Effects of land tenure systems on resource-use productivity and efficiency in Ghana's rice industry

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Abstract

This study examines the effects of land tenure systems on resource-use productivity and efficiency in the Upper East region of Ghana with data drawn from the Ghana Agricultural Production Survey. A stochastic frontier model is employed to analyse resource-use productivity and efficiency of the rice farms. The study establishes that rice farms under the various land tenure systems are technically inefficient. Technical efficiency for the pooled sample was 61.80%. The estimated technical efficiencies for the farms under owned, rented and sharecropping were 68.19%, 61.61% and 45.17% respectively. The rice production frontier is influenced by farm size, fertiliser, seed and labour. Furthermore, owned land and fixed rent reduce the inefficiency of rice production. Other factors, such as dibbling and credit access, increase inefficiency, while marital status, extension contact and broadcasting decrease inefficiency in rice production. The study suggests that the formulation of appropriate land policies should gear towards ensuring secure rights to farmlands.

Key words: efficiency; Ghana; land tenure; productivity; resource use

1. Introduction

Efficient land tenure systems confer entitlements and rights to the use of land, including other natural resources, in developing countries like Ghana. It has been observed that in countries and societies where land tenure systems did not evolve properly to accommodate changes in agriculture, industry and services, the growth and development of such economies have stagnated (Bugri 2008; Ubink & Quan 2008). In the northern part of Ghana, chiefs are the custodians of the land and individuals do not own land (Tonah 2002). Farmlands are transferred from chiefs to family heads, who in turn distribute the land among family members in the households. A given parcel of farmland apportioned to a family is shared among the family members from one generation to another. Parents divide their portion of farmland among their children. Therefore, as family size increases, the land received by the family members tends to become smaller. This compels family members to engage in all forms of tenurial arrangements. Due to the insecure nature of the tenurial systems, farmers are not motivated enough to invest intensively in these lands, especially regarding long-term land-improvement measures. There also is a high probability of losing their farmlands because most of the farmers are not the real owners of the land. These tenurial problems are also associated with the acquisition of land for rice production in Ghana. Therefore, the inability of rice farmers to produce optimal output despite high climatic potential for rice production in the northern part of Ghana may be due to the nature of the land tenure system in the area.

Empirical evidence shows that rice producers in Ghana are not getting maximum returns from the resources committed to their enterprises (Seidu 2008; Donkoh *et al*. 2013). The current national average rice yield is estimated to be 2.71 mt/ha (SRID 2013). However, comparing Ghana's rice yield with that of other countries, such as Egypt (9.8 mt/ha), the USA (7 mt/ha), Japan and Vietnam (4 mt/ha), Senegal (4.10 mt/ha), Benin (4.07 mt/ha) and Mali (3.36 mt/ha), it is obvious that the performance of Ghana's rice industry is relatively poor (Donkoh & Awuni 2011; Oladele *et al*. 2011). In 2009, rice producers were able to produce only 2.4 mt/ha out of a climatic potential yield of 6.5 mt/ha. Farmers were able to increase the yield from 2.4 mt/ha in 2009 to only 2.73 mt/ha in 2010. The yield declined from 2.73 mt/ha in 2010 to 2.71 mt/ha in 2011 and 2012 (SRID 2013). These productivity levels indicate that, in the year 2009, Ghanaian rice producers achieved only 37% of the maximum achievable yield of 6.5 mt/ha, with the years between 2010 and 2012 witnessing yields of approximately 42% of the climatic potential yield.

The poor performance of the agricultural sector in Ghana has been attributed to the insecure nature of the communal land tenure systems in Ghana (Kasanga & Kotey 2001; Kandine *et al*. 2008; Abdulai *et al*. 2011; Nyasulu & Ampadu 2011; Oladele *et al*. 2011). This is because land rights insecurity impedes investment in both the rural and urban areas of West Africa, particularly in Ghana, and this contributes to slow economic growth and development in these areas (Kandine *et al*. 2008; Dlamini & Masuku 2011; USAID 2011). The issue of access to land in Ghana is critical due to its role in achieving sustainable rural development and increasing technological change (IFAD 2008; Nyasulu & Ampadu 2011). It has been argued that farmers with secured tenure tend to invest in their lands, which promotes land productivity (Abdulai *et al*. 2011). Thus, secure tenure increases incentives to undertake productivity-enhancing land-related investments (IFAD 2008). Land tenure security results in higher levels of labour and management effort, which in turn encourage higher levels of investment in enhancing land fertility (IFAD 2008). The aforementioned low rice yield in Ghana therefore is likely to be due to the nature of the aforementioned land tenurial systems in the rice belt in Ghana. This raises the following issues: What are the effects of the land tenure systems in the rice belt in Ghana on resource-use productivity and efficiency in Ghana's rice industry? What are the effects of other socioeconomic characteristics of rice producers on resource-use efficiency in Ghana's rice industry? These are the issues that will be addressed in this paper.

A couple of studies have been done on the efficiency of Ghana's rice industry. Some of the studies directed their attention towards the adoption of improved rice varieties (see Donkoh & Awuni 2011; Oladele *et al*. 2011; Wiredu *et al*. 2011), whilst others focused on technical efficiency (see Seidu 2008; Donkoh *et al*. 2013). For instance, Wiredu *et al*. (2011) examined the impact of improved rice varieties on rice yield. The study did not include land tenure variables in the analysis, despite the critical role land plays in rice production. Donkoh and Awuni (2011) observed a negative correlation between the adoption of improved farm techniques and land ownership, but their study did not provide any empirical evidence on the effects of land tenure on rice yield and efficiency. Oladele *et al*. (2011) analysed the relationship between land tenure, investment and the adoption of Sawah rice production technology. The study employed a qualitative approach and failed to outline the direction and magnitude of the effect of land tenure on investment in rice production. The other studies on the technical efficiency of rice farms (Seidu 2008; Donkoh *et al*. 2013) did not provide any comprehensive empirical evidence of land tenure effects on the efficiency of rice production in Ghana. As a result, there is scanty information on the effects of land tenure systems on resource-use productivity and efficiency in Ghana's rice industry. The present study, which analyses the effects of land tenure systems on the resource-use productivity and efficiency of rice farms in Ghana, therefore contributes to this knowledge.

The present study employs stochastic frontier analysis to examine the effects of land tenure systems on the resource-use productivity and efficiency of rice farms in Ghana. A single-stage procedure is used, in which the parameters of the production function are estimated simultaneously with that of an inefficiency model, in which inefficiency effects are specified as a function of variables such as land tenure systems and other socioeconomic characteristics of rice producers. The present paper observes, inter alia, that land tenure systems tend to influence resource-use productivity and efficiency of rice farms in Ghana. The directions and magnitudes of the effects of land tenure systems on the resource-use productivity and efficiency of rice farms constitute key empirical findings of the present study; likewise the corresponding effects of other socioeconomic characteristics of rice producers.

The paper is structured into four sections. The second section presents the methodology employed to address the research questions. The third section presents the key empirical findings of the study. Conclusions and policy recommendations are outlined in the last section.

2. Methodology

2.1 The stochastic frontier

The production frontier has undergone a substantial development in recent years. The earliest works on production frontiers, developed by Farrell (1957), Farrell and Fieldhouse (1962) and Afriat (1972), assumed these to be deterministic (Schmidt & Lovell 1978). Deterministic frontiers attribute all deviations from the frontiers to inefficiency. Aigner and Chu (1968) and Seitz (1971) argued that the parameters of deterministic frontiers were estimated with a mathematical programming technique (which is non-statistical). Seitz (1971) also indicated that the one-sided disturbance term of the deterministic frontier explicitly assumes some particular form that violates the regularity of conditions for the application of maximum likelihood. Therefore, the estimation of deterministic frontiers is not completely straightforward. This issue motivated Timmer (1971) to develop a probabilistic frontier. However, since a probabilistic frontier is a deterministic frontier computed from a subset of the original sample using a mathematical programming technique, it remains non-statistical, which makes hypothesis-testing impossible. Aigner *et al*. (1977) and Meeusen and Van den Broeck (1977) attempted to address the problems associated with deterministic and probabilistic production frontiers by introducing a stochastic production frontier. The stochastic production frontier decomposes the disturbance term into measurement error and inefficiency effect. The parameters in the stochastic frontiers are estimated with the maximum likelihood approach.

The present study adopts the stochastic frontier approach developed by Aigner *et al*. (1977) and Meeusen and Van den Broeck (1977). The production frontier of the rice farms can be modelled with a general stochastic frontier model:

$$R_i = f(x_{ij};\beta)e^{(\phi_i-\eta_i)}\ ,\ u_i=\phi_i-\eta_i \text{ and } i=1,2,3,...,N\ ;\quad j=1,2,...,J \qquad (1)$$

where R_i denotes the output of the i[th] farm, $x_{ij}\ (i=1,2,...,N; j=1,2,...,J)$ represents a (1 x K) vector of inputs, and β is (K x 1) vector of the unknown parameters to be estimated. Equation (1) is a nonlinear function that is linearised (1) by taking the natural logarithm of both sides and manipulating the relevant terms to give (2), which is a Cobb-Douglas production frontier.

$$\ln R_i = \alpha + \sum_{j=1}^{J}\beta_j \ln x_{ij} + \phi_i - \eta_i, \quad u_i = \phi_i - \eta_i \qquad (2)$$

where ϕ_i is the systematic random error that accounts for measurement error and other factors that are not under the control of the farm household, and η_i denotes the asymmetric non-negative random error component that measures technical inefficiency effects. The systematic random error variable ϕ_i is assumed to be independently and identically distributed with zero mean and variance σ_ϕ^2 (Coelli 1995). The non-negative variable, η_i, is assumed to be independently and identically distributed truncations (at zero from below) of the $N(\mu, \sigma_\eta^2)$ distribution (Coelli 1995). Moreover, ϕ_i and η_i are assumed to be independent of each other and also independent of the input, x_{ij}. The variance parameters of the model are parameterised as in (3):

$$\sigma^2 = \sigma_\phi^2 + \sigma_\eta^2, \quad \gamma = \sigma_\eta^2 / \sigma_u^2 \text{ and } 0 \le \gamma \le 1 \tag{3}$$

The technical efficiency of a farm, denoted by TE_i, can be estimated as:

$$TE_i = \frac{R_i}{R_i^*} = \frac{f(x_i;\beta)e^{(\phi_i - \eta_i)}}{f(x_i;\beta)e^{(\phi_i)}} = e^{-\eta_i} \text{ (so that } 0 \le \gamma \le 1) \tag{4}$$

2.2 Statements of hypotheses

The following hypotheses were formulated:

1. $H_0 : \beta_1 = ... = \beta_5 = 0$: The study expected that factors of production, such as fertiliser, seed, pesticides, labour and farm size, have no joint effect on rice output.
2. Absence of inefficiency (η = 0): The study hypothesised that there is an absence of technical inefficiency in rice production and that all deviations are due to statistical noise.
3. $H_0 : TE_{own} - TE_{rent} = 0$: The study proposed that there is no significant difference between the mean technical efficiencies of owner-operated farms and rent-tenants.
4. $H_0 : TE_{own} - TE_{share} = 0$: The study also postulated that there is no significant difference between the mean technical efficiencies of owner-operated farms and sharecrop-tenants.
5. $H_0 : TE_{rent} - TE_{share} = 0$: The study hypothesised that there is no significant difference between the mean technical efficiencies of rent-tenants and sharecrop-tenants.

2.3 Empirical specification of the stochastic Cobb-Douglas model

The study assumed that the stochastic frontier assumes a Cobb-Douglas form and that it is specified as:

$$\ln R_i = \beta_0 + \beta_1 \ln S_i + \beta_2 \ln F_i + \beta_3 \ln Lab_i + \beta_4 \ln P_i + \beta_5 \ln Fz_i + \phi_i - \eta_i \tag{5}$$

where R_i denotes rice output (kg) and ln denotes natural logarithm. S_i denotes quantity of seed planted (kg), F_i represents fertiliser (kg), Lab_i equals labour (man-days), P_i denotes amount of money spent on pesticides (Ghana Cedis) and Fz_i denotes farm size (hectares). β_0 denotes the constant term, $\beta_1, ..., \beta_5$ denote coefficients of the factor inputs, ϕ_i denotes measurement error, and η_i denotes the technical inefficiency term. The determinants of technical inefficiency can be modelled using equation (6):

$$\eta_i = \omega_0 + \omega_1 Lt_{1i} + \omega_2 Lt_{2i} + \omega_3 Ec_i + \omega_4 Dm_i + \omega_5 Ca_i + \omega_6 Ir_i + \omega_7 G_i + \omega_8 Age_i + \omega_9 Age_i^2 + \omega_{10} Edu_i + \omega_{11} Ms_i + \omega_{12} Kn_i + \omega_{13} Fe_i + \omega_{14} Hz_i + \omega_{15} Dl_i + \omega_{16} Br_i + \varepsilon_i \quad (6)$$

where η_i denotes the inefficiency term. Lt_{1i} denotes land ownership (1 if farmer owned the land and 0 otherwise), and Lt_{2i} denotes fixed-rent tenancy (1 if farmer rented the land and 0 otherwise). Sharecropping was used as a base category in the inefficiency model. Ec_i denotes extension contact (1 if farmer received extension service in 2011 and 0 otherwise), Dm_i denotes distance to market access (km), Ca_i denotes access to credit facility (1 if farmer had access to credit facility in 2011 and 0 otherwise), and Ir_i denotes access to irrigation facility (1 if farmer had access to irrigation facility and 0 otherwise). Age_i denotes age (years) and Age_i^2 denotes age squared (years). Edu_i denotes educational level (number of years of formal schooling), G_i denotes gender (1 if farmer is a male and 0 otherwise), Ms_i denotes marital status (1 if farmer was married and 0 otherwise), Kn_i denotes Kassena Nankana (if farmer came from Kassena Nankana and 0 otherwise), Fe_i denotes farming experience (years), Hz_i denotes household size, Dl_i denotes dibbling (1 if farmer used the dibbling planting technique and 0 otherwise), Br_i denotes broadcasting (1 if farmer broadcast his seeds and 0 otherwise), and row-planting was used as a base category. ω_0 denotes the constant term, $\omega_1, \omega_2, ..., \omega_{16}$ denote the coefficient terms, and ε_i denotes the error terms. Since the stochastic frontier model assumes that efficiency is independently identically distributed, Kumbhakar (1990), Huang and Liu (1994) and Coelli and Battese (1996) proposed that the parameters in the stochastic production frontier and the inefficiency model should be estimated simultaneously using a single procedure. Therefore, to obtain accurate estimates, the study estimated the parameters in equations 5 and 6 using the single-stage approach as proposed by the scholars. Stata 11 econometric software was used to run the models.

2.4 Sources of data and sampling procedure

The survey data was extracted from the Ghana Agricultural Production Survey (GAPS) conducted by the Ministry of Food and Agriculture (MoFA) in conjunction with the International Food Policy Research Institute (IFPRI) in 2011. The GAPS employed the multistage sampling technique to select the respondents. The dataset of rice farmers was extracted from the two districts in the Upper East region of Ghana, namely Bawku Municipal and Kassena Nankana East. The total sample size of 470 rice farmers was extracted from the dataset. This comprised 350 rice farmers from Kassena Nankana East and 120 from Bawku Municipal. The GAPS questionnaire and the dictionary of variables were employed. The survey questionnaire captured information on the socioeconomic characteristics of the respondents, such as age, gender, household size, education, extension contact, credit access, land tenure, distance to nearest market and farming experience. It also solicited information on technical factors such as labour, seed, fertiliser, pesticides and farm size. Information on rice output was captured by the survey questionnaire.

3. Results and discussion

3.1 Descriptive results

Table 1 shows the descriptive results of the socioeconomic characteristics of the rice producers. The majority (51%) of the rice farmers were males (Table 1), while 49% were females. Fifty-four percent (54%) were married and 46% were single (Table 1). The results indicate that most of the rice farmers were young, with a mean age of 34 years (Table 1). Most of them had spent an average of three (3) years in formal schooling (Table 1). The results show that most of the farmers had engaged in the cultivation of rice for about 6.71 years. The average household size was five (5) people (Table 1). The study observed that 62% had received no extension service with respect to their rice-farming operations (Table 1). Only 38% had benefited from extension services (Table 1). As demonstrated by the results in Table 1, only 3% of the rice farmers had accessed credit before, but the majority (97%) did not have access to agricultural finance. The mean distance to the nearest market was 7.8 km (Table 1). The results reveal that 91% of the rice farmers depended solely on rainfall for production, while 9% had water sources for irrigation. These water sources included dams or ponds, and rivers and streams.

The study identified three main land tenure arrangements operated by the rice farmers in the Kassena Nankana and Bawku districts. These were owned land, fixed-rent and shared titles. The study observed that 76% of the respondents farmed on their own farmlands. Twenty-one percent (21%) rented the farmland and only 3% operated on sharecropping (Table 1). In addition, the farmland owners had acquired their lands through the family, marriage and inheritance, or as a gift. Among these modes of land acquisition, the majority (70%) owned their farmlands through their family. This confirms that most of the land belonged to family (particularly the family head) (Table 1). Eighteen percent (18%) acquired their farmlands through marriage, implying that their spouses transferred those lands to them. This is very common with women. Four percent (4%) inherited the farmland from their family (Table 1). This happens when a man dies and his properties, including farmlands, are inherited by his next of kin. Others (8%) acquired the farmland as a gift (Table 1). Some people can hand out acreage of land to someone to show appreciation for a task done.

Table 1: Socioeconomic characteristics of the rice producers

Variable	Description	Owned land (N = 356)	Fixed-rent (N = 99)	Sharecropping (N = 15)	Total (N = 470)
Gender	1= male and 0 otherwise	0.50 (0.50)	0.55 (0.50)	0.53 (0.51)	0.51 (0.50)
Marital status	1 = married and 0 otherwise	0.48 (0.50)	0.43 (0.49)	0.60 (0.51)	0.48 (0.50)
Age	Years	34.14 (17.25)	31.28 (16.46)	35.73 (16.76)	33.59 (17.08)
Education	Years of formal schooling	2.65 (4.24)	2.80 (4.32)	3.00 (4.32)	2.70 (4.27)
Household size	Number of persons in household	5.35 (2.79)	5.59 (3.24)	5.80 (3.08)	5.41 (2.89)
Farming experience	Years of rice farming	6.85 (8.10)	5.52 (6.83)	11.53 (11.62)	6.72 (8.03)
Kassena Nankana	1 = Kassena Nankana and 0 otherwise	0.67 (0.47)	0.67 (0.47)	0.60 (0.5)	0.65 (0.48)
Extension contact	1 = extension access and 0 otherwise	0.43 (0.50)	0.43 (0.50)	0.47 (0.52)	0.44 (0.49)
Credit access	1 = credit access and 0 otherwise	0.15 (0.36)	0.08 (0.27)	0.13 (0.34)	0.13 (0.34)
Irrigation	1 = irrigation access and 0 otherwise	0.096 (0.29)	0.09 (0.29)		0.09 (0.29)
Market distance	Distance to nearest market in kilometres	7.69 (6.31)	7.86 (7.75)	10.00 (11.59)	7.80 (6.84)
Dibbling	1 = dibbling and 0 otherwise	0.21 (0.41)	0.20 (0.40)	0.20 (0.41)	0.21 (0.41)
Broadcasting	1 = broadcasting and otherwise	0.77 (0.42)	0.78 (0.41)	1.00 (0.00)	0.78 (0.42)
Fertiliser use	1 = fertiliser use and 0 otherwise	0.40 (0.49)	0.37 (0.49)	0.33 (0.49)	0.39 (0.49)

Pesticide use	1 = pesticide use and 0 otherwise	0.31 (0.46)	0.34 (0.48)	0.27 (0.46)	0.31 (0.46)

Source : Authors’ computation. Values in parentheses are standard deviations

3.2 Summary statistics of rice output and input use among land tenure operators

Table 2 presents the summary statistics of the rice output and the quantity of input employed the rice producers. The average output of paddy rice obtained by the farmers in the Kassena Nankana East and Bawku districts was 1 020.68 kg (Table 2). The survey revealed that farmers who operated on owned farmlands had the highest mean rice output of 1 424.03 kg and a yield of 853.50 kg/ha (Table 2). A possible reason could be that, when farmers are cropping on their own farmlands, they tend to invest in both short- and long-term land improvement measures because they are more likely to benefit in the long run. Farmers who rented their land obtained a mean rice output of 1 095.95 kg/ha and a yield of 786.25 kg/ha (Table 2). Rice farmers who operated under sharecropping had the least mean output, of 781.63 kg, and a yield of 636.50 kg/ha (Table 2). Those who rented and sharecropped were more likely to invest in short-term land improvement measures, since they would benefit in the short run. Tenants’ farmlands could be taken away from them after the contractual agreement had expired and they will not benefit from long-term investment in the land. Despite these possible reasons for the low yields, rent tenants may invest in inputs more than sharecroppers. This is because farmers who rent land have to make little effort to break even and pay for their rent charges. The average farm size of the pooled sample was 1.22 ha (Table 2). Farmers who owned their farmlands had a relatively larger farm size of 1.57 ha. This is followed by those who rented their farmlands (Table 2), who cultivated an average farm size of 1.46 ha. Farmers who operated on the sharecropping system had the smallest farm size of 1.02 ha (Table 2).

The average quantity of seed planted was 53.29 kg (Table 2). Farmers who owned farmlands recorded the highest planting density of 53.75 kg, followed by those who rented (52.12 kg). Those under sharecropping recorded the least seeding rate of 50.00 kg (Table 2). From the pooled sample, the rice producers spent on average ₵Gh 5.39 on pesticides (Table 2). Farmers who owned their farmlands spent ₵Gh 5.67 on pesticides. The average expenditure on pesticides was ₵Gh 4.67 for those who rented their farmlands. Sharecroppers spent the least amount on pesticides, which was ₵Gh 3.47 (Table 2). The expenditure on pesticides was relatively low, indicating a low application of pesticides on rice farms. The rice farmers applied an average fertiliser quantity of 119.46 kg (Table 2). Among the various land tenure operators, fixed-rent tenants applied the highest fertiliser quantity, of 135.92 kg, while owner-operated rice farms applied 116.64 kg (Table 2). Those under sharecropping applied the least quantity of fertiliser, at 66.55 kg. The average labour use of the rice farmers was 185.51 man-days. Farmers who owned their farmlands employed more labour on their farms, with an average labour use of 188.65 man-days (Table 2). This is followed by rent tenants, with a mean labour use of 177.55 man-days, which is quite significant in relation to that of the sharecroppers (163.65 man-days).

Table 2: Input use among the land tenure operators

Variable	Owned land (N = 356)	Fixed-rent (N = 99)	Sharecropping (N = 15)	Total sample (N = 470)
Rice output (kg)	1 424.03 (1 161.42)	1 095.95 (578.90)	781.63 (243.58)	1 020.68 (392.11)
Yield (kg/ha)	907.03 (915.98)	750.00 (573.17)	704.54 (785.74)	836.62 (828.34)
Labour productivity (kg/man-days)	3.37 (2.74)	2.57 (2.54)	2.072 (1.81)	2.57 (2.29)
Farm size (ha)	1.57 (1.22)	1.46 (1.01)	1.02 (0.31)	1.22 (1.01)
Seed (kg)	53.75 (12.93)	52.12 (9.93)	50.00 (2.72)	53.29 (12.16)
Fertiliser (kg)	116.64 (80.82)	135.92 (77.46)	66.55 (48.99)	119.46 (79.85)
Labour (man-days)	188.65 (101.54)	177.55 (89.17)	163.37 (74.44)	185.51 (98.32)
Pesticides (Cedis)	5.67 (26.47)	4.67 (12.36)	3.47 (6.65)	5.39 (23.75)

Source: Authors' computation. Values in parentheses are standard deviations.

3.3 Empirical results

3.3.1 Results of hypothesis testing

Table 3 presents the results of the hypothesis testing. The Wald chi-square statistic (391.97) was highly significant at 1%, which implies that the explanatory variables jointly influenced the rice output. It was hypothesised that the explanatory variables fitted into the inefficiency model had no joint effect on technical inefficiency. Furthermore, we rejected the null hypothesis that there is an absence of inefficiency in rice production. This demonstrates that a deviation from the frontier is not only due to statistical noise, but also inefficiency. The null hypothesis that the difference between the mean technical efficiency of farms operated under owned and rented land tenure systems was not significantly different from zero was rejected at the 1% level, indicating that there was a significant difference between the mean technical efficiency of rice farms under owned and rented tenures. Similarly, we rejected the null hypothesis that the difference between the mean technical efficiency of farms operated under owned and shared land tenure systems was not significantly different from zero. This implies that the average technical efficiency of owner-operated rice farms was significantly different from that of sharecropped farms. However, we failed to reject the null hypothesis that the average technical efficiency of rent-operated farms was not significantly different from that under sharecropping, which indicates that the technical efficiencies of farms under renting and sharecropping tenures were similar.

Table 3: Results of hypotheses testing

Null hypotheses	Statistic	Decision rule
1. Explanatory variables have no joint effect on rice output $H_0 : \beta_1 = ... = \beta_5 = 0$	Wald Chi-square 152.10*** (0.000)	Reject null hypothesis at 1%
2. No significant difference between technical efficiency of farms under owned and rented land tenure systems $H_0 : TE_{own} - TE_{rent} = 0$	t-statistic 15.45*** (0.000)	Reject null hypothesis at 1%
3. No significant difference between technical efficiency of farms under owned and sharecropped land tenure systems $H_0 : TE_{own} - TE_{share} = 0$	t-statistic 4.21*** (0.000)	Reject null hypothesis at 1%
4. No significant difference between technical efficiency of farms under rented and sharecropped land tenure systems $H_0 : TE_{rent} - TE_{share} = 0$	t-statistic 7.24** (0.000)	Reject null hypothesis at 1%
5. Absence of inefficiency $H_0: \eta = 0$	Chi-square 5.36*** (0.010)	Reject null hypothesis at 1%

Source : Authors' computation. ***, **, * denote statistical significance at the 1%, 5% and 10% level respectively.

3.3.2 Estimates of the Cobb-Douglas stochastic production frontier

The maximum likelihood estimates of the Cobb-Douglas stochastic frontier are presented in Table 4 together with the diagnostic statistics. The estimated gamma (0.755) and sigma-squared (0.841) values were significant at 1%, suggesting a good fit and correctness of the specified distribution assumption. The estimated gamma value (0.755) is close to unity and highly significant at the 1% level, which indicates that almost all variability in rice output is due to technical inefficiency effects. In other words, 75.50% of the variability is due to technical inefficiency, while 24.50% is due to measurement error (Table 4). The diagnostic results justify the need to employ the stochastic production frontier and maximum likelihood estimation approach in analysing the resource productivity of rice farms.

Quantity of seed sown had a positive effect on rice output and was significant at the 1% level. The coefficient of 0.867 implies that a proportionate increase in the quantity of seed sown would result in less than a proportionate increase in rice output. This implies that the quantity of seed planted is inelastic. The result agrees with a recent study by Donkoh *et al*. (2013), who observed that seed had a positive influence on rice output. Fertiliser was significant at the 1% level and negatively correlated with rice output. The coefficient of -0.128 indicates that a 1% increase in fertiliser would reduce the rice output by 0.128%. The reason for this negative effect is that most of the respondents did not apply fertiliser to their rice fields. Even though the government of Ghana subsidises fertiliser prices, farmers can still not afford the subsidised price. However, those who used fertiliser had inadequate knowledge of fertiliser application and therefore applied the fertiliser below the recommended rate. The various fertiliser types were also combined inappropriately and applied untimely, due to a delay in obtaining some of the subsidised fertiliser supplied by the government. Inappropriate combinations of mineral elements and untimely fertiliser application could be detrimental to the crops and this could reduce the rice output. This result is consistent with that of Aung (2011), who observed that fertiliser application had a negative effect on rice production in Myanmar. Nevertheless, the result is inconsistent with a previous study by Donkoh *et al*. (2013), who observed a positive association between rice output and fertiliser. Labour was significant at 1% and positively associated with rice output. A percentage increase in labour resulted in a 0.356% increase in rice output. The result is consistent with the findings of Donkoh *et al*. (2013). Farm size was significant at the 1% level and positively related to rice output. The study indicated that a percentage increase in farm size would increase rice output by 0.751%.

Table 4: The estimates of the Cobb-Douglas stochastic production frontier

Variable	Parameter	Coefficient	Standard error	z-statistic	P < |z|
Constant	β_0	3.149***	0.684	4.600	0.000
lnseed (kg)	β_1	0.867***	0.155	5.590	0.000
lnfertilizer (kg)	β_2	-0.128***	0.018	7.030	0.000
lnlabour (man-days)	β_3	0.356***	0.114	3.100	0.002
lnpesticides (Ghana Cedis)	β_4	0.003	0.041	0.080	0.934
lnfarm size (ha)	β_5	0.751***	0.149	5.050	0.000
Observation		470			
Log pseudo likelihood		-404.160			
Sigma squared	σ^2	0.841 ***	0.119	7.067	0.000
Gamma	γ	0.755***	0.120	6.320	0.000

Source: Authors' computation. ***, **, * denote statistical significance at the 1%, 5% and 10% level respectively.

3.3.3 Technical efficiency scores among land tenure operators

Table 5 presents the technical efficiency scores among the various land tenure operators. The lowest level of technical efficiency of the pooled sample was 18.23%, and the best-performing rice farm achieved a technical efficiency of 90.34% (Table 5). The mean technical efficiency for the pooled sampled farms was 61.80%, indicating that rice farmers in the Kassena Nankana and Bawku districts of Ghana produced below the frontier. The modal technical efficiency was 60% to 69%. The results in Table 5 show that owner-operated rice farms had the highest mean technical efficiency level of 68.19%. The modal technical efficiency ranged from 60% to 69% for owner-operated rice farms. This efficiency level is not significantly different from that of the pooled sample. Farms under fixed-rent had a mean technical efficiency of 61.61%, which is significantly different from owner-operated farms but not significantly different from sharecropping tenants, as demonstrated by the results in Table 5. Rice farms under the sharecropping arrangement had the least mean technical efficiency, of 45.17% (Table 5).

Table 5: Technical efficiency (TE) scores among the land tenure operators

TE score	Owned land (N = 356)	Fixed-rent (N = 99)	Sharecropping (N = 15)	Total sample (N = 470)
10-19	0	0	2 (13.33%)	2 (0.43%)
20-29	3 (0.90%)	5 (5.30%)	0	8 (1.70%)
30-39	6 (1.80%)	7 (7.40%)	0	13 (2.77%)
40-49	13 (3.60%)	10 (9.60%)	6 (40.00%)	29 (6.17%)
50-59	31 (8.60%)	14 (13.80%)	2 (13.33%)	47 (10.00%)
60-69	157 (44.10%)	31 (31.90%)	2 (13.33)	190 (40.43%)
70-79	113 (31.80%)	22 (22.30%)	1 (6.66%)	136 (28.94%)
80-89	31 (8.60%)	10 (9.60%)	2 (13.33%)	43 (9.15%)
90-99	2 (0.50%)	0	0	2 (0.43%)
Total	356	99	15	470
Mean	68.19	61.61	45.17	61.80
Maximum	90.34	87.75	83.64	90.34
Minimum	24.64	21.72	18.08	18.08
Standard deviation	15.31	16.33	15.76	15.31

Source: Authors' computation

It is important to note from the stochastic production frontier estimates that the respective returns to factors of production, particularly that of seed and farm size, were observed to be unusually high, resulting in higher returns to scale. To remedy this situation we divided the farms by size in terms of deciles and computed the efficiency scores to be able to show what size farms are more efficient. The results on this scale efficiency, as shown in Table 6, tend to provide a better indication of scale efficiency of rice production. For instance, the majority (45) of the rice producers who obtained the highest efficiency (90 to 99%) operated on a small scale (less than 1 ha), 21 cultivated 1 to 4 ha of rice, while only one person farmed a large rice field (4 to 8 ha). The results therefore generally indicate that small rice farms are more efficient than large farms. Large farms are difficult to be managed efficiently by less resourced farmers who use rudimentary practices, as rice production (particularly large farms) is capital intensive.

Table 6: Farm size and efficiency

TE scores	Farm size		
	Less than 1 ha	1-4 ha	4-8 ha
Less than 10	0	1	0
10-19	10	8	1
20-29	10	12	3
30-39	23	10	2
40-49	12	16	1
50-59	26	25	1
60-69	49	25	3
70-79	70	13	1
80-89	60	19	2
90-99	45	21	1

Authors' computation

3.3.4 The sources of technical inefficiency

Table 7 shows the maximum likelihood estimates of factors that influence inefficiency in rice production. The estimated level of technical efficiency among the rice producers is inadequate to derive recommendations for the policy intervention. It also is necessary to identify the sources of variation in the technical efficiency among the producers and to quantify their effects. This is possible by specifying an inefficiency model, the regressors of which are the exogenous factors related to the production unit. The determinants of the inefficiency in rice production are presented in Table 7.

Owned land had a negative influence on inefficiency and was significant at the 1% level. The results show that farmers who owned their rice fields were more technically efficient that those under sharecropping. Landowners are more likely to invest in short- and long-term productivity-enhancing measures that promote rice output because they will reap from the investment in the long run. The variable fixed-rent tenancy had the expected negative effect and was highly significant at the 1% level. This suggests that farmers who rented their farmlands were more efficient than sharecroppers. This result agrees with previous studies, which observed that farmers operating under fixed-rent tenancy were more likely to increase productivity than owner-operators (Iqbal *et al*. 2001; Pender *et al.* 2004; Kariuki *et al*. 2008; Tchale 2009; Oladele *et al*. 2011). This is because tenants who pay rent tend to use relatively more productive resources, which have the potential to increase productivity. This increases farm profit, which helps the tenants to pay land rent.

The variable extension contact was highly significant at the 1% level and negatively correlated with technical inefficiency. The result shows that farmers who had access to extension contact were more efficient than their counterparts. Seidu (2008) explains that farmers who have adequate contact with extension agents easily have access to modern agricultural technology on input use and disease control, which helps them to decrease inefficiency. The findings of this study are consistent with those of Seidu (2008), Stefan *et al*. (2011) and Tchale (2009), namely that extension contact promotes technical efficiency. The effect of credit access deviated from the a priori expectation of negative but significant at the 1% level. This implies that rice farmers who had access to credit tended to have higher technical inefficiency. The positive impact of credit access on technical inefficiency might be due to the fact that most of the rice farmers did not access credit. Those who sourced a credit facility might not have committed it to rice production but used it for other purposes, like paying school fees and other home expenses. This finding is consistent with that of Stefan *et al*. (2011), who observed that access to microfinance had a positive impact on technical inefficiency. The coefficient of Kassena (which is a location-specific variable) was found to be highly significant and negatively correlated with technical inefficiency. This shows that farmers in the Kassena Nankana district of Ghana were more efficient than those in Bawku district. The result shows that dibbling had a positive effect on inefficiency and was significant at the 10% level. A possible reason is that farmers might have little experience with this new technology. This result does not agree with the findings of Hoang and Mitsuyasu (2012), who observed that improved planting techniques, like row planting, increased profit efficiency and decreased production cost. The broadcasting technique had a negative effect on inefficiency and was significant at the 5% level. This suggests that farmers who broadcast their seed were more technically efficient than those who employed improved techniques such as dibbling and row planting.

Table 7: Determinants of inefficiency in rice production

Variable	Parameter	Coefficient	Standard error	z-statistic	P > |z|
Constant	ω_0	0.646	0.823	0.78	0.433
Owned land (Lt_1)	ω_1	-2.161	0.382***	-5.66	0.000
Fixed-rent (Lt_2)	ω_2	-0.748	0.309**	-2.42	0.016
Extension contact (Ec)	ω_3	-1.650	0.414***	-3.98	0.000
Market distance (Dm)	ω_4	-0.0000946	0.035	0.00	0.988
Credit access (Ca)	ω_5	0.737	0.392*	1.88	0.060
Irrigation (Ir)	ω_6	-0.306	0.418	-0.73	0.464
Gender (G)	ω_7	0.198	0.229	0.87	0.385
Age (Age)	ω_8	0.044	0.036	1.23	0.218
Age squared (Age^2)	ω_9	-0.000306	0.0004	-0.83	0.406
Education (Edu)	ω_{10}	-0.052	0.037	-1.41	0.158
Marital status (Ms)	ω_{11}	-0.098	0.340	-0.29	0.773
Kassena (Kn)	ω_{12}	-0.471	0.244*	-1.93	0.054
Farming experience (Fe)	ω_{13}	-0.016	0.024	-0.66	0.509
Household size (Hz)	ω_{14}	-0.062	0.057	-1.07	0.283
Dibbling (Dl)	ω_{15}	0.261	0.323	0.88	376
Broadcasting (Br)	ω_{16}	-0.790	0.323**	-2.44	0.015

Source : Authors' computation. ***, **, * denote 1%, 5% and 10% respectively.

4. Conclusion and policy recommendations

This study examined the effects of land tenure systems on the resource-use productivity and efficiency of rice farms in Ghana. The study concludes that rice farms under the various land tenure systems are technically inefficient. However, higher inefficiency is associated more with sharecropping than with other land tenure systems. Farm size, fertiliser, seed and labour tend to influence rice production. The quantity of seed planted had the greatest effect on rice output, followed by labour and fertiliser. The rice producers operated in stage one (which is the irrational or inefficient stage) of the production function. Furthermore, dibbling and credit access increased inefficiency, while marital status, extension contact and broadcasting reduced inefficiency in rice production. Fixed-rent tenancy and owned land decreased inefficiency. Based on the results we therefore can infer that owner-operated rice farms are more technically efficiency than fixed-rented and sharecropping farms. The technical efficiency of various land tenure operators was low, suggesting the presence of technical inefficiency. Therefore, there is a need for policy makers to formulate land policies to ensure secured tenancy of farmlands. Moreover, it is important to enhance farmers' access to extension services by recruiting enough extension agents and equipping them with physical infrastructure that facilitates their operations. Informal educational programmes such as farmer field schools should be established and promoted to enhance efficiency in rice production.

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