



Technical Efficiency and Its Influencing Factors of Farmers' Meat Sheep Production in China: Based on the Survey Data of Farmers

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Abstract: Although both meat sheep stocks and mutton yield in China are ranked as the first largest in the world, we observe that meat sheep is not produced with full technical efficiency in the country. A review of existing literature reveals that so far little attention has been given by the researchers in investigating the efficiency of Chinese meat sheep production with micro data on household. Thus, the main objective of this paper is to analyze the technical efficiency of meat sheep production in China using data from 204 meat sheep-rearers. We employ the Translog Stochastic Frontier Production function approach and Technical Efficiency Loss Model respectively. Results indicated that technical efficiency of meat sheep in China is 34.37%. It is also found that education level, scale farming, percent household income from meat sheep, government support and training experience are positive and significantly related to technical efficiency. Although family size has a significant negative impact, it is minimal.

Keywords: Technical Efficiency, Influencing Factors, Meat Sheep Production, Farmers

1. Introduction

Regard less of the rapid development of animal husbandry in China or the improvement of herders' income, meat sheep industry has still played a vital role since the late 1970s. Furthermore, number of meat sheep in China ranked first in the world since 1972 (FAOSTAT, 2015). Chinese mutton yield accounting for 30% of world meat production is also the highest in 2014, far more than other major mutton production countries in the world (FAOSTAT, 2015). However, mutton yield level in China is still far behind developed countries such as Australia, Britain, and New Zealand. The average carcass weight of meat sheep in China reached 16.0 kg in 2013, but Australia, New Zealand, Japan and Ireland were 21.7 kg, 19.0 kg, 29.0 kg and 20.0 kg respectively. With the rapid economic development in China, people's living standards have improved significantly as well. People's diet tends to be healthier and more nutritious. Compared to pork, mutton has low fat, less cholesterol and high protein, which makes it more positively in the meat consumption at present and in the foreseeable future. Meat sheep production lays an important role in increasing herders'

income and people's living standards in rural communities; therefore, more attention should be paid to it.

As we all known, meat sheep industry is increasingly facing the dual constraints of resources and environment, especially in China. The development of major production areas is still relatively backward, farming methods are more traditional, and the situation of "Livestock is at the mercy of the forces of nature" did not change. Facing increasing domestic lamb gap between supply and demand, grassland ecological environment pressure and resources supply constraints, it is determined that we must constantly improve meat sheep's production technology level and economic efficiency, instead of unlimited expand the number of meat sheep or production inputs.

Previous studies have shown that the productivity and efficiency of the meat sheep industry can be explained by a number of factors. These include operation and management (Pérez et.al, 2007; Raineri et.al, 2015), medication and labour (Zalkuwi et.al, 2014), pasture irrigation level (Ates et.al, 2013), grazing and climate conditions (Shomo et.al., 2010; Yang et.al, 2013; Sherif et.al, 2014). At present, Chinese meat sheep production technology was apparent losses, and

improved varieties, scale and human capital have a significant positive impact on it (Geng, 2013). Technical efficiency measures the maximum possible expansion of the outputs for a given level of input allowed, and this is helpful for a deeper understanding with regard to the rationality of input-output structure (Battese, 1992). The average production technical efficiency of Greece Chios island's meat sheep reached 76% (Theodoridis et.al, 2012), the same was 83% in China's seven provinces (Liu et.al, 2014)

This paper aims to investigate the productivity of the Chinese meat sheep industry and determine the factor that drives productivity. Using survey data, we will provide evidence to show that extension service and formal education play a significant role in enhancing meat sheep productivity. Thus, the implication of the study might force the government to increase the investment on education facility, research and development as well as the extension service, in order to ensure the effective supply of mutton and realize meat sheep industry sustained and healthy development.

2. Research Method and Data

2.1. Method

To estimate the efficient frontiers of Chinese meat sheep production, a popular parametric method, the stochastic frontier analysis (SFA), was utilized. It has the main strength to be able to deal with the statistical noise in the data and also permits statistical testing of both the hypotheses pertaining to the production structure and the degree of inefficiency (Alwarritzi, 2015). The specific form of SFA includes Cobb-Douglas and Translog, and the former is a special case of the latter. Translog stochastic frontier model used to analyze the technical efficiency in meat sheep production and its corresponding technical efficiency loss model are defined respectively by:

$$\ln Y_i = \beta_0 + \sum_{i=1}^n \beta_i \ln X_i + \frac{1}{2} \left(\sum_{i=1}^n \sum_{j=1}^n \beta_{ij} \ln X_i \ln X_j \right) + V_i - U_i$$

$$E(U_i) = m_i = \delta_0 + \sum_{j=1}^n Z_{ji} + \varepsilon_i \quad (1)$$

Where $i=1,2,3,\dots,N$. Y_i represents slaughter live weight of meat sheep for the i th farm households; X_i and X_j are vectors of factors inputs for the i th and j th farm households respectively. $\beta_0, \beta_i, \beta_{ij}$ are parameters to be estimated. V_i is a random error. U_i is the nonnegative error component representing technical inefficiency in production, Z_{ji} is a vector of explanatory variables associated with technical inefficiency, δ_0, δ_j are vectors of unknown parameters and ε_i is a random variable. When the estimated value of β_{ij} is equal to 0, the translog stochastic frontier production function is transformed into Cobb-Douglas stochastic frontier production function:

$$\ln Y_i = \beta_0 + \sum_{i=1}^n \beta_i \ln X_i + V_i - U_i \quad (2)$$

We will use the Maximum Likelihood Ratio to determine which form of the stochastic frontier production model is adopted.

2.2. Data Collection

In the study, primary data collected from 204 sheep-rearers belonging to 24 cities of seven provinces in China during July to August in 2014 was used. Data collection was done by The Industrial Economy Research Team of Wool-sheep and Cashmere-goat in China. These countries were selected purposively since all of them are the main producing area of meat sheep in China. Such as Inner Mongolia's Bairin Right Banner, Bairin Left Banner, Uxin Banner, AoHanqi, Otog Front Banner, Otog Banner and Hexigten Banner; Gansu's Tianzhu County and Sunan County; Xinjiang's Xinyuan Country and Gongliu County, and soon. From the identified countries, meat sheep breeding farm households were selected randomly, and data were collected by personal interview, using a structured survey schedule.

2.3. Variable Selection and Data Description

According to the requirements of the stochastic frontier production function model to the input and output indicators, we selected meat sheep slaughter live weight as output variable when calculating the technical efficiency of farmers' meat sheep production. The input variables are concentrate feeding amount (the sum feeding amount of produced or purchased corn, buckwheat, wheat bran, sunflower, soybean meal and compound feed), roughage feeding amount (the sum feeding amount of produced or purchased straw, hay, alfalfa, silage and so on), labor input (total working days of free labor and employee in the process of sheep farming work, and converted into standard work by eight hours) and other material costs (including baby purchase fees, costs of salt, medical and epidemic prevention costs, damages for death, depreciation of fixed assets, grassland construction and maintenance fees and other expenses). In the aspect of analyzing the factors affecting technical efficiency of meat sheep production, we adopted farmers' personal and family characteristics, farmers' sheep breeding characteristics and socio-economic conditions as the main three aspects. Firstly, farmers' personal and family characteristics, such as householder's age, the education situation of householder, family size, and whether family members as village cadres. Secondly, farmers' sheep breeding characteristics, such as breeding age, breeding scale, breeding pattern, the proportion of earnings from raising sheep in total household income and whether received training in breeding techniques. Lastly, socio-economic conditions, such as whether participated in the cooperative or association organization, borrowed money or not and whether received government policies support.

In the present study, data on output and inputs are used to estimate farmers' level technical efficiency of meat sheep production. The results of the statistical analysis of the variables and the main results are shown in Table 1.

Table 1. Variable description & its main descriptive statistical analysis results.

Variables	Description/unit	Average	Standard Deviation
Meat sheep slaughter live weight per household	Kilograms	3535.63	6419.75
Concentrate feeding amount	Kilograms	6279.8	23646.81
Roughage feeding amount	Kilograms	38149.77	390880.72
Labor input	Standard work day	412.66	972.53
Other material costs	Yuan	25771.3	197261.59
Age	Years	44.34	9.64
Education degree	Never=1, Primary=2, Junior=3, Senior=4, College and above=5.	2.68	0.94
Family size	Number of people	4.32	1.55
Village cadres	0/1	0.15	0.36
Years farming	Years	1992.45	11.84
Scale farming	Number of meat sheep	214.34	203.47
Pattern farming	Feeding=1, Half-feeding=2, Grazing=3.	2.15	0.50
Percent household income from meat sheep	Percent	67.93	27.61
Training in farming techniques	0/1	0.60	0.49
Cooperative or association Organization	0/1	0.42	0.49
Borrowed money	0/1	0.58	0.49
Government policies support	0/1	0.79	0.41

Source: Authors own calculation.

Table 2. Statistical hypothesis testing results of the specific set of stochastic frontier production function model.

Test Method	H ₀	Log likelihood function	Statistic test (LR)	Critical value	Test Result
Test (1)	$\beta_{11}=\beta_{22}=\beta_{33}=\beta_{44}=\beta_{12}=\beta_{13}=\beta_{14}=\beta_{23}=\beta_{24}=\beta_{34}=0$	-87.8895	35.388108	21.21	RejectH ₀
Test (2)	$\gamma=\delta_0=\delta_1=\dots=\delta_{13}=0$	-153.8841	167.377322	35.43	RejectH ₀

Note: without limitations for the maximum value of log likelihood function under the alternative hypothesis H₁ is equal to -70.1955.

Source: Authors own calculation.

Table 3. Maximum likelihood estimates for parameters of translog stochastic frontier production function model.

Variable	Parameter	Coefficients	Std.Error	t-ratio
Constant	β_0	2.1288**	0.8389	2.5374
$\ln X_1$	β_1	0.7453*	0.3769	1.9775
$\ln X_2$	β_2	-0.0759	0.2014	-0.3769
$\ln X_3$	β_3	0.3438	0.2769	1.2418
$\ln X_4$	β_4	0.1932	0.1695	1.1401
$(\ln X_1)^2$	β_5	-0.0317	0.0441	-0.7192
$(\ln X_2)^2$	β_6	0.0054	0.0229	0.2351
$(\ln X_3)^2$	β_7	0.1031**	0.0505	2.0415
$(\ln X_4)^2$	β_8	0.0147	0.0255	0.5753
$\ln X_1 \times \ln X_2$	β_9	0.0674*	0.0497	1.3546
$\ln X_1 \times \ln X_3$	β_{10}	-0.0756	0.0807	-0.9367
$\ln X_1 \times \ln X_4$	β_{11}	-0.0231	0.0563	-0.4104
$\ln X_2 \times \ln X_3$	β_{12}	-0.0768	0.0582	-1.3193
$\ln X_2 \times \ln X_4$	β_{13}	-0.0176	0.0362	-0.4850
$\ln X_3 \times \ln X_4$	β_{14}	0.0097	0.0525	0.1841
σ^2		0.1321***	0.0157	8.4037
γ		0.5707***	0.1218	4.6839
Log likelihood function			-70.1955	
LR test of the one-sided error			168.7070	

Note: ***, ** and * are significant at 1%, 5% and 10% levels, respectively.

Source: Authors own calculation with Froniter4.1.

3. Results and Discussion

3.1. Estimated Stochastic Frontier Production Function

Before estimating the technical efficiency, we must examine the specific set of the stochastic frontier production function model firstly. Usually, we use the maximum

likelihood ratio test by constructing a statistic LR to test. According to the test results (Table 2), LR statistics tests are bigger than its respective critical values (significant at 5%), so we could reject the null hypothesis for two tests. It suggests that the translog stochastic frontier production function model and technical efficiency loss model will be adopted to research the technical efficiency of farmers' meat sheep production and its effect.

The maximum likelihood estimates for parameters of translog stochastic frontier production function (equation 1) for meat sheep-rearers are shown in Table 3. From that, we ascertain the ratio (γ) of the technology inefficiency variance of U_i (σ_u^2) and the composite variance (σ^2) is equal to 0.5707 and it is statistically insignificant at 1% level. It is not only indicated the technical efficiency loss is widespread and significant in meat sheep production, but also the traditional production function unable to fit adequately our research data.

3.2. Elasticity Analysis of Input Factors

Taking into account production elasticity of input factors could better reflect the input-output relationship of meat sheep production; we will obtain input-output elasticity of various elements by calculating its partial derivatives. So the input-output elasticity of i th production factors, X_i can be expressed as:

$$e_{x_i} = \frac{\partial \ln Y}{\partial \ln X_i}$$

Thus, the specific calculation equation of inputs and output

factors for farms' meat sheep production are present as following:

$$e_{x_1} = \beta_1 + \beta_{11} \ln X_1 + \frac{1}{2} \beta_{12} \ln X_2 + \frac{1}{2} \beta_{13} \ln X_3 + \frac{1}{2} \beta_{14} \ln X_4$$

$$e_{x_2} = \beta_2 + \beta_{22} \ln X_2 + \frac{1}{2} \beta_{12} \ln X_1 + \frac{1}{2} \beta_{23} \ln X_3 + \frac{1}{2} \beta_{24} \ln X_4$$

$$e_{x_3} = \beta_3 + \beta_{33} \ln X_3 + \frac{1}{2} \beta_{13} \ln X_1 + \frac{1}{2} \beta_{23} \ln X_2 + \frac{1}{2} \beta_{34} \ln X_4$$

$$e_{x_4} = \beta_4 + \beta_{44} \ln X_4 + \frac{1}{2} \beta_{14} \ln X_1 + \frac{1}{2} \beta_{24} \ln X_2 + \frac{1}{2} \beta_{34} \ln X_3$$

Where $\ln X_1$, $\ln X_2$, $\ln X_3$ and $\ln X_4$ are the average of concentrate feeding amount, roughage feeding amount, labor input and other material costs respectively. With the former parameters estimate results in Table 3, we can calculate the average output elasticity of inputs and output factors for farms' meat sheep production. The result is presented in Table 4.

Table 4. The average output elasticity of inputs & output factors for farmers' meat sheep production.

Factors	Concentrate (X ₁)	Roughage (X ₂)	Labor (X ₃)	Other material costs (X ₄)
Average output elasticity	0.4848	-0.0532	0.3389	0.1792

Source: Authors own calculation.

The average output elasticity of concentrate (X₁), roughage (X₂), labor input (X₃) and other material costs (X₄) are 0.4848, -0.0532, 0.3389 and 0.1792 respectively. It indicates when concentrate feeding amount, labor input and other material costs both increased 1%, meat sheep slaughter live weight will increase 0.4848%, 0.3389% and 0.1792% respectively (Table 4).

Through our investigations, we learned that the majority of farmers in China still use traditional farming ways currently. Most farmers take herding way, merely proper feed to sheep with some hay, straw, silage, yellow storage and soon. However, most farmers lack of mechanical equipment such as the fodder grinder due to fund constraints in their feeding process. That easily leads to a low degree of processing fed roughage, and further brings about a lower use efficiency of roughage. In addition, many farmers fed sheep according to their own experience but not scientific and reasonable. Cause meat sheep appear unbalanced nutrition or disease. Therefore, the lack of roughage processing technology and the arbitrary feeding ways are the main problems leading to input less flexibility and negative effect of roughage.

3.3. Determinants of Technical Efficiency

The consequence of technical inefficiency in meat sheep is presented in Table 5. In interpreting these results, it is important to remember that when the estimated values is statistically significant and negative, it means that variables have a significant positive impact on technical efficiency of

farmers' meat sheep production.

Table 5. Estimation results of technical efficiency loss model.

Variable	Parameter	Coefficients	Std.Error	t-ratio
Constant	δ_0	2.1856***	0.3680	5.9392
Age	δ_1	-0.0011	0.0036	-0.2974
Education degree	δ_2	-0.1024**	0.0414	-2.4759
Family size	δ_3	0.0502**	0.0215	2.3316
Village cadres	δ_4	-0.0419	0.0980	-0.4275
Years farming	δ_5	0.0016	0.0028	0.5535
Scale farming	δ_6	-0.0027***	0.0002	-11.4908
Pattern farming	δ_7	0.0616	0.0788	0.7825
Percent household income from meat sheep	δ_8	-0.0025*	0.0016	-1.5155
Training in farming techniques	δ_9	-0.1537**	0.0684	-2.2466
Cooperative or association	δ_{10}	-0.0624	0.0904	-0.6906
organization				
Borrowed money	δ_{11}	-0.0262	0.0738	-0.3559
Government policies support	δ_{12}	-0.1345*	0.0886	-1.5191

Note: ***, ** and * are significant at 1%, 5% and 10% levels, respectively.

Source: Authors own estimation with Froniter4.1.

Firstly, education degree, family size, scales farming, percent household income from meat sheep, whether received training in farming techniques and whether received government support is significant related to technical efficiency. However, only scale farming affects the technical efficiency at significant 1% level, education degree, family size and whether received training in farming techniques affect at significant 5% level, otherwise, percent household income from meat sheep and whether received government support affect at significant 10% level.

Secondly, education degree, scale farming, percent household income from meat sheep, whether received training in farming techniques and whether received government support are positive and significantly related to technical efficiency. Whereas, family size has a significant and negatively impact on the technical efficiency, but the impact is minimal.

Generally speaking, the higher level received education, the better to understand and use learning farming techniques. Education enhances farmer's ability to derive, decode and evaluate useful information as well as improving labor quality (Adedeji, 2013). Education also plays a positive role on their surroundings with technical guidance and diffusion, as well as increases efficiency of meat sheep production areas. However, generally longer labor input time, coupled with homogenization process and low technology may exaggerate labor input, lead to family size has a significant negative impact on the technical efficiency of meat sheep production. Besides, although both age of the household head and whether as village cadres or not have a positive impact on their technical efficiency, it's not significant. Because the overwhelming majority of our samples are elderly and primary level education, even as village cadres, they breed meat sheep almost depending on their own experience

instead of professional knowledge and scientific skills.

Scale economy showed obviously in meat sheep production. To some extent, the larger scale of meat sheep production, the more technical efficiency. Usually, large scale farmers are supposed to be more educated, risk takers, to have greater accessibility to credit and to adopt agricultural technologies more than small scale farmers (Adedeji, 2013). Years farming and pattern farming are not significant, possibly because farmers usually adopt the traditional way to breed sheep. The overwhelming majority of sheep farming area is located pastoral counties or semi-pastoral counties, belong to the relatively backward areas of economic development, where many farmers' income mainly or entirely comes from farming. Accordingly, farmers substantially devote their whole energy to meat sheep production, which will be undoubtedly conducive to improving the technical efficiency.

Whether a farmer received training in farming techniques and whether received government support have significant and positively impact on the technical efficiency. On the one hand, farmers could better grasp the relevant farming technology and improve their available management approaches to raise technical efficiency by participating in the farming techniques trains. On the other hand, Chinese government pay more and more attention to the development of meat sheep industry, and formulate a series of support policies to take the merit of meat sheep industry recently years. It is definitely conducive to promote farmers improving their rearing conditions and environment, thus improving the technical efficiency of meat sheep production.

The results suggest that neither a farmer being part of a cooperative (or associations) or the use of debt finance are determines production efficiency. For one thing, the majority of professional meat sheep farming cooperatives development lag behind, irregular operation and nominal, basically had not provided substantive services to members, and its advantage not reflected. For another thing, under the loan conditions and amount restrictions of formal financial institutions, most farmers borrowed a small quantity of funds from their relatives or friends, so it played a limited effect on the process of farmers' meat sheep breeding.

4. The Conclusions and Deficiency

The results of our analysis show that technical efficiency of farmers' meat sheep production range from 9.32% to 97.51% with a mean of 34.37%. Our results suggest that there exists significant loss efficiency and substantial opportunities to increase productivity and income of table meat sheep producers in China. The average output elasticity of concentrate feeding amount (X_1), labor input (X_3) and other material costs (X_4) are 0.4848, 0.3389 and 0.1792 respectively. However, the output elasticity of roughage feeding amount (X_2) is negative. This is because the Chinese meat sheep farming way is more traditional currently, most farmers have taking herding way, merely

proper feed to sheep with some hay, straw, silage, yellow storage and so on. Education degree of householder, scale farming, percent household income from meat sheep, whether received training in farming techniques and whether received government support have a positive impact on the improvement of technical efficiency. However, family size has a significant and negatively impact on the technical efficiency, but the impact is minimal.

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