the enterprise model suggests that increased meat goat breeding stock production increased the productive share or contribution of land. The output-interactions between meat goat production and all crops and other livestock production ($lnY_1 lnY_2$) and meat goat breeding stock and meat goat and/or goat meat were statistically significant in both Southeastern U.S. meat goat whole farm and enterprise models. We also found that these interactions were positive, implying their jointness or complementarity.

Five interactions, $lnY_1 lnX_2^*$,$lnY_1 lnX_3^*$, $lnY_2 lnX_2^*$, $lnY_2 lnX_3^*$ and $lnY_2 lnX_4^*$, between inputs and outputs were statistically significant in the meat goat whole-farm analysis. We found that three input-output interactions, $lnY_1 lnX_2^*$, $lnY_1 lnX_4^*$, and $lnY_2 lnX_4^*$, were statistically significant in the meat goat enterprise model. Contribution of medium sized (R_{mf}) and large sized (R_{lf}) meat goat operations to productivity were statistically significant relative to small-sized operations (R_{sf}) in both meat goat whole-farm and enterprise models. Elasticity of R_{lf} also confirms that large meat goat farms required the greatest land input share or contribution, with the medium sized farm second in both the whole farm and enterprise models.

Estimated inefficiency model parameters are also presented in Table 1. We found that operator education level, percentage of annual net farm income from goat operations, extensive-range production system, percentage of goat sales for breeding stock and show, operator off-farm job, and gender (female) were the efficiency drivers for both the Southeastern U.S. meat goat whole farm and enterprise analyses. The parameter estimate for experience was statistically significant and increased the technical efficiency of Southeastern U.S. meat goat whole farms. The parameter estimate results for age showed that it was statistically significant and an efficiency driver in the Southeastern U.S. meat goat enterprise model. Fruitful Rim and Southern Seaboard farm resource regions were more technically efficient than those in the Eastern Uplands farm resource regions in the whole farm model. Farms in the Mississippi Portal and Southern Seaboard farm resource regions were more technically efficient than those in the Eastern Uplands farm resource region in the enterprise model. The dry-lot production system was technically inefficient.

The results show that the average technical efficiencies were 0.82 and 0.88, respectively, for the Southeastern U.S. meat goat whole farm and enterprise. These indicated that the average Southeastern U.S. meat goat farmer and enterprise could reduce about 18% and 12%, respectively, in inputs to produce the same output as an efficient Southeastern U.S. meat goat farm and enterprise on the production frontier.

Marginal productive contributions for Southeastern U.S. meat goat whole farm and enterprise inputs and outputs had the expected signs, negative for inputs and positive for outputs, as shown in Table 2. MPC measures for land, feed, and total fixed expenses were statistically significant at the $P \leq 0.01$ level in the meat goat whole farm analysis. However, the MPC measure for total variable expense was statistically non-significant in the whole farm model. All

MPC measures for outputs were statistically significant in the Southeastern U.S. meat goat whole farm analysis. MPC measures for land, feed, total other variable and total fixed expenses were statistically significant at the P ≤ 0.01 level in the Southeastern U.S. meat goat enterprise analysis.

Table 5. MPCs of Inputs and Outputs for Southeastern Meat Goat Farms

	Whole Farm		Enterprise	
MPCs	Coeff.	t-test	Coeff.	t-test
$ln\ X_1$	-0.41***	-5.30	-0.32***	-3.20
lnX_2^*	-0.31***	-4.41	-0.31***	-4.58
lnX_3^*	-0.11	-1.02	-0.15***	-2.97
lnX_4^*	-0.17***	-4.13	-0.22***	-2.76
lnY_1	0.42**	2.04	0.32*	1.72
lnY_2	0.44***	4.09	0.62***	4.97

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

We found increasing returns to scale (RTS) for Southeastern U.S. meat goat whole farms and enterprises, respectively (Table 3). The estimated scope economies parameter estimates were statistically significant, indicating that scope economies existed in Southeastern U.S. meat goat production from both whole farm and enterprise perspectives (Table 3). The estimated scale efficiency measures for the Southeastern U.S. meat goat whole farm and enterprise production are also presented in Table 6. We found that, in the Southeastern U.S., meat goat whole farms are, on average, scale efficient if the farm's scale of production is greater than 57 meat goats or greater than 40 breeding does per operation. We also found that from the Southeastern U.S. meat goat enterprise perspective, farms were scale efficient if the enterprise scale of production was greater than 58 meat goats or greater than 39 breeding does per operation.

Table 3. RTS, Scope Economies and Scale Efficiency for Southeastern Meat Goat Farms

	Whole Farm		Enterprise	
Measurements	Coeff.	t-test	Coeff.	t-test
Returns to scale	0.86***	4.03	0.84***	5.46
Scope economies	0.14*	1.81	0.12***	2.99
Scale efficiency	1.00***	57.21	1.00***	48.03

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

The empirical MC simulation results for Southeastern U.S. meat goat whole farm and enterprise production are presented in Appendixes C and D, respectively. We performed 250, 500, and 1,000 MC simulations and obtained parameter estimates, standard errors, and rejection rates of the parameters for the t-tests of the null hypothesis in both models. The results of the 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 69 in both models.

5. Conclusions

This study measures the economic performance of Southeastern 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 costs and returns of U.S. meat goat operations in 2011.

The results show that all input variables were significant for Southeastern U.S. meat goat farms. We also found substitution effects between the feed and total fixed expenses. The measures of marginal productive contributions had the correct signs for inputs and outputs, and they were significant. We also found increasing returns to scale for Southeastern U.S. meat goat farms. Meat goat farms can be scale efficient at greater than 57 total goats or greater than 40 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.

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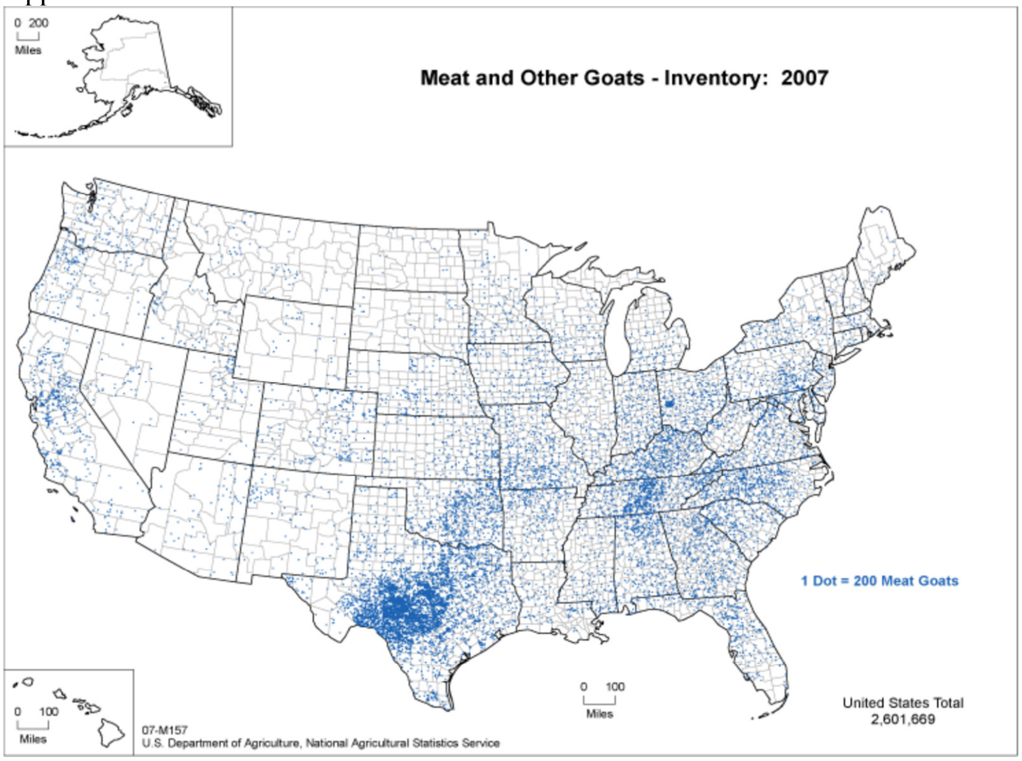
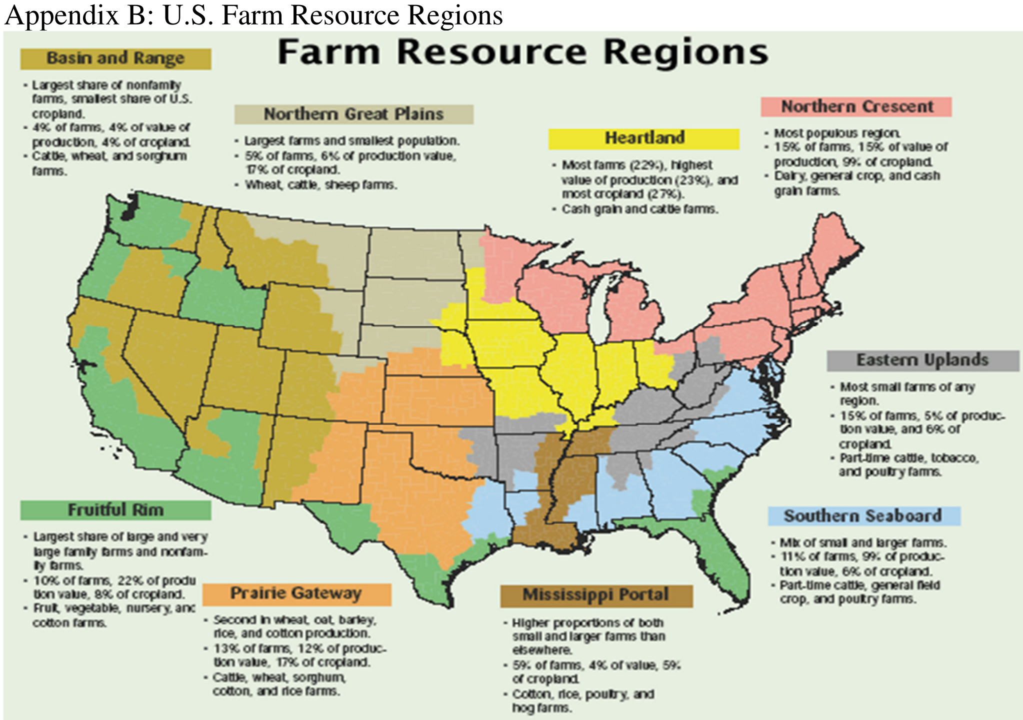
Appendix

Appendix A: Distribution of Meat Goats in the U.S.



Source: USDA APHIS 2011

Appendix B: U.S. Farm Resource Regions



Source: USDA Economic Research Service