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Abstract: This paper attempts to estimate the technical efficiency of grape producers using stochastic frontier analysis (SFA) approach as well as survey data of 1388 farmers in Hebei, Liaoning, Shandong and Xinjiang Province in China, and clarify the relationship between technical efficiency and traceability information transfer. The results show that technical efficiency of grape producers ranges from 0.8 to 0.9 with a stable but low distribution; input of land and physical makes a great contribution to the increase of rural income which is followed by input of labor and agricultural machine; the level of technical efficiency has a significant impact on the traceability information transfer in the way that the higher the technical efficiency is, the higher the willingness for participants to transfer the traceability information will be. Therefore, the technical efficiency of grape producers should be increased to establish the grape traceable system, ensure the safety of grape products and improve the development of grape industry.

Keywords: Grape, Technical efficiency, Stochastic frontier analysis, Traceability information, Information transfer

1Introduction

With the development of China economy and people living standard, the consumption and demand of vegetables and fruits are increasing rapidly, which, according to the data of population and consumption of urban and rural residents in China Statistical Yearbook, has been increased by 33.11% in the past decade from 2003 to 2012. As a result, the consumption and demand of grape and its products are increased rapidly. This leads to a fast development of grape industry and, given its high benefit, grape industry become an important part of the rural economy economy[1]. Meanwhile, consumers pay more and more attention to the issue of food safety which makes the valid transfer of grape traceability information become an important guarantee of the healthy and stable development of grape industry. On the other hand, the valid transfer of traceability information can help participants achieve the improvement of supply chain performance, help consumers distinguish the high quality food from the low quality food and improve the quality and safety level of agricultural products to keep up with market demand and preferences[2]. The valid transfer, therefore, is important to the increase of rural income and the improvement of development of rural economy.

Nowadays, the grape traceability system in China is still imperfect, which means the willingness of all participants to transfer the traceability information is low and the cost of transfer this information is high. On the other hand, the productivity and efficiency of grape production are both low which leads to a depression of rural income with the increasing production cost. As a result, the cost of transfer traceability information becomes higher and higher and significantly decrease the willingness of all participants to share the traceability information. A better understand of the relationship between technical efficiency and traceability information transfer is important and meaningful to the clarification of the impact productivity and efficiency on the willingness to share traceability information and to solve problems behind the establishment of traceability system.

A large number of studies have been conducted on agricultural traceability system, in which the authors pay attention to three areas including government, enterprises and consumers. The studies on government were devoted to the effect of government behaviors on the establishment of traceability system[3] and on the willingness of enterprises and consumers[4]; researches on the enterprises pay attention to the impact of traceability system on the clarification of responsibility and increasing of profit[5]; studies on consumers pay much attention to the recognition issues[6]. There are, however, few literatures on traceability information transfer of grape supply chain and the specific studies about the relationship between grape production efficiency and willingness to share traceability information are not found to be reported. Therefore, this paper pays attention to the technical efficiency of grape producers and analyses the willingness of all participants to share the traceability information with different level of technical efficiency to improve the grape safety level, increase the profit of all participants and achieve an advance in the improvement of the healthy and stable development of grape industry.

2 Materials and methods

2.1 Data

The data used in this paper is mainly from a fieldwork conducted by our research team in Hebei, Liaoning, Shandong and Xinjiang Province in China, which are the major grape production areas[7]. 1388 farmers were interviewed through a face to face approach. The questionnaire mainly focuses on the physical input, input of agricultural mechanization and labors during the production of grape. Table 1 shows the distribution of samples we have interviewed.

Table 1. Distribution of sample

Province	Sample size	Samples account for total[%]
Hebei	376	27
Liaoning	338	24
Shandong	290	21
Xinjiang	384	28
Total	1388	100

According to the exist studies on the technical efficiency, this paper selects the physical input, input of agricultural mechanization and labors during the production of grape as the indicators for input. Given the fact that the variety, production and farm gate prices of grape are different in different areas, and farmers pay most attention to the economic outcomes[8], according to Liu Z., et al. (2000)[9], this paper select the sales revenue as the indicator of output. In order to distinguish the difference of areas, this paper regards the areas as dummy variables. Table 2 shows the statistical description of samples.

Table 2.statistical description of input and output indicators

Variables	Unit	Mean	Standard deviation	Minimum	Maximum
Sales revenue (y)	CNY/667m^2	9859.3	7821.55	1420	50000
Farm size (x_1)	667 m^2	15.76	34.09	0.7	350
Physical input (x_2)	CNY/667m^2	2508.43	2137.76	794	14170
Mechanical input (x_3)	CNY/667m^2	306.58	621.82	0	6050
Labor input (x_4)	CNY/667m^2	2989	1283.37	1456	6364

Some interesting observations can be found in Table2 are: Firstly, there is an obvious difference in the sales revenue in different regions, which may resulted from the different agricultural technology, level of management and production input. On the other hand, to a significant extent, the production, market and price risks taken by farmers has an impact on their outcomes; secondly, the labor input is high while the mechanical input is relatively low. This may result from the dependence of labor input in grape production and the absence of mechanical utilization which implies the low level of mechanization; thirdly, there is a diversity of the scale of grape production ranging from 233335m^2 to 467 m^2 with an average farm size of 10507 m^2.

2.2Estimation of technical efficiency

The Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA) are the most popular ways used by many recent researches to evaluate the technical efficiency. When there are multi-input and multi-output with no specific formulation, the DEA approach is more useful than SFA approach in the estimation of technical efficiency. The advantages of DEA approach are its objectivity and diversity, while the conduction of a statistical test and exclusion of the impact of statistical errors seem to be impossible. On the contrary, the SFA approach can clarify and estimate the impact of stochastic and statistical errors on the production frontier as well as the effect of technical inefficiency on the real production. On the other hand, a SFA approach also can evaluate and find out the critical factors impacting on productivity and efficiency. Taking all these advantages of SFA approach into consideration, this paper choose SFA model to analyze the productivity and efficiency of grape production in China, the basic formula of our model is following:

$$y_i = \beta x_i + v_i - u_i$$

$i = 1,2,\cdots,I$is the number of farmers,$y_i$presents the output of grape production, $x_i$is the input during the production of grape, β is theestimated parameters, $v_i - u_i$ denotes the combined errors, v_i is the stochastic errors, $u_i$presents the technical inefficiency, bothv_i and u_i are independent identically distributed, and $v_i \sim N(0, \sigma_v^2)$, $u_i \sim N(\alpha_i, \sigma_u^2)$.

According to Battese and Corra[10], we can let $\sigma^2 = \sigma_v^2 + \sigma_u^2$, $\gamma = \sigma_u^2/(\sigma_v^2 + \sigma_u^2)$ and estimate the production function and technical inefficiency function, then the parametersβ、δ、σ^2、γcan be evaluated as well as technical efficiency of each producer, σ^2presents combined variance, γ is the proportion of technical inefficiency account of combined errors. When $\gamma = 0$, stochastic errors make the greatest contribution to total errors and when $\gamma = 1$, technical inefficiency makes the greatest contribution to total errors.

The technical efficiency of each producer is calculated by the followed function:

$$TE_i = E(y_i|u_i, x_i)/E(y_i|u_i = 0, x_i)$$

$E(\cdot)$is the mathematical expect. When $TE_i = 1$, there is no technical inefficiency, while when $TE_i < 1$, there is technical inefficiency.

The formulations of SFA are often set as the types of Cobb-Douglas and trans-log production function. Considering the production lead time of grape is very long, the production of grape is dependenton the current and past input, and the relationship among all inputs is unknown. Hence, the trans-log production function form is chose as a basic formula to evaluate and calculate the technical efficiency of each producer. The model is as follows:

$$Lny_i = \beta_0 + \sum_{n=1}^{4}(\beta_n Lnx_{ni}) + \frac{1}{2}\sum_{n=1}^{4}\sum_{m=1}^{4}(\beta_{nm} Lnx_{ni} Lnx_{mi}) + \beta_5 d_1 + \beta_6 d_2 + \beta_7 d_3 + v_i - u_i$$

$y_i$is the sales revenue of farmers, $n, m = 1,2,3,4$presents the number of inputs, x_1 denotes farm size, x_2 denotes the physical costs, x_3 denotes the agricultural machine costs, x_4 denotes the labor costs, d_1, d_2, d_3 are dummy varieties, $d_1 = 1$ denotes Hebei, $d_2 = 1$ denotes Liaoning, $d_3 = 1$ denotes Shandong, $d_1 = d_2 = d_3 = 0$ denotes Xinjiang.

3Results and discussion

This paper estimates the production function by using Frontier 4.1 software; the results are showed in Table 3.

Table 3. Results of parameter estimation

Variable	Coefficient	T value	Variable	Coefficient	T value
Lnx_1	-0.3262**	-1.6823	Lnx_1Lnx_4	0.0099	0.4470
Lnx_2	0.2271*	1.3636	Lnx_2Lnx_3	-0.0624***	-3.9893
Lnx_3	0.2109***	2.3940	Lnx_2Lnx_4	-0.0002	-0.0093
Lnx_4	-0.0812	-0.4345	Lnx_3Lnx_4	0.0148*	1.3598
$(Lnx_1)^2$	0.0253	0.8742	(d_1)	0.0268	0.4301
$(Lnx_2)^2$	-0.0020	-0.5984	(d_2)	-0.0134	-0.1845
$(Lnx_3)^2$	-0.0287***	-4.2655	(d_3)	0.2233***	3.3574
$(Lnx_4)^2$	0.0264*	1.5947	Constant	8.2148***	19.7581
Lnx_1Lnx_2	0.0206*	1.4610	σ^2	0.7789***	7.5275
Lnx_1Lnx_3	-0.0267*	-1.3870	γ	0.6457***	12.8243
Log likelihood function			-730.2154		
LR test			102.3675***		
Total number of samples			1388		

According to the data showed in Table3, the model we selected works well, and the inefficiency γ is significant at 1% confidence level, which implies there is loss of technical efficiency in grape production. Most variables are successes to the test of significance and this implies the model we selected is appropriate and reasonable.

Figure1 shows the distribution of technical efficiency of grape producers. According to this figure, the current technical efficiency of grape producers is low and there is room and potential for improvement. On the other hand, most grape producers located in the interval of 0.8-0.9 in technical efficiency, and the distribution is relatively stable.

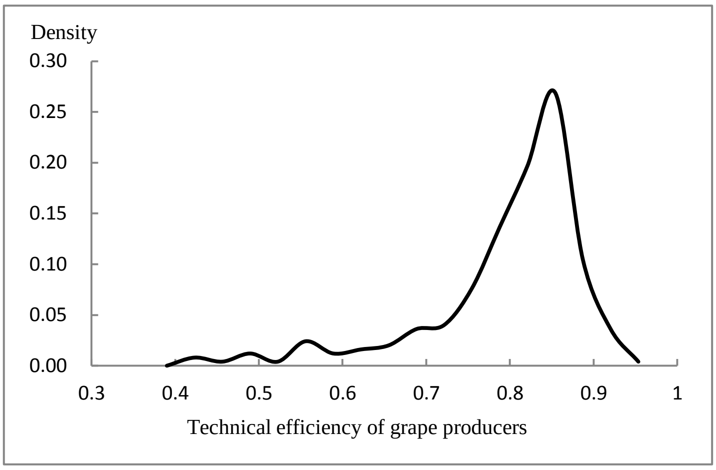

Fig 1. Distribution of technical efficiency of grape producers

Trans-log production function reflects the complex relationship among all inputs and coefficients are interpretable as elasticities of output evaluated at the sample mean. The formulation is as follow:

$$\frac{\partial Lny}{\partial Lnx_n} = \beta_n + 2\beta_{nn}Lnx_n + \sum_{m=1}^{4}\beta_{nm}Lnx_m$$

$n,m = 1,2,3,4$denotes the number of input, $(\partial Lny)/(\partial Lnx_n)$ denotes the elasticity of nth input, β_{nm} denotes the coefficient of the nth and mth input. Table 4 shows the elasticity of each input in grape production.

Table 4. Elasticity of each input

Variable	Land input	Physical input	Mechanical input	Labor input
Elasticity	0.2665	0.3439	0.1002	0.1622

According to table5, land input and physical input make a great contribution to the outcomes of grape producers while the contribution made by labor input is higher than that made by mechanical input, which implies that grape production is more dependent on the labor input.

4 Relationship between technical efficiency and traceability information transfer

A higher technical efficiency means that the outcomes of grape producers will be higher, that is to say, a higher sales revenue given the input series. There will be three dimensions that technical efficiency has impact on the transfer of traceability information: Firstly, a higher technical efficiency implies that grape production cost is lower and this will leads to a higher profit creation to conduct the share of traceability information; secondly, a higher technical efficiency means the output value of produced grape will be higher and famers will share the traceability information with much incentive to meet the demand and preference of consumers to expand the sales value of grape and increase their profit; thirdly, a higher technical efficiency means a lower cost of traceability information sharing, and encourage participants to share traceability information. All these conclusions can be analyzed through the model followed.

Table5 provides the name and main definitions of each variable.

Table 5. Name and definitions of variables

Variable	Definition	Variable	Definition
T	Technical efficiency	α	Constant of market demand curve
a	Volume of traceability information transfer	β	Price coefficient of market demand curve
c	Marginal cost of traceability information transfer	γ	Information transfer of market demand curve
q	market demand	P_H	Price of traceable grape
P_L	Price of non-traceable grape	C_P	Grape production cost
ε	Technical efficiency coefficient of traceability information transfer	C_I	Cost of traceability information sharing

According to Table 5, the cost for grape producers to share the traceability information can be defined as $C_I = ac - \varepsilon T$, and market demand for grape can be defined as $q = \alpha - \beta P + \gamma C_I$. Therefore, the sales revenue of grape producers can be defined as two types, one is with traceability information sharing:$\pi_1 = P_H q - C_p - \gamma(ac - \varepsilon T)$, the other is without traceability information sharing: $\pi_0 = P_L q - C_p$. According to the analysis above, a higher technical efficiency will leads to a decrease of production cost and the willingness to share traceability information will be relatively higher. When the technical efficiency is low, the fund that used to share the traceability information will be sequent low while the cost of traceability information transfer is also high. When consumers' willingness to pay for grapes with or without traceability information is a constant (that is to say, $P_L$and P_H are constants), this will result to relative lower outcomes when grape producers are sharing the traceability information than there is no traceability information sharing (that is to say, $\pi_1 < \pi_0$). On the contrary, when the technical efficiency of grape producers is high, the outcomes will be higher when they share traceability information. Therefore, the willingness of grape producers to share traceability information will be high.

5 Conclusions and implications

This paper estimates the technical efficiency of 1388 grape producers based on the field survey in Hebei, Liaoning, Shandong and Xinjiang Province in China in 2013 using stochastic frontier analysis (SFA) approach.And a further study on the relationship between technical efficiency and traceability information sharing is conducted. The results show that the technical efficiency of most grape producers are located at the interval of 0.8 to 0.9 and the distribution is stable but the level of technical efficiency is low, which implies that the increase of technical efficiency still could make a great contribution to the rural income; land and physical input makes a great contribution to the increase of rural income which is followed by labor input and mechanical input. This is the result of the over dependency of grape production on labor and the fact that the level of mechanization is still low; the level of technical efficiency has a significant impact on the willingness of participants to share traceability information, which will significantly increase their outcomes. Therefore, the technical efficiency of grape producers should be increased to establish the grape traceable system, ensure the safety of grape products and improve the development of grape industry.

Acknowledgments

This study was supported by China Agricultural Research System (CARS-30), Humanities and Social Sciences Foundation of Ministry of Education ofChina (13YJCZH182) and National Key Technology R&D Program of the Ministry of Science andTechnology (2014BAL07B05).

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