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Estimation of Technical Efficiency for Share Contract of Producing Gum Arabic: Kordofan Gum Arabic Belt, Sudan

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Abstract: The purpose of this study was to estimate the production technical efficiencies for share contract of producing gum arabic and to test whether sharecropping is an efficient mode of production in Kordofan gum arabic belt farming system. A paired sample of 40 gum producers who operate owned and shared orchards and represent different share contract arrangements was selected. The study utilizes stochastic frontier production functions to calculate technical efficiency scores. Land, gum trees capital services flow, family and hired labours and tapping intensities as inputs in frontier production function have significant effects on gum arabic yield. Moreover, the technical inefficiency effects that are assumed to be functions of age and education of mixed sharecroppers, amount of rainfall, soil type and different share contract arrangements were significantly affected the technical efficiency levels. Results revealed that 98% of the shared orchards of mixed sharecropping farmers have technical efficiency less than 50% while only 12.5% of owned orchards are less than this technical efficiency level. This recommends that the mixed sharecropping farmers are less efficient in allocating their input resources in shared than owned orchards.

Key words: *Acacia senegal*, mixed share farmer, production function, efficiency performance

INTRODUCTION

The enigma of share tenancy contract as an efficient economic institution has a long history in the literature. Early economists generally condemned sharecropping as an inefficient institution in that it did not provide incentives to the sharecropper, because producers had to share the output with the landlords (Marshall, 1956). Since, the work by Cheung (1969), which claimed that sharecropping to be as efficient as any other tenure system, there has been a plethora of theoretical and empirical work to show the efficiency of sharecropping. Those comparing plots under separate tenancy arrangements have tended to confirm Cheung's view (Dwivedi and Rudra, 1973; Nabi, 1986). Other studies using mixed sharecropping present evidence and arguments favouring the traditional hypothesis (Bell, 1977; Shaban, 1987; Acharya and Ekelund, 1998; Elkhidir *et al.*, 2000). Chew (1993, 1998) provided an analytical framework that could accommodate sharecropping in both the Marshallian and Cheungian forms. This, then, could be the theory required to reconcile both schools of thought in sharecropping.

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Gum arabic from Sudan is a non-timber product of *Acacia senegal* (gum hashab) and *Acacia seyal* (gum talha). Production of the gum arabic is concentrated in the gum belt between latitudes 10° and 14° North spanning 12 states with an estimated area of 520,000 km². The Hashab tree provides about 90% of the total gum arabic production in Sudan and the rest (10%) comes from Talh trees (*Acacia seyal* variety *seyal* and *Acacia seyal* variety *fistula*). Gum arabic from *Acacia senegal* (L.) Willd is a highly acknowledged natural product, which has drawn international attention. This is due to its comparative advantages over all other natural and synthetic gums, mainly because of its high solubility in water and low viscosity. Consequently, it has been put within the category of Acceptable Daily Intake (ADI) food additives. In Sudan, gum arabic is an important cash crop that contributes significantly to the income of farmers within the so-called gum arabic belt and to the economics of the country as a whole in terms of foreign exchange. The Sudan thus, produces about 60% of the total world production of gum arabic. Great Kordofan Region with its two states (South and North Kordofan) is the leading producer of high quality natural gum arabic. It contributes by an average of 12% to the gross domestic product of the country (Mahmoud, 2004). It also accounts for about 15.3 and 10% of the household income of gum producers and other farmers in the Sudanese gum belt respectively (Elamin and Balal, 1989). Uses of gum arabic fall in the three main categories; food, pharmaceutical as well as technical and miscellaneous (FAO, 1995; Chikamai, 1996).

Management of the *Acacia senegal* tree for gum production falls into either of two systems: hashab owner or hashab renter. Hashab owners are either small- or large-holder farmers. The former make up the majority of gum producers across the gum belt. They own small holding gum orchards which are part of the *A. senegal* rotation system and practise gum production in one of three ways: tap gum by themselves (most dominant form of production), hire labour to carry out the production operations and share crop production with the gum workers. Large-holder farmers include traditional hashab owners, sheiks, well-to-do families and mechanised scheme owners. They depend on hiring labour and on sharecropping for production. However, with farming changes from subsistence to market economy and the growth of agriculture entrepreneurship, a category of producers under this system have developed who may be labeled as production organizers or operators. Sharecropping is a more commercial type of production and requires larger gum plantations and financial credit support to labourers, until the gum reaches the buying merchants. The sharecropping arrangement is on 2/3:1/3 basis, whereby one-third of the produce goes to the owner or operator of the land (the organiser of production). The other two-thirds go to the workers who tap the trees and collect the gum. The agreement may include a Majool, which is a fixed amount of gum allocated from the first collection that goes to the hashab owner or operator, over and above his one-third of the produce (IIED and IES, 1990). An exception to the above arrangement is the sharing on a 50:50 basis of the produce. This applies when the hashab plantations are remotely located, or where the operator is not providing any food or water to the tenant producers. The first category of the sharecropping arrangement predominates in the Southern Kordofan State while the second category is the norm in the Northern and Western Kordofan States.

Success of obtaining maximum output by using the input composition in the most appropriate way is the technical efficiency, which allows one to compare between decision making units in terms of production maximization (Armagan, 2008). Hence, the main objective of this research work was to measure the technical inefficiencies of share tenancy contracts using non-neutral stochastic production frontier proposed by Huang and Liu (1994). The intuition behind the proposed formulation is that share tenancy contracts may affect output

differently causing a diversity in input productivities as well as in the marginal rates of technical substitution among gum arabic producers. Consequently, the effects of technical inefficiency on input productivity may be greater on some inputs than on others, implying that the estimated frontier could be more accurately modeled as a non-neutral shift of the traditional average production function. In addition, the present study used a formal statistical approach to test the difference of mean efficiency scores between the owned and shared gum orchards. This study is important in predicting the technical efficiencies for the average gum orchard household, but also in indicating the differences of the efficiencies between owned and shared gum orchards.

MATERIALS AND METHODS

Stochastic Frontier Production Model

Stochastic frontier production functions have been applied in a large number of empirical studies to account for the existence of technical efficiencies of production. Since, the basic stochastic frontier model was first proposed by Aigner *et al.* (1977), various other models have been suggested and applied in the analysis using both cross-sectional and panel data. Reviews of some of these models and their applications are found in Bauer (1990), Battese (1992), Bravo-Ureta and Pinheiro (1993) and Coelli (1995), to have a few. Some models have been proposed in which the technical inefficiency effects in the stochastic frontier models are also modelled in terms of other observable explanatory variables. Kumbhakar *et al.* (1991), Huang and Liu (1994), Battese and Coelli (1995) and Seyoum *et al.* (1998) present different models for the technical inefficiency effects.

This study takes these possibilities into account in the following model by employing a comparison between technical efficiencies of owned and shared gum orchards. The following stochastic frontier production model specification was used in the analysis:

$$\begin{aligned} \ln Y_i = & \beta_0 + \beta_1 \ln(\text{Land}_i) + \beta_2 \ln(\text{Capital}_i) + \beta_3 \ln(\text{Labour}_i) + \beta_4 (\text{HL}_i / \text{Labour}_i) \\ & + \beta_5 \ln(\text{Otherin}_i) + \beta_6 \ln(\text{Tapint}_i) + \varepsilon_i \end{aligned} \quad (1)$$

where, the subscript *i* refers to the *i*-th mixed sharecropping tenant's gum orchard (owned-operated as well as shared-operated); *Y* represents the quantity of gum collected (in kantar) per orchard; Land is the total area of land (in hectare) on which gum trees are grown per orchard; Capital is the total amount of gum trees capital services flow (kilograms) per orchard; Labour is the total amount of Labour (in man-days) by family members and hired labourers in the tapping and collecting of gum arabic per orchard; HL Represents the amount of hired labour (in man-days) used in the tapping and collecting of gum arabic per orchard; Other in is other inputs include the cost of food, drinking water, tapping tools and empty sacks (in US\$ per orchard); Tapint is the tapping intensity refers to the number of tapped branches and stem area of gum tree. It is measured in percentage per orchard and ε_i is a composite error term.

The composite error term consisting of two independent elements such that $\varepsilon = v-u$. The component *v* is a symmetric independent and identically distributed (normal random variable with mean, zero and variance, σ_v^2). It represents random variation in output due to factors not under sharecroppers control (e.g., weather, pests and diseases) as well as the effects of omitted explanatory variables, measurement errors and statistical noise. The component *u* is a non-negative error term representing the stochastic shortfall of gum orchards' output from the production frontier due to technical inefficiency. Thus, technical inefficiency is defined

in an output-expanding manner indicating the maximum amount by which output can be increased given the production technology and observed input usage.

The identification of the share contract performance requires knowledge of its impact on individual technical inefficiency. This can be done by adopting Huang and Liu's generalization of the stochastic frontier model. Specifically, the component u can be replaced by a linear function of sharecropping arrangements and gum orchard specific characteristics that presumably affect individual sharecroppers' performance. Specifically:

$$\mu_i = \delta_0 + \delta_1 \text{Age}_i + \delta_2 \text{Education}_i + \sum_{m=1}^M \delta_m D_m + \sum_{j=1}^J \delta_j E_j \quad (2)$$

$$i = 1, \dots, n, m = 1, \dots, 3 \text{ and } j = 1, \dots, 3.$$

where, Age is number of years of gum arabic farmer involved; Education is number of years of formal education of gum arabic farmer involved; D_m are dummy variables. D_1 refers to the amount and fluctuation of rainfall in a season, (1 = good, 0 = otherwise). Soil type is classified into three categories: sand, clay and gardud. Dummy variable D_2 is assigned to sand and D_3 to clay soil while the gardud soil is used as the control group; E_j are region dummy variables to reflect the different arrangements of share contracts that are expected to have a differential impact on frontier output on owned and shared orchards of mixed share farmers across the Kordofan gum arabic belt region: Western Kordofan (E_1), Northern Kordofan (E_2) and Southern Kordofan (E_3).

The model for the technical inefficiency effects, defined by Eq. 2, specifies that the technical inefficiency effects in the stochastic frontier (Eq. 1) are a function of the age and education of the mixed share gum arabic farmers. More years of formal education are expected to result in smaller technical inefficiency, whereas the older tenants are expected to have greater inefficiencies because they are less adaptable to new technological developments. Rainfall amount and fluctuation, soil type and the different arrangements of share contracts are also expected to have impact on technical inefficiency.

The maximum-likelihood estimates for all the parameters of the stochastic frontier and inefficiency model, defined by Eq. 1 and 2, are simultaneously obtained by using the program, FRONTIER Version 4.1 (Coelli, 1994), which estimates the variance parameters in terms of the parameterisation:

$$\sigma_s^2 = \sigma_v^2 + \sigma^2 \quad (3)$$

$$\gamma = \sigma^2 / \sigma_s^2 \quad (4)$$

where, the ratio-parameter γ has a value between 0 and 1. The closer the estimated value of γ to one, the higher the probability that technical inefficiency is significant in explaining output variability among sample participants.

The technical efficiency of the i th sharecropper in the appropriate data set, given the levels of his inputs, is defined by:

$$TE_i = \exp(-u_i) \quad (5)$$

The technical efficiency of a farmer is between 0 and 1 and is inversely related to the level of the technical inefficiency effect. The technical efficiencies can be predicted using the

FRONTIER program which calculates the maximum-likelihood estimator of the predictor for Eq. 5 that is based on its conditional expectation (Battese and Coelli, 1988). Wilcoxon signed rank test was used to test the hypothesis these predicted technical efficiencies are less than the moderate level (60%).

Sample Data

In order to facilitate a comparison of the technical efficiency and productivity of sharecropping as an efficient tenure system, a paired sample of 40 mixed share farmers of 02/2003 season was randomly selected. These farmers who represent Eastern (Abu gubeiha Locality), Northern (Sheikan Locality) and Western (Ennahud Locality) regions of Kordofan gum arabic belt were interviewed using prepared questionnaire to obtain gum arabic inputs and output data.

RESULTS AND DISCUSSION

The frequency distribution of the technical efficiencies for both types of gum arabic orchards are calculated and presented in Table 1. The picture that emerged from Table 1 shows a wide variation in the level of technical efficiencies across gum arabic orchards especially in the shared crop orchards. About 98% of the shared orchards of mixed sharecropping farmers have technical efficiency less than 50% while only 12.5% of owned orchards are less than this technical efficiency level. This suggests that the mixed sharecropping farmers are less efficient in allocating their input resources in shared than owned orchards. This finding agrees with Shaban’s (1987) work, where he showed that input use was significantly lower (19-55%) on shared land when compared to owned land.

However, 2.5% of the shared orchards appeared to be efficient to allocate their input resources with higher than 80% level of efficiency. The conclusion that can drawn from these results is that sharecropping can be efficient in certain environments and inefficient in others as documented elsewhere (Quibria and Rashid, 1986; Otsuka and Hayami, 1988). Therefore, supporting the view there cannot be just one single theory to explain sharecropping in so many diverse situations.

The maximum-likelihood estimates of the stochastic frontier and the parameters of the inefficiency model are reported in Table 2 for both owned and shared gum arabic orchards of the mixed sharecropping farmers. The estimated coefficients of the stochastic frontier model in Table 2 indicate that the cultivated land (ha) for both shared and owned gum arabic orchard showed positive values of 0.72 and 0.34, which were highly significant, respectively.

Table 1: Frequency distribution of technical efficiency for sampled mixed sharecropping gum arabic orchards

Efficiency interval	Frequency					
	Owned orchard			Shared orchard		
	No.	Percent	Cumulative %	No.	Percent	Cumulative %
Less than 0.10	0	0.00	0.00	4	10.00	10.00
0.10-0.20	1	2.50	2.50	18	45.00	55.00
0.20-0.30	3	7.50	10.00	10	25.00	80.00
0.30-0.40	0	0.00	10.00	6	15.00	95.00
0.40-0.50	1	2.50	12.50	1	2.50	97.50
0.50-0.60	1	2.50	15.00	0	0.00	97.50
0.60-0.70	3	7.50	22.50	0	0.00	97.50
0.70-0.80	7	17.50	40.00	0	0.00	97.50
0.80-0.90	18	45.00	85.50	1	2.50	100.00
0.90-1.00	6	15.00	100.00	0	0.00	100.00
Total	40	100.00		40	100.00	

Table 2: Maximum-likelihood estimates for parameters of the stochastic frontier model for gum arabic mixed sharecropping tenants

Variable	Parameter	Mixed Sharecropping Orchard ^a	
		Owned orchard	Shared orchard
Constant	β_0	-0.00 (1.66)	-1.59 (2.63)
Ln (Land)	β_1	0.72 (0.10)**	0.34 (0.14)**
Ln (Capital services flow)	β_2	0.70 (0.28)**	1.18 (0.42)**
Ln (Labour)	β_3	-0.13 (0.08)*	0.23 (0.10)**
HL/Labour	β_4	0.76 (0.25)**	-0.09 (0.28)
Ln (Otherin)	β_5	-0.02 (0.04)	0.13 (0.11)
Ln (Tapint)	β_6	0.20 (0.19)	0.45 (0.34)***

The estimated standard errors of the coefficients are given in parentheses. Significant levels: *p<0.05, **p<0.01 and ***p<0.001.

Table 3: Maximum-likelihood estimates for parameters of the inefficiency model for gum arabic mixed sharecropping tenants

Variable	Parameter	Mixed Sharecropping Orchard ^a	
		Owned orchard	Shared orchard
Constant	δ_0	-3.76 (3.52)	-1.64 (0.85)*
Age	δ_1	1.21 (0.63)***	0.35 (0.18)*
Education level	δ_2	-4.84 (0.23)***	-0.54 (0.34)***
Rainfall and fluctuation	δ_3	-0.64 (0.02)***	-0.59 (0.35)***
Sand soil	δ_4	-0.01 (1.02)	-0.00 (0.01)
Clay soil	δ_5	-0.33 (0.24)***	-0.04 (0.02)*
Western Kordofan region	δ_6	0.99 (1.19)	-0.70 (0.54)***
Northern Kordofan region	δ_7	-2.22 (1.76)*	0.34 (0.55)
Southern Kordofan region	δ_8	-0.59 (1.23)	0.61 (0.61)
Variance parameters:	σ^2	0.99 (0.49)*	0.19 (0.04)**
	γ	0.96 (0.03)**	1.00 (0.39)**
Ln (Likelihood)		-13.14	-23.04
Sample average technical efficiency		0.757	0.213

The estimated standard errors of the coefficients are given in parentheses. Significant levels: *p<0.05, **p<0.01 and ***p<0.001.

Therefore, increment of cultivated land by one percent will increase output by a larger proportion for owned operated gum orchard if compared to the shared one. This means that gum arabic belt land has specificity of use and it is occupationally immobile. Gum trees capital services flow coefficient is significant with superior elasticity (1.18) for shared orchards of mixed sharecropping gum arabic orchards.

The estimated labour coefficient for owned orchard is significant and negatively affected the gum yield. However, the elasticity of labour for shared orchard (0.23) is highly significant. The inelastic labour input is an indication of underemployment and lack of labour. The coefficient for the proportion of hired labour to total labour for owned orchards is highly significant and positive, indicating that a higher ratio of hired labour is associated with higher levels of gum arabic output. However, it appears that this variable is highly elastic only in gum arabic owned orchards, which indicates that the mixed sharecropping farmers are operating in the zone increasing returns to scale of production. The tapping intensity coefficient is highly significant and positively resulted in more gum yield. This result could be attributed to the fact that the gum tree sharecropper tapped the whole tree branches and stem.

Table 3 presents the maximum-likelihood estimates of the inefficiency model. The estimated coefficients for age of the mixed share farmers are significant and positive for both owned and shared gum arabic orchards. Considering the owned orchard, the age of mixed share farmers has a highly significant impact, which indicates that younger mixed share

farmers are more technically efficient in gum production than the older farmers, irrespective of whether the farmers are tapping their owned and/or shared orchards. This finding agrees with Erhabor and Emokaro (2007) work, that the positive relationship between farmers age and technical efficiency confirms the view of experts that, learning-by-doing contributes little to the catch-up of inefficient farmers.

The coefficient of education level is significantly negative for mixed share farmers within the owned and shared gum arabic orchards, which indicates that farmers with more years of formal schooling tend to be technically less efficient. The coefficient of education for mixed share farmers cultivating shared orchards is lower compared to those who owned orchards. This result indicates that more years of education for shared orchard tenants do not increase their technical efficiency of gum arabic production.

The rainfall variable has a significantly negative effect. This result indicates that unfavorable changes in the amount and fluctuation of rainfall is more technically inefficient in gum production. The soil type is significantly add an impact on gum production. It is estimated to be negative on sandy and clay shared orchards, which indicates that the mixed share farmers monitored their shared orchards at a higher level of technical efficiency.

The coefficients of the different arrangements of share contract across the Kordofan gum arabic belt region are significantly affect the gum production. They are estimated to be negative on shared orchards for Western and owned ones for Northern Kordofan regions. These results indicate that mixed share farmers who involved in lower different arrangements of sharecropping tend to be more technically efficient in their owned gum orchards.

The constant term, δ_0 , which assumed to capture the effect of gardud soil showed a significant negative coefficient, which means that mixed share farmers are technically more efficient in managing their shared orchards of gardud soil. This result could be referred to the fact that gardud soils are not attractive for cultivation because of their hard structure and they support less vegetations than the sandy and clay soils.

The γ -parameter (defined by $\gamma = \sigma^2/\sigma^2$, where $\sigma^2_s + \sigma^2$) associated with the variance of the technical inefficiency effects in the stochastic frontiers are estimated to be close to unity for owned orchards and equal to unity for shared orchards. These results indicate that the technical inefficiency effects are a significant component of the total variability of gum arabic outputs for both types of orchards and that the traditional production function, with no technical effects, is not an adequate representation of the data.

The technical efficiencies of the sample gum arabic mixed share farmers are less than one. The predicted technical efficiencies for the farmers who owned gum arabic orchards ranged from 0.173 to 0.948 (Table 1), with the mean technical efficiency estimated to be 0.757. For farmers cultivating shared orchards, the technical efficiencies ranged from 0.009 to 0.998, with the mean estimated to be 0.213 (Table 3). These estimates indicate that, on average, mixed share farmers with owned gum arabic orchards have higher technical efficiency than those with shared orchards.

Based on Wilcoxon signed rank test, the null hypothesis that the efficiency scores of the owned and shared gum orchards are significantly less than the moderate (60%) efficiency level is tested as shown in Table 4. The Wilcoxon test statistics of 667 and 2 are the number of Walsh averages exceeding 60% for owned and shared orchards, respectively. There is insufficient evidence to reject the hypothesis that the population median of shared orchards was greater than 60% of efficiency level because the p-value of the test is not less than $\alpha = 0.05$. This finding is agreed with the Marshallian approach of sharecropping in that it does not provide an incentive for gum arabic producers.

Table 4: Wilcoxon signed rank test for technical efficiency scores

Gum orchard	N	N for test	Wilcoxon statistic	P-value	Estimated median
Owned	40	40	667.00	0.000	0.81
Shared	40	40	2.00	1.000	0.19

CONCLUSION

This research showed that a stochastic frontier production approach could be a useful tool for understanding the mixed sharecropping tenure system as a choice of contracts for gum arabic producers. It indicates the potential of the model in production frontier analyses and points to the need for collection of data on relevant variables for the explanation of levels of technical inefficiency effects, in addition to traditional input-output data.

In general, mixed sharecropping farmers cultivating shared orchards are less efficient to optimally allocate their input resources compared to those owned orchards. The results provide additional empirical evidence to the traditional hypothesis that sharecropping is an inefficient type of tenure contract.

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