Effect of Urea Deep Placement Technology Adoption on the Production Frontier: Evidence from Irrigation Rice Farmers in the Northern Region of Ghana

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***Abstract*—**Rice is an important staple crop, with current demand higher than the domestic supply in Ghana. This has led to a high and unfavourable import bill. Therefore, recent policies and interventions in the agricultural sub-sector aim at promoting various improved agricultural technologies in order to improve domestic production and reduce the importation of rice. In this study, we examined the effect of the adoption of Urea Deep Placement (UDP) technology by rice farmers on the position of the production frontier. This involved 200 farmers selected through a multi stage sampling technique in the Northern region of Ghana. A Cobb-Douglas stochastic frontier model was fitted. The result showed that the adoption of UDP technology shifts the output frontier outward and also move the farmers closer to the frontier. Farmers were also operating under diminishing returns to scale which calls for redress. Other factors that significantly influenced rice production were farm size, labour, use of certified seeds and NPK fertilizer. Although there was an opportunity for improvement, the farmers were highly efficient (92%), compared to previous studies. Farmers' efficiency was improved through increased education, household size, experience, access to credit, and lack of extension service provision by MoFA. The study recommends the revision of Ghana's agricultural policy to include the UDP technology. Agricultural Extension officers of the Ministry of Food and Agriculture (MoFA) should be trained on the UDP technology to support IFDC's drive to improve adoption by rice farmers. Rice farmers are also encouraged to expand their farm lands, improve plant population, and also increase the usage of fertilizer to improve yields. Mechanisms through which credit can be made easily accessible and effectively utilised should be identified and promoted.

***Keywords*—**Efficiency, rice farmers, stochastic frontier, UDP technology.

I. Introduction

AGRICULTURE, has been the backbone of Ghana's economy in the entire post-independence history. Predominantly, crop production is on a small-scale, with about 90% of farm holdings being less than 2 hectares. The sector continues to contribute substantially to Ghana's GDP and employs about 42% of the total workforce [17], [23]. Like in the other parts, the majority of the farmers in Northern Ghana are peasants who depend heavily on rainfall for rice production. The northern part of Ghana is the main producer of cereals and livestock. About 70% of the country's cereals and grain legumes come from the northern part of the country [23].

Rice production in Ghana has increased significantly over the past decades. For instance, the Statistics, Research and Information Directorate (SRID) of MoFA [23] reported that the land area under the production of rice has increased from 123,000 hectares in 2002 to about 189,000 hectares in 2012. However, average yield per hectare is still 2.5mt/ha, as against the achievable yield of 6.5 MT/Ha in Ghana [23]. Until 2008, the total output of paddy rice for Ghana was below 300,000 MT. However, local production has increased from 391,000 MT in 2009 to 481,000 MT in 2012. The expansion in the production of rice is largely attributable to the expansion in the area under production. Favourable rainfall patterns, the national fertilizer subsidy programme and the block farm programme could also have accounted for the increase in the national rice output. Similar to the general production level, about 80% of the rice produced in Ghana is by smallholder farmers, mostly on farmlands less than one hectare in size [9].

Even though rice is produced in all the 10 regions of Ghana, the Northern, Upper East and Volta regions are mainly responsible for the majority of rice produced. In the three regions, average yield is around 2.96 MT/Ha. This exceeds the national average of 2.5 MT/Ha. The average yield for the Greater Accra Region of Ghana is 5.48 MT/Ha, an indication that the adoption of the right agricultural practices such as the UDP technology could enhance the output of rice farmers [9].

Technology and innovation are therefore central to improve domestic rice production in Ghana. Various research institutions and Non-Governmental Organisations are promoting various forms of technologies in the sector. The fertility of the soils for crop production has also declined, suggesting that production can only be supported with fertilization. One of such fertilizer requirement for improved output is urea. The UDP is therefore introduced to enhance urea usage. Although the adoption of this and other technologies are expected to improve production, this can be inconclusive without empirical research to ascertain the fact. Therefore, the objective of this study is to examine the effect of the UDP technology adoption on the technical efficiency among rice farmers in the northern region of Ghana.

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A. The UDP Technology

The International Fertilizer Development Centre (IFDC) developed the UDP technology while working with farmers for several years in Bangladesh [25]. The main goal of the UDP technology is to improve nitrogen use efficiency in rice production which is expected to improve the rice output. The UDP technology is made up of two key components. First, is a fertilizer 'briquette' produced by compacting prilled urea fertilizer that weighs about 1-3 grams per briquette. The second key component of the technology is the placement of the briquette below the soil surface at the root zone of the plant. The briquettes are centred among four rice plants at a spacing of 20cm x 20cm and at a depth of about 7cm and 10cm. It is applied within a week to two after transplanting the rice. Placement can be done either by hand or through a mechanical process. The briquette releases nitrogen slowly, meeting with the crop's requirements during the growing season [19]. Also, in this production process nitrogen fertilizer is required to be applied only once for the entire crop life unlike the conventional urea production process where 1-2 split applications are required mainly through broadcasting.

B. Hypotheses

The study is guided by two hypotheses:

- H_0: UDP technology adoption does not significantly shift the rice production frontier.
  H_1: UDP technology adoption significantly shifts the rice production frontier.
- H_0: UDP technology adoption does not significantly affect the efficiency of rice farmers.
  H_1: UDP technology adoption significantly affects the efficiency of rice farmers.

II. Materials and Methods

A. Study Areas

This study was conducted in the northern region of Ghana using farmers from two irrigation schemes – Golinga and Bontanga irrigation Schemes.

The Golinga Irrigation Project is a medium-scale gravity-fed scheme located at Golinga in the Tolon District of Ghana [22]. The project is fed by the Kornin River. The scheme has a potential of 100 hectares, of which, 40 hectares is currently cropped. Vegetables are produced only in the dry season from October to April while rice is produced both in the dry and wet seasons. Five communities (Golinga, Gbulahigu, Tunaayili, Galinkpegu and Naha) share the Golinga Irrigation Project's area. In 2012, 150 farmers organised into a cooperative made up of five FBOs used the scheme [13]. The average farm size on the project is 0.2 hectare. The farmers on this project cultivate the same crops as those on the Bontanga irrigation scheme.

The Bontanga Irrigation Project is a large-scale gravity-fed scheme, and the largest in the northern region of Ghana [13]. It is located at Bontanga in the Kumbungu District of Ghana, 34 km North West of Tamale, the regional capital of the northern region. The scheme covers a potential area of 800 hectares. However, only about 450 hectares is considered irrigable, of which 240 hectares is used for rice cultivation and the remaining 210 hectares for upland vegetables production [13]. Presently, 13 communities (Tibung, Kumbungu, Kpalsogu, Dalun, Wuba, Kukuo, Kpong, Saakuba, Yipelgu, Voggu, Kushibo, Zangbalung and Gbugli) are using the Bontanga Irrigation Project area [2]. The farmers' population on the project as at 2012 was 525 and they were organised into a cooperative comprising 10 farmers-based organisations (FBOs) [13]. The average farm size on the project is 0.6 hectare. The main crops cultivated within the project area include rice, maize, onion, pepper, tomato and okro [22].

B. Sampling Techniques and Data Collection

The study employed multi-stage sampling technique, where a mix of sampling approaches was used. In the first stage, purposive sampling technique was used to select the Bontanga and Golinga irrigation schemes because they are the major rice producing schemes in the study area. In the second stage, stratified sampling was used to form two groups of farmers-UDP adopters and Non-UDP adopters. Simple random sampling was then applied to select 200 farmers from the two strata; 138 adopters and 62 non-adopters. In terms of the irrigation scheme areas, 80 farmers were selected from Golinga, while the rest of the 120 farmers were selected from Bontanga. Primary data were collected using a questionnaire. This was done through face-to-face interviews with the farmers.

C. Analytical Framework – The Stochastic Frontier Model

Unlike the average response production functions, the stochastic frontier model separates the error term into two. The part of main interest in the frontier analysis is the inefficiency component. Efficiency is decomposed into technical efficiency and allocative efficiency; the product of the two gives the economic efficiency. Technical efficiency, which is the focus of this study, is described as the extent to which a firm/farm produces the maximum attainable output from a given set of inputs (Output oriented) or the extent to which a firm uses the minimum possible input combination to produce a known output level (Input oriented) [15]. On his part, [12] defined technical efficiency as 'the factor by which the level of production of the firm is less than its frontier output'. The stochastic frontier is attributed to the independent works of [5], [21] and generally given as [12]:

$$Y = f(x_i;\beta)\exp(V_i - U_i) \quad i = 1,2.....,N \qquad (1)$$

where Y is the observed output, X is the set of inputs and β are the parameters to estimate. $V_i - U_i$ is the composed error term. V_i is a stochastic error associated with random factors such as weather, this is independent and identically distributed of the half normal distribution as $N(0, \sigma_v^2)$. On the other hand, the U_i is independent and identically distributed nonnegative truncation of the $N(\mu, \sigma^2)$, independent of the V_i and measures the inefficiency that is within the control of the farmers. This means that while V_i has similar properties like the classical regression models, the U_i differs by having a non-zero mean [14].

Taking the natural logarithm of (1) gives:

$$InY_i = \beta_0 + \sum_{j=1}^{J} \beta_j InX_{ij} + V_i - U_i \qquad (2)$$

This gives the Cobb-Douglass specification of the frontier which is based on marginal productivity theory.

This study also estimated the Cobb-Douglass stochastic frontier model. Since efficiency is given as the ratio of the frontier output to the observed output, the efficiency can be written as:

$$TE = \frac{Y_i}{Y_i^*} = \frac{f(x_i;\beta)\exp(V_i - U_i)}{f(x_i;\beta)\exp V_i} = \exp(-U_i) \qquad (3)$$

Given that the U_i component is defined as controllable, we can model the factor effects on this component using:

$$U_i = \gamma_0 + \sum_{j=1}^{J} \gamma_j Z_{ij} + \varepsilon_i \qquad (4)$$

where γ are the parameters to be estimated and Z_i are the farmer specific factors influencing efficiency. From [11], the best predictor of $\exp(-u_i)$, thus, the individual efficiency levels are obtained by:

$$E\left[\exp(-u_i)/e_i\right] = \frac{1-\Phi\left(\sigma_A + \gamma e_i/\sigma_A\right)}{1-\Phi\left(\gamma e_i/\sigma_A\right)} \exp(\gamma e_i + \sigma_A^2/2) \qquad (5)$$

The variance parameters can be estimated using:

$$\sigma^2 = \sigma_v^2 + \sigma_u^2, \quad \gamma = \sigma_u^2/\sigma^2 \text{ and } 0 \le \gamma \le 1 \qquad (6)$$

D. Empirical Models Specification

Given the theoretical background, the present study estimated (7) and (8), from (2) and (4), respectively:

$$\begin{aligned} Output &= \beta_0 + \beta_1 Farm\,size + \beta_2 Hired\ labour + \\ &\beta_3 Unpaid\ labour + \beta_4 improved\ seed \\ &+ \beta_5 Weedicides + \beta_6 NPK\ Fertiliser + \beta_7 Briquette + v_i \end{aligned} \qquad (7)$$

and

$$\begin{aligned} Inefficiency &= \gamma_0 + \gamma_1 Age + \gamma_2 Household\ size + \\ &\gamma_3 Education + \gamma_4 Experience \\ &+ \gamma_5 Extension + \gamma_6 Credit + \gamma_7 UDP\ adoption + \varepsilon_i \end{aligned} \qquad (8)$$

where farm size is the total number of acres cultivated by the farmer; hired labour is the number of labourers hired for the rice production; unpaid labour (family labour) is the number of people who worked on the farm but are not paid, usually from the farmer's household; weedicides is the total number of litres of weedicides (both pre and post emergence) used on the farm; NPK fertilizer is the total number of 50kg bags of the fertilizer used; and briquette is the total number of 50kg bags of the fertilizer used by a farmer. Age is the number of years from birth of a farmer; household size is the total number of people in the same house, pooling and sharing the same (household) resources and controlled by one person as the head; education is the total number of years of formal education a farmer had; extension is a dummy defined as 1 for farmers who had access to extension service during the cropping season and 0 for those farmers who had no contact; credit is a dummy, 1 for farmers who had access to credit and 0 for those who did not have access to credit; and UDP adoption is a dummy, 1 for farmers who adopted the technology and 0 for farmers who did not adopt. Equations (7) and (8) were estimated using maximum likelihood due to its desirable asymptotic properties.

E. Testing the Hypotheses

The Akaike Information Criterion (AIC) was used to test the two hypotheses guiding the study. This is a measure for comparing maximum likelihood models. The AIC is defined and specified mathematically as [26], [6]: $AIC = -2 * In(likelihood) + 2k$ where k is the number of parameters estimated. The AIC is calculated by using the variance-covariance matrix of the estimated parameters. This method is widely used since it combines both fitness (measured negatively by $-2 * In(likelihood)$) and complexity (measured positively by $2k$). From the calculations, the model with the least AIC value is considered to be better.

III. Results and Discussion

A. Descriptive Statistics of Farmers

Table I provides the descriptive statistics of the variables included in the study. The average farmer was 44.7 years old while the younger and older were 20 and 80 years, respectively. Household distribution ranged between three and 26, with an average household size of 15. Formal education was low among the farmers considering the fact that the average farmer did not complete primary three of Ghana's education system. Although some farmers had no farmer education, others had as high as university level degrees. The farmers were generally experienced since the average farmer had been into rice production for as high as almost 17 years, with the most experienced farmer cultivating rice for the past 45 years. The majority (56%) of the farmers had access to extension service during the cropping season. On the other hand, less than half (37%) of the farmers had access to credit during the cropping season.

The land area for rice production ranged from 1 to 20 acres with the average farmer cultivating 2.7 acres. Hired labour usage was higher than unpaid or family labour. On the average, a farmer used 3.7 bags (20 kilograms/bag) of improved seed for cultivating the farm and also used 4.35 litres of weedicides. Among the two fertilizers, farmers used higher quantities of NPK (3.04 bags/farm) than briquette (0.89 bags/farm). The average weight of a bag of fertilizer used is 50 kg. Given the inputs usage, an average farmer had 31.31 bags (100 kilogram/bag) of rice output per farm.

TABLE I
DESCRIPTIVE STATISTICS OF RICE FARMERS

Variable	Mean	Std. Dev	Min	Max
	Socioeconomic			
Age	44.69	13.20	20	80
Household size	15.22	6.53	3	26
Education	2.58	5.39	0	18
Experience	16.91	10.25	3	45
Extension	0.56[a]	0.50	0	1
Credit	0.37[a]	0.48	0	1
	Input-Output			
Farm size	2.66	3.99	1	20
Hired labour	23.02	14.82	3	26
Unpaid labour	5.21	2.90	1	15
Improved seed	3.70	4.60	1	20
Weedicides	4.35	2.59	2	15
NPK fertilizer	3.04	2.09	2	14
Briquette	0.89	0.79	0	3
Output	31.31	20.69	7	102

[a] indicates proportion from dummy variables

B. Hypotheses Test Result

The objective of the study was to estimate the effect of UDP technology adoption of rice farmers on the position of the frontier. In other words, whether farmers who adopted the technology are more efficient and/or have more output. Therefore, to determine the model choice, the AIC was used, and the results presented in Table II. Using the AIC, the lower the value, the better the model and the higher the value, the less appropriate the model. From the test result, the model with UDP technology in both parts of the function had the lowest AIC value (18.66) which implies that this specification is most appropriate than the other two model specifications. The model without UDP adoption decision is the model where the quantity of UDP used is included in the output function but the adoption decision is not included in the inefficiency function. On the other hand, the model without UDP fertilizer quantity is that which has UDP adoption in the inefficiency model but not in the output model. This later model is the less appropriate specification among the three. The test result indicates that UDP adoption shifts both the frontier and the farmer's efficiency, hence the rejection of both hypotheses.

C. Determinants of Output of Rice

Table III provides the Maximum Likelihood (ML) and the Ordinary Least Square (OLS) results of the output model. However, based on the objective of the study, we proceeded with the discussion of the ML result. From the result, UDP technology (usage of briquetted urea) had a positive and significant effect on rice output. Other significant factors influencing rice production include farm size, hired labour, unpaid labour, improved seed and the use of NPK fertilizer. Among these input variables, farm size had a higher elasticity than the other factors. The estimated returns to scale is 0.927 (obtained by summing the elasticities) which means that rice farmers are operating within the third stage of the production function, thus, a decreasing returns to scale. The implication is that a 100% increase in factor inputs would lead to less than proportionate percentage increase in output.

TABLE II
TEST RESULTS OF MODEL SPECIFICATION

Model	Log likelihood	df	AIC
Without UDP adoption decision	5.889	16	20.221
With UDP adoption decision and quantity	7.671	17	18.658
Without UDP fertilizer quantity	4.902	16	22.196

TABLE III
DETERMINANTS OF OUTPUT OF RICE AND EFFICIENCY OF FARMERS

Variable	Elasticity	Std. error	P value	Elasticity	Std. error	P value
Output		ML-SFA			OLS	
Farm size	0.557***	0.031	0.000	0.539***	0.043	0.000
Hired labour	0.072**	0.037	0.049	0.129***	0.031	0.000
Unpaid labour	-0.120***	0.033	0.000	-0.049	0.047	0.297
Seed	0.111***	0.028	0.000	0.045	0.027	0.101
Weedicides	-0.026	0.053	0.625	-0.014	0.072	0.852
NPK fertilizer	0.168**	0.070	0.017	0.195**	0.082	0.019
Briquette	0.165**	0.070	0.018	0.092	0.091	0.310
Constant	2.808	0.142	0.000	2.469	0.120	0.000

Note: *** and ** indicate significance at 1% and 5%, respectively

The positive elasticity of farm size means that as farmers increased their farm holdings, their output also increased. Thus, if farmers double their farm size (100% increase), output would increase by 55.7%. This justifies the support for expanding the land area under rice production in the region. Considering the availability of vast arable land for rice production, stakeholders should provide the necessary support to farmers to expand their farm sizes. Reference [8] also using a Cobb-Douglass frontier found that, not only was farm size positive and significant but also, had the highest impact on rice production in Northern Ghana. Similarly, [3], [20], [16] also estimated a positive effect of farm size on rice output. Relatedly, increasing farm size leads to increasing maize output in Ghana [1]. These provide sufficient reason for policy makers to reflect on the mechanisms through which farmers can be assisted to increase their farm sizes and also provide the suitable production environment for the farmers.

Labour for rice production was in two folds - hired labour and unpaid (family) labour. While some farmers used hired labour in addition to unpaid labour, others rely solely on the latter for rice production in the study area. From the result, while hired labour had a positive effect on rice production, unpaid labour had a negative effect. This means that while more hired labour was needed, less of family labour was needed for increasing rice production. This could be attributed to the fact that famers who used hired labour ensured that the workers performed the assigned tasks effectively and efficiently. This may not be the case in unpaid labour as there is less supervision on the part of the farmers and also because there was no value incentive for effective work to be done by the labour force. This studies of [16], [7] also estimated a positive effect of labour on rice production in Ghana. Outside Ghana, [20], [18], [24] also found a positive and significant effect of labour on rice production.

Improved seed had a positive and significant effect on rice output. Consistent with previous studies such as [8], [18], [16], the result indicates that a 100% increase in the use of improved seed led to an increase of 11.1% in the output of rice. The implication is that the current seed density usage by the farmers is lower and can be increased without a negative effect on output. This is consistent with the increasing research efforts in improving the rice seed variety especially for high yielding, short duration and pest resistance. This is an important finding to improve upon, justifying the support and expansion of the AfricaRice and IFDC USAID Agriculture Technology Transfer program in providing improved seeds to the farmers in the SADA intervention zone.

One important fertilizer required for rice production is NPK. It is not surprising therefore that it had a positive and significant effect on rice output. NPK is required for sparking the initial growth of the plant, thus, its requirement is most crucial at the early stages of growth. While the N is necessary for proper vegetative growth, P and K are necessary for proper root development and the absorption of nutrients by the plant.

The urea briquette, which is also known as Urea Super Granule (USG), also had a positive and significant effect on rice output. This finding suggests that a 100% increase in urea briquette usage leads to 16.5% increase in output. The implication of this finding is that UDP technology shifts the rice production frontier outward. This finding was consistent with [8], [20], [7], which also estimated a positive effect of fertilizer on rice production, but contrary to the finding of [16] who found a negative effect of fertilizer use on output.

D. Factors Influencing Rice Farmers' Technical Efficiency

From the previous discussion, the study provided the factors that determined the movement or shift of direction of rice output frontier. In this section however, the factors that determined the position of the farmers below the frontier are discussed. From Table IV, all the inefficiency terms were found to improve efficiency except "experience of the farmer" that had a negative effect on efficiency. Age of the farmer was the only insignificant variable.

TABLE IV
FACTORS INFLUENCING TECHNICAL EFFICIENCY OF RICE FARMERS

Variable	Coefficient	Standard error	P Value
Age	-0.053	0.058	0.363
Education	-0.359***	0.115	0.002
Household size	-0.530***	0.147	0.000
Experience	-0.185**	0.074	0.013
Extension	9.792***	3.064	0.001
Credit	-1.448*	0.795	0.068
UDP adoption	-2.558*	1.523	0.093
Constant	2.629	3.046	0.388
Sigv	0.198	0.014	
lnsig2v	-3.234	0.140	0.000

Note: ***, ** and * indicates significance at 1%, 5% and 10%, respectively

The negative coefficient of education in the inefficiency model meant that it had a positive effect on the efficiency of rice farmers in the study area. Education is an important factor that improves the knowledge level of people. In other words, human capacity is developed through education. It is therefore not surprising that farmers with higher levels of formal education were more technically efficient than those with less formal education. Perhaps, the educated farmers are able to appreciate the processes of rice production and are able to carry out their farm operations efficiently. This finding contradicts [8] who found a negative effect of education on efficiency of farmers, but corroborates with others such as [4], [10] who found a positive effect of education on technical efficiency of farmers of bambara groundnuts and tomatoes respectively.

The estimated negative coefficient of household size suggests that farmers with larger household sizes are more efficient than those with smaller household sizes. This could be attributed to the fact that household members could provide additional assistance to the farmers during rice production. However, it is important to recall that unpaid labour had a negative effect on rice output (see Table III). Therefore, the mechanisms through which household size leads to higher technical efficiency, but to a lower output, needs further exploration. Nonetheless, [7] also estimated a positive effect of household size on efficiency of rice farmers. Experienced farmers also had a higher efficiency than relatively new entrants. Farmers who had cultivated rice over the years might have gained knowledge and developed skills on rice production processes and are therefore able to improve their efficiency. It is important that these experienced farmers provide the needed assistant to the less experienced farmers to improve rice production in the region. Considering the importance of extension service in rice production, it was ironical that the farmers who had more contacts with extension officers had a lower efficiency. Meanwhile, [3], [16] estimated a positive effect of extension service on rice production.

Generally, rice production is quite capital intensive compared with other food crops. This makes agricultural credit an important variable to expand rice production in the country. In this study, farmers who had access to credit were more technically efficient than those who did not receive credit during the production season. This was consistent with the findings of [1], [7], but contrary to that of [16]. It is plausible that, not the access to credit that led to a higher efficiency, but the effective utilisation of the credit. This finding therefore, justifies the need to provide credit to resource poor rice farmers in order to improve domestic rice production and to relieve government of the high expenditure of rice importation. However, the mechanisms through which credits can be utilised effectively have to be identified, beyond this study.

One of the aspects of the study was to examine whether the adoption of the UDP technology moves farmers closer to the frontier or draws them away from the frontier. The estimated coefficient of the adoption of UDP in Table IV addressed this. The result revealed that the adoption of UDP technology moves farmers closer to the production frontier. Thus, farmers who adopted the technology were more efficient than their counterpart non-adopters.

TABLE V
EFFICIENCY DISTRIBUTION OF THE RICE FARMERS

Efficiency level	Frequency	Percentage
0.30-0.40	7	3.5
0.61-0.70	15	7.5
0.71-0.80	18	9
0.81-0.90	13	6.5
0.91-1.00	147	73.5
Min	0.32	
Max	1.00	
Mean	0.92	

Source: Authors' computation from data

E. Efficiency Level of Rice Farmers

The efficiency score distribution of the farmers is provided in Table V. The farmer with the least efficiency score was 32% efficient, while the best performing farmer was 100% efficient. On the average however, the sampled rice farmers in the study area are 92% technically efficient. The majority of the farmers (73.5%) had efficiency scores greater than 90%. Only 3.5% of the farmers had efficiency scores below 50%. These farmers can be said to be highly efficient since the average efficiency was higher than studies, such as [3] with an estimated efficiency of 89.9%; [18] with an estimated mean score of 89.5%; and [16] with an average efficiency of 61.8%. Studies on other crops such as [1], [4] also estimated lower mean efficiencies of 47.6% and 83%, respectively.

IV. CONCLUSION, POLICY IMPLICATION AND RECOMMENDATION

Rice is an important staple crop, second to maize in Ghana. Because domestic rice production is unable to meet demand, Ghana's import bill for rice continues to surge upward. This is having a negative effect on the country's balance of trade. Stakeholders including researchers are on a constant search for better ways to increase domestic rice production to offset for import losses. One such critical effort is the promotion of the relatively new UDP technology in Ghana by the IFDC-led Feed the Future USAID Ghana Agriculture Technology Transfer Project. This study applied the stochastic frontier analysis to measure the effect of the adoption of UDP on both output and efficiency. Hypotheses test suggested that UDP adoption should be included in both parts of the stochastic frontier model. Again, the study concludes that the adoption of UDP technology increases rice output as well as farmers' efficiency. What this means is that rice production can be improved through the promotion of this technology. Generally, rice farmers in the area were highly efficient. However, there is the potential of increasing output by 8% without an additional input if production processes are further improved. The study recommends an integration of the UDP technology into the national agricultural and rice development policies of Ghana. MoFA extension agents across the country should be trained on the protocols of the UDP technology to compliment the efforts of IFDC aimed at improving adoption by farmers. Since this study did not determine the factors that influenced farmers' adoption decision of the technology, further research on this aspect is needed. Rice farmers are also encouraged to expand their farm lands simultaneously with increasing planting density as well as fertilizer usage to improve output. Providing credit to farmers is vital, considering its role in improving farmers' efficiency.

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