



## **COST REDUCING AND PROFIT ENHANCING EFFECTS OF SYSTEM OF RICE INTENSIFICATION UNDER INPUT AND OUTPUT ENDOGENEITY IN ZAMFARA STATE, NIGERIA**

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### **ABSTRACT**

The study analyzed the cost and profit efficiency causal effect of System of Rice Intensification (SRI) in the Bakolori Irrigation Scheme (BIS), Zamfara State. A pre-tested structured questionnaire was used to collect primary data from 300 rice farming households in BIS, consisting of 40 (15%) and 260 (85%) adopters and non-adopters of SRI. Primal cost and profit systems and endogenous switching regression (ESR) models were used to achieve the research objectives. The findings reveal that under farmers' cost minimization and profit maximization objectives, price of fertilizer, price of agrochemicals, amount of credit received and distance to rice plots significantly influenced adopters' cost and profit efficiency. Similarly, the cost and profit efficiency of non-adopters were primarily determined by the price of organic fertilizer, agrochemicals and the distance to rice plots. Results further showed that SRI use reduced the excess cost in rice production by about 5.3% and the profit loss by about 40%. Based on the findings of this study, we recommend that more efforts should be harnessed by the government and research institutes in scaling up the testing and promotion SRI technology across other States of the economy in order to significantly reduce the current deficit of rice and for financial empowerments in rural areas. Extension agents should be used extensively in the process of dissemination of the technology.

**Keywords:** Cost Efficiency, Endogenous Switching Regression, Profit Efficiency, System of Rice Intensification

### **INTRODUCTION**

Rapid demand from growing economies, poor harvest due to climate variability and rise in energy and fertilizer prices have often been mentioned as some of the major underlying causes of increase in food prices in developing countries (Egwuma *et al.*, 2017; Rother *et al.*, 2023; Adjemian *et al.*, 2024; Erdogan *et al.*, 2024). The unprecedented and regular price surges are constantly weakening the purchasing power due to lower production thereby pushing many into a critical state of food insecurity and poverty. Additionally, the security challenges and the threat posed by herdsmen, bandits and kidnappers have become an even greater obstacle to the growth and development of the agricultural sector in Nigeria in particular. Taking into account farmers' budget is extremely critical to ensure that their multiple goals are attained at least to a satisfactory level. To this end, any technology that minimizes the cost of production will probably be well perceived and adopted by income-poor farmers. It has become a common knowledge that rice farmers in Nigeria are generally small-scale farmers, resource-poor and in most cases misallocate the limited resources at their disposal partly due to poor management. Furthermore, being constrained by their level of capital, they often rely on rainfed systems of



farming. Therefore, their production level and productivity are greatly subject to changes in environmental conditions such as rainfall, drought and flood. The irrigation system is capital intensive and therefore accessible only to few farmers especially those with enough assets or who are beneficiaries of government's interventions like the Bakolori Irrigation Scheme (BIS) in Zamfara State.

Although, it is understood that about 34 States in the country are actively involved in rice production (Udemezue, 2018), the local demand remains above the quantity produced. The aforementioned challenges represent some of the factors that have trailed the supply of rice in Nigeria and have raised questions regarding how best to help smallholder farmers in improving their production over the years. Based on six agronomic principles namely, use of younger seedlings, transplanting at most two seedlings per hill, use of wider spacing of at least 25 cm × 25 cm, alternate wedding and drying, use of rotary weeders and application of compost, the system of rice intensification (SRI) is understood to reduce seed, fertilizer and water use significantly while providing a conducive environment for profuse tillering, significant yield growth and maintenance and enhancement of soil fertility. It is regarded as an ideal method of rice production especially among resource poor farmers. Some studies have also demonstrated that even the cost of production tend to decrease over time due to decline in labour cost as farmers gain mastery of the principles, suggesting that excess cost and profit loss resulting from production inefficiency are reduced significantly under SRI (Sato, 2005, 2006; Gathorne-Hardy *et al.*, 2016). It is implied that resource use inefficiency will lead to excess cost and ultimately profit loss, but such information is usually not provided in studies on production efficiency even though it can play a major role in raising farmers' and other stakeholders' consciousness for the need to take measures in complying with recommended agronomic practices.

Another important gap in the extant literature on production efficiency is that production inputs are usually taken exogenously in modelling and estimating farmers' production efficiency in a in a more or less competitive market. In some other cases, output is also taken exogenously even when farmers' objective is to maximize profit. But microeconomic analysis shows that the demand for inputs is determined through an optimization process such as cost minimization or profit maximization. Specifically, under cost minimization process, inputs are chosen by farmers with the aim of producing a given level of output at minimum cost, which means that production inputs are endogenous. Under profit maximization, both output and inputs are equally endogenously determined. The implication is that not accounting for the endogeneity of inputs and outputs in modeling cost and profit efficiency will lead to biased cost and profit frontiers which in turn can be misleading in policy formulations and interventions. In accounting for inputs' endogeneity, a recent study by Vabi *et al.* (2021) employed a cost system approach proposed by Kumbhakar *et al.* (2014). But unlike Vabi *et al.* (2021). The study was therefore carried out to determine the factors influencing cost and profit efficiency under SRI and farmers' practice (FP) and identify the effect of SRI on cost and profit efficiency.

## **METHODOLOGY**

### **Description of the Study Area**

Bakolori Irrigation Scheme (BIS) is located in Zamfara State and particularly in three of its fourteen Local Government Areas (LGAs) namely Talata Mafara, Maradun, and Bakura (Sa'adu *et al.*, 2017). The Bakolori dam whose water is used to supply the project site, had a water storage capacity of 450 million cubic meters at the time its construction was completed

in 1979, but is currently estimated to be 351,010,027 cubic meters as at 2013. It presently supplies water to 7,039 ha (31%) by gravity and 15,961 ha (69%) through sprinklers, which makes up the total land area of 23,000 ha covered by the project. The major occupation in the State in general and in the project site in particular is farming which is carried out by resource-poor farmers, but other important occupations include craft, trading, hunting and nomadic pastoralism. Aside rice, other crops mainly produced in BIS include millet, sorghum, groundnut, maize, cassava, sweet potatoes, pepper and tomatoes.

### Sampling Procedure and Sample Size

A multi-stage sampling technique was used to select rice farmers consisting of both adopters and non-adopters of SRI within the BIS. In the first stage, seven (7) sectors or intakes where the project was carried out were purposively selected. In the second stage all the 40 main farmers who participated in the promotion of the best-bet SRI (BB-SRI) were selected (Table 1). In the third stage, based on the sample frame and using a proportional random sampling technique, a total of 260 non-SRI farmers were selected, thereby making a total of 300 rice farmers for the study.

**Table 1:** Sampling frame and sample size of rice farmers in BIS

Sector	Sample Frame	Prop.	SRI	Sample size	
				Non-SRI	Total
E-Down	1,295	0.077	3	20	23
E-Left	1,645	0.097	4	25	29
M-Rice B	1,750	0.104	4	27	31
N-Rice	3,500	0.207	8	54	62
G-Rice B	2,730	0.161	6	42	48
Intake C	3,325	0.197	8	51	59
F-Right	2,660	0.157	6	41	47
<b>Total</b>	<b>16,905</b>	<b>1</b>	<b>40</b>	<b>260</b>	<b>300</b>

Source: TRIMING-SRI (2020)

### Data Collection

This study used primary data which were collected using pre-tested structured questionnaires by trained extension agents. The main managers of rice plots in the study area were interviewed and detailed data on input and output with their respective market prices were collected. Data on cost and returns were equally collected from the scientists that supervised the SRI plots in order to crosscheck the data provided by farmers.

### Analytical Framework

The primal cost and profit systems and Endogenous Switching Regression (ESR) models were used to achieve the research objectives. For brevity, let us suppose that  $V_{Ti}$  is the excess cost or profit loss under SRI and  $V_{Ui}$  his/her profit loss when FP is used. The production efficiencies can be stated as:

$$V_{Ti} = X_i \delta_T + u_{Ti} \quad (1)$$

$$V_{Ui} = X_i \delta_U + u_{Ui} \quad (2)$$

where  $X_i$  is a vector of factors explaining  $V_{Ti}$  and  $V_{Ui}$ ;  $\delta_T$  and  $\delta_U$  are vectors of parameters;  $u_{Ti}$  and  $u_{Ui}$  are independently and identically distributed statistical errors. We hypothesize that the method of rice farming with the lower excess cost or profit loss is chosen in order to achieve

maximum benefits. Therefore, it can be stated mathematically that the choice of using the SRI is made when  $V_{Ti} < V_{Ui}$ . However, at the beginning of a farming season, farmers often make such decisions based on their preferences (perceived productivity), which are unknown to researchers. The decision to use SRI is therefore endogenous in nature in which case a simple difference in profit loss between SRI and FP will be biased due to self-selection. Following Pitt (1983), another source of selectivity can be inferred in that farmers with more than the SRI's average profit loss would not choose SRI but would rather continue with the FP. In a latent variable model, the unobserved profit loss from using SRI can be expressed as:

$$V_i^* = \beta'W_i + \eta_i, \quad T_i = I(V_i^* < 0) \quad (3)$$

where  $\beta$  is a vector of parameters,  $W_i$  is a vector of observed characteristics that influence profit loss or excess cost;  $\eta_i$  is a statistical error term with zero mean and variance  $\sigma_\eta^2$ ;  $T_i$  is an endogenous dummy variable taking 1 and 0 if SRI and FP is used, respectively;  $I(\cdot)$  is an indicator function that states that the decision to use SRI is realized when the profit efficiency gain is positive. Following Lee (1982), equation (1) and (2) can be rewritten as:

$$V_{Ti} = X_i\delta_T + u_{Ti} \quad \text{if } T_i = 1 \quad (4)$$

$$V_{Ui} = X_i\delta_U + u_{Ui} \quad \text{if } T_i = 0 \quad (5)$$

where (4) and (5) are the production efficiency (outcome) equations for the users of SRI (Regime 1) and FP (Regime 2), respectively; other variables in the model are defined as previously. The parameters  $\delta_T$  and  $\delta_U$  in (4) and (5) are biased in the presence of self-selection (Lee, 1982). This is because self-selection into users of SRI and FP due to unobservable factors causes equations (3) through (5) to be correlated. The ESR model was estimated in three steps. In the first step, a probit regression model was specified as follows:

$$\Pr(T_i = 1|W_i) = \Phi(W_i'\beta) \quad (6)$$

where  $\Pr(T_i = 1|W_i)$  is the probability that SRI is used given some observed characteristics named  $W_i$ ;  $\Phi(\cdot)$  is the standard normal distribution function;  $T_i$  is a dummy variable taking 1 if an RFH used the SRI and 0 if otherwise;  $\beta$  is a vector of parameters representing the marginal effect of  $W_i$  on the probability that SRI is used to cultivate rice; the vector of explanatory variables included in  $W_i$  were:

$w_{1i}$  = Log Price of seed (₦);  $w_{2i}$  = Log Price of organic fertilizer (₦);  $w_{3i}$  = Price of Agrochemical (₦);  $w_{4i}$  = Number of household members between 18 and 60 years old;  $w_{5i}$  = Number of contacts with extension agents during the current farming reason;  $w_{6i}$  = Distance to rice plots (km);  $w_{7i}$  = Experience in rice farming (years);  $w_{8i}$  = use of tube well (1 if tube well was used to supply water to the rice plots, 0 if otherwise);  $w_{9i}$  = Rice plot type (1 if rice plot is sloppy, 0 if otherwise);  $w_{10i}$  = E-Down (1 if RFH is located in E-Down, 0 if otherwise);  $w_{11i}$  = E-Left (1 if RFH is located in E-Left, 0 if otherwise);  $w_{12i}$  = Intake C (1 if RFH is located in Intake C, 0 if otherwise);  $w_{13i}$  = log of the number of persons from which advices are received regarding improved farming practices.

In the second stage, the outcome equations in (4) and (5) were estimated by first specifying their unbiased and consistent expected values as:

$$E(V_{1i}) = X_i \delta_1 - \sigma_{1\eta} \lambda_{1i} \quad (7)$$

$$E(V_{0i}) = X_i \delta_0 - \sigma_{0\eta} \lambda_{0i} \quad (8)$$

where  $E(V_{1i})$  is the expected production efficiency using the SRI, conditional on  $T_i = 1$ ;  $E(V_{0i})$  is the expected production efficiency of the FP;  $X_i$  is a vector explanatory variables;  $\sigma_{1\eta}$  is the covariance between the error terms in (1) and (2);  $\sigma_{0\eta}$  is the covariance between the error terms in (7) and (8);  $\lambda_{1i}$  and  $\lambda_{0i}$  are the selectivity terms in (7) and (8). To avoid the issue of inconsistent standard errors that arise from estimating the first and the second stage equations independently, the full information maximum likelihood (FIML) proposed by Lokshin and Sajaia (2004) and Greene (2000) was adopted to simultaneously estimate the first and the second stage equations.

The production efficiency of each farmer under his/her original assignment and his/her counterfactual were predicted using the following equations:

$$E(V_{1i} | T_i = 1) = X_i \delta_1 - \sigma_{1\eta} \lambda_{1i} \quad (9)$$

$$E(V_{0i} | T_i = 0) = X_i \delta_0 - \sigma_{0\eta} \lambda_{0i} \quad (10)$$

$$E(V_{1i} | T_i = 0) = X_i \delta_1 - \sigma_{1\eta} \lambda_{0i} \quad (11)$$

$$E(V_{0i} | T_i = 1) = X_i \delta_0 - \sigma_{0\eta} \lambda_{1i} \quad (12)$$

where  $E(V_{1i} | T_i = 1)$  is the expected production efficiency under the SRI conditional on farmer being a user of SRI;  $E(V_{0i} | T_i = 0)$  is the expected production efficiency under the FP conditional on farmer being a user of FP;  $E(V_{1i} | T_i = 0)$  is the expected production efficiency under the SRI conditional on farmer being a user of FP;  $E(V_{0i} | T_i = 1)$  is the expected production efficiency under the FP conditional on farmer being a user of BB-SRI. The three causal effect parameters of interest were therefore estimated as:

$$\begin{aligned} \widehat{ATT} &= E(V_{1i} | T_i = 1) - E(V_{0i} | T_i = 1) \\ &= (\delta_1 - \delta_0) X_i + (\sigma_{1\eta} - \sigma_{0\eta}) \lambda_{1i} \end{aligned} \quad (13)$$

$$\begin{aligned} \widehat{ATU} &= E(V_{1i} | T_i = 0) - E(V_{0i} | T_i = 0) \\ &= (\delta_1 - \delta_0) X_i - (\sigma_{1\eta} - \sigma_{0\eta}) \lambda_{0i} \end{aligned} \quad (14)$$

$$\begin{aligned} \widehat{ATE} &= E(V_{1i} | T_i = 1) - E(V_{0i} | T_i = 0) \\ &= (\delta_1 - \delta_0) X_i - (\sigma_{1\eta} \lambda_{1i} - \sigma_{0\eta} \lambda_{0i}) \end{aligned} \quad (15)$$

where  $\widehat{ATT}$  = Average Treatment Effect on the treated;  $\widehat{ATU}$  = Average Treatment Effect on the Untreated;  $\widehat{ATE}$  = Average Treatment Effect; all other variables and parameters are defined as previously.



## RESULTS AND DISCUSSION

### Determinants of Cost Efficiency among Adopters and Non-adopters

#### *Determinants of adoption of SRI assuming cost minimization objective*

The result in Table 2 shows that the correlation coefficient between the selection equation and the cost efficiency among the adopters of SRI was positive and statistically significant ( $Rho1 = 0.845, p < 0.01$ ), which implies that there was endogenous switching and evidence of negative sample selection bias (Abdulai and Huffman, 2014). In other words, both observed and unobserved characteristics influenced the decision to use SRI and the cost efficiency given the adoption decision. Moreover, it can be said that farmers with less than the average cost efficiency had a higher probability than their counterparts in using SRI as a method of rice production, all things being equal. The Wald statistic estimate was statistically significant at 1% level of probability (Wald = 36.9,  $p < 0.01$ ), which means that there was good fit and that the model was adequate to explain cost efficiency among adopters and nonadopters. The result is consistent with several studies where the ESR model was found to be appropriate in estimating the impact of improved technologies on productivity and income (Asfaw *et al.*, 2012; Abdulai and Huffman, 2014; Manda *et al.*, 2019; Tufa *et al.*, 2019; Wossen *et al.*, 2019; Dontsop *et al.*, 2020).

The estimates of the adoption (selection) equation revealed that the price of seed, price of organic fertilizer, extension services, distance to rice plots, experience in rice farming and the dummy variable Intake C were significantly associated with adoption of SRI. Specifically, the log of the price of seed had a positive and significant influence on adoption of SRI at 10% level of probability ( $\beta = 1.162, p < 0.1$ ). Similarly, the log of the price of organic fertilizer had a positive and significant influence of adoption of SRI at 1% level of probability ( $\beta = 0.941, p < 0.01$ ). The results imply that increase in input prices will increase the probability to adopt SRI, which is consistent with the study of Abdulai and Huffman (2014) and Ullah *et al.* (2018). Unlike conventional methods of rice farming where substantial quantity of inorganic fertilizers and seeds are used, SRI uses significantly smaller quantity of seed - between 4 to 5 kg per hectare (TRIMING-SRI, 2018, 2019) - such that increase in the price of seed seems not to deter farmers' decision to adopt SRI.

Extension services had a positive and significant effect on adoption of SRI at 1% level of probability ( $\beta = 0.026, p < 0.01$ ), suggesting that farmers with more contact with extension services will be more likely to adopt SRI than their counterpart, which is in line with previous adoption studies (Abdulai and Huffman, 2014; Asfaw *et al.*, 2012; Feleke *et al.*, 2016; Wossen *et al.*, 2017; Ullah *et al.*, 2018; Dontsop *et al.*, 2020). This was probably because access to extension services enables farmers to obtain relevant production and market information on improved technologies, agronomic practices and production inputs. Experience in rice farming had a positive and significant effect on adoption of SRI at 5% level of probability ( $\beta = 0.017, p < 0.05$ ), which indicates that farmers with more experience in rice farming will be more likely to adopt SRI than their counterpart, holding other variables constant. Farming experience is understood to increase farmers' efficiency over time through improved resource use. In other words, experience enables farmers to reduce mismanagement of resources and increases their ability to search and process information relevant to the production process. The finding is in agreement with many previous studies such as Ullah *et al.* (2018) and Dontsop *et al.* (2020). The positive and significant influence of the dummy variable Intake C implies that farmers in Intake C were more likely to adopt SRI than those in E-Down, E-Left, M-Rice B, N-Rice, G-Rice B and F-Right.

### ***Determinants of cost efficiency***

In terms of the outcome equations, there was difference in the coefficient estimates of the cost efficiency equation between the users and non-users of SRI, which illustrate that there was heterogeneity in the sampled data. In other words, the cost efficiency equations of adopters and nonadopters of SRI were different. Specifically, the price of organic fertilizer, distance to rice plots, E-Left and Intake C dummies were significantly associated to cost efficiency among adopters. Among non-users, the price of organic fertilizer and agrochemicals, distance to rice plots and Intake C dummy were significant determinants of cost efficiency. Increase in the price of organic fertilizer by 1% will increase excess cost by 0.05% for users and reduce excess cost by 0.15% for non-users. The effect of the price of agrochemicals on cost efficiency was insignificant among users, but will significantly reduce excess cost by 0.68% among non-users for 1% increase in the price of agrochemicals. There was indirect relationship between distance to rice plots and cost efficiency among users and non-users, which implies that increase in distance to rice plot by 1 km will reduce excess cost of users and non-users by 1% and 4%, respectively, holding other variables constant. Farmers in E-Left will have about 5% more excess cost than farmers in other intakes, all things being equal. On the other hand, SRI use in Intake C will have 4% less excess cost than their counterparts.

**Table 2:** Full information maximum likelihood estimates of the endogenous switching regression model for the impact of SRI on cost efficiency due to technical and allocative inefficiency

<b>Variable</b>	<b>Selection (1)</b>	<b>BB-SRI (2)</b>	<b>FP(3)</b>
Log Price of seed	1.162 (0.661)*	-0.034 (0.086)	-0.059 (0.107)
Log Price of organic fertilizer	0.941 (0.343)***	0.054 (0.023)**	-0.149 (0.075)*
Log Price of agrochemical	-0.29 (0.849)	-0.028 (0.077)	-0.682 (0.142)***
Members' work age (Dummy)	0.006 (0.046)	-0.00003 (0.002)	-0.01 (0.009)
Extension services	0.135 (0.026)***	0.001 (0.001)	0.004 (0.006)
Distance to rice plots	-0.202 (0.087)**	-0.01 (0.004)**	-0.039 (0.015)***
Experience in rice farming	0.036 (0.017)**	0.001 (0.001)	0.001 (0.003)
Use of tubewell (Dummy)	0.364 (0.296)	0.018 (0.015)	0.01 (0.053)
Plot type (Dummy)	-0.527 (0.346)	0.016 (0.021)	-0.007 (0.055)
E-Down (Dummy)	-1.329 (1.032)	-0.046 (0.044)	0.07 (0.092)
E-Left (Dummy)	0.698 (0.551)	0.052 (0.021)**	0.105 (0.105)
Intake C (Dummy)	-1.961 (0.587)***	-0.039 (0.022)*	-0.504 (0.094)***
Number of advisors	-0.095 (0.484)		
Constant	-7.561 (6.997)	0.461 (0.608)	6.086 (1.23)***
Sigma( $\sigma$ )		0.043 (0.009)***	0.394 (0.017)***
Rho( $\rho$ )		0.845 (0.193)***	0.135 (0.284)
Log likelihood	-107.86		
Wald chi2(11)	36.9***		
Number of observations	300		

\*\*\*<0.01, \*\*<0.05 and \*<0.1; Standard errors are inside the brackets.

## **Determinants of Profit Efficiency among Adopters and Non-adopters of SRI**

### ***Determinants of adoption of SRI assuming profit maximization objective***

Table 3 presents the results of the ML estimate of the ESR for the profit efficiency of rice farmers under the assumption of profit maximization in rice farming. There was a positive and significant correlation between the use equation and the profit efficiency of users ( $Rho1 = 0.118, p < 0.01$ ), which means that there was negative sample selection bias and evidence of endogenous switching. This shows that the profit efficiency equation of users is different from that of non-users. The Wald statistic estimate was statistically significant at 1% level of probability ( $Wald = 41.17, p < 0.01$ ), which means that there was good fit and that the independent variables jointly and significantly influenced the dependent variables (use of SRI and profit efficiency). Age of household head, price of inorganic and organic fertilizer, price of labour, number of extension contacts, amount of credit received and distance to rice plots were significant determinants of SRI practices. Age of household head, price of inorganic and organic fertilizer, price of labour, number of extension contacts, amount of credit received all had a positive correlation with SRI use while only distance to rice plots had a negative influence on adoption. The positive influence of age on SRI use shows that older farmers will be more likely than younger ones to use SRI. The result is consistent with other studies (Adesina and Baidu-Forson, 1995; Grazhdani, 2013; Ullah *et al.*, 2018). The direct relationship between the price of fertilizer (organic and inorganic) and the price of labour with the SRI use confirmed the previous results that adoption of SRI depends on external inputs. Similarly, there was equally a confirmation of the positive SRI use effect of extension services among rice farmers. The effect of amount of credit received on SRI use was positive, which means that farmers with more credit will be more likely to use SRI practices. The negative SRI use effect of distance to rice plot indicates that farmers closer to their rice plots will be likely to use SRI.

### ***Determinants of profit efficiency***

The price of inorganic fertilizer, the price of agrochemical, having a primary education, amount of credit received and distance to rice plots influenced the profit efficiency of the users. On the other hand, only the price of agrochemical and being in E-Left sector were important determinants of profit efficiency. This finding further confirms the evidence of endogenous switching in the sense that some determinants of the profit efficiency of users were different from those of non-users. There was a negative and significant effect of the price of inorganic fertilizer on the profit efficiency of the users ( $\beta = -1.086, p < 0.1$ ), which suggests that if the price of inorganic fertilizer increases by 1% the adopters' profit loss will be reduced by about 1.1%, holding other variables constant. The price of agrochemicals had a negative and significant effect on the price of profit efficiency ( $\beta = -2.125, p < 0.01$ ), implying that if the price of agrochemicals increases by 1%, users' profit loss will decrease by about 2.11%. Primary education had a positive and significant effect the profit efficiency of users ( $\beta = 0.394, p < 0.01$ ), which means that farmers with primary education will have about 40% more profit loss than their counterparts. The effect of amount of credit received was positive and significant ( $\beta = 0.17, p < 0.1$ ), which reveals that if the amount of credit received increases by 1%, the profit loss will be increased by about 0.17%. This finding, however, is contrary to expectations. Distance to rice plot had a positive and significant effect on profit loss ( $\beta = 0.063, p < 0.05$ ), which implies that if distance to rice plot increases by 1 km, the profit loss will increase by about 6.3%. There was a positive and significant effect of agrochemicals on the profit efficiency of non-users ( $\beta = 0.316, p < 0.05$ ), which means that if the price of agrochemicals increases by 1%, the profit efficiency will increase by about 0.32%, holding other variables constant. The positive and significant effect of the dummy variable E-Left on profit efficiency

of non- users ( $\beta = 0.281, p < 0.05$ ), implies that, non- users in E-Left sector will have about 28% more profit loss than their counterparts.

**Table 3:** Full information maximum likelihood estimates of the endogenous switching regression model for the impact of SRI on profit efficiency due to technical and allocative inefficiency

Variable	Selection (1)	Peff1	Peff0
Age of household head	0.04 (0.019)**	0.001 (0.009)	-9.6E-06 (0.002)
Log Price of Inorganic fert	9.852 (2.526)***	-1.086 (0.591)*	-0.002 (0.181)
Log Price of organic fertilizer	1.084 (0.568)*	0.235 (0.238)	0.046 (0.073)
Log Price of Agrochemical	-1.431 (1.693)	-2.125 (0.761)***	0.316 (0.148)**
Log Price of labour	3.478 (1.529)***	-0.203 (0.472)	-0.056 (0.099)
No formal educ. (Dummy)	-0.465 (0.958)	0.178 (0.231)	-0.068 (0.103)
Primary educ. (Dummy)	-0.931 (0.97)	0.394 (204)*	-0.09 (0.106)
Secondary educ. (Dummy)	-0.608 (0.947)	0.023 (0.242)	-0.069 (0.10)
Work. age members (Dummy)	-0.083 (0.08)	-0.007 (0.027)	0.007 (0.008)
Contacts with ext. agents	0.134 (0.037)***	-0.01 (0.015)	0.001 (0.005)
Log amount of credit	0.623 (0.213)***	0.17 (0.091)*	-0.009 (0.028)
Distance to rice plots	-0.304 (0.124)**	0.063 (0.031)**	0.017 (0.016)
Use of tubewell (Dummy)	0.022 (0.427)	0.121 (0.15)	0.037 (0.056)
E-Left (Dummy)	7.579 (12.053)	0.009 (0.546)	0.281 (0.133)**
M-Rice B (Dummy)	4.998 (11.988)	-0.198 (502)	-0.027 (0.115)
N-Rice (Dummy)	5.036 (11.982)	-0.071 (0.491)	0.096 (0.102)
G-Rice B (Dummy)	4.566 (12.021)	-0.305 (501)	0.016 (0.145)
Intake C (Dummy)	5.689 (12.01)	-0.358 (0.5)	-0.046 (0.131)
F-Right (Dummy)	4.88 (11.993)	-0.132 (0.483)	0.032 (0.11)
Number of advisors	-0.743 (0.632)		
Constant	-71.116 (21.098)***	20.26 (6.641)***	-1.654 (0.156)
Sigma		0.307 (0.035)***	0.384 (0.017)***
Rho		0.118 (0.012)***	0.156 (0.244)
Log likelihood	-160.39		
Wald chi2(11)	41.17***		
Number of observations	300		

\*\*\* $<0.01$ , \*\* $<0.05$  and \* $<0.1$ ; Standard errors are inside the brackets.

### Causal Effect of SRI on Cost and Profit Efficiency

The estimates of the effect of SRI on cost and profit efficiency are given in Table 4. Based on the pooled sample, there was a negative and significant impact of SRI use on cost ( $ATT = -0.053, p < 0.01$ ) and profit ( $ATT = -0.401, p < 0.01$ ) efficiency of the adopters, which implies that SRI use reduced the excess cost in rice production by about 5.3% and the profit loss by about 40%. Had non- users used SRI, their cost efficiency would not have been affected

significantly, but their profit loss would have decreased significantly by about 5%. Had all farmers in the sampled data used SRI, the average reduction in excess cost would have been about 16% with no significant impact on profit efficiency. There was significant heterogeneity across the seven intakes in terms of the impact of SRI on profit and cost efficiency. Generally, users experienced a significant reduction in excess cost and profit loss except in M-Rice B. Also, it can be noted that the magnitude of the impact of SRI on profit loss was significantly higher than the causal effect on excess cost for users. For instance, the highest impact of SRI on the profit efficiency of the users was in E-Left ( $ATT = -0.746$ ) followed by Intake C ( $ATT = -0.631$ ) while the highest impact of SRI on cost efficiency was in G-Rice B ( $ATT = -0.071$ ) followed by F-Right ( $ATT = -0.063$ ). Had non-users in N-Rice and Intake C used SRI, neither their cost nor profit efficiency would have changed significantly.

**Table 4:** Impact estimates of the Best Bet SRI on excess cost and profit loss due to technical and allocative inefficiency

Outcome	ATT	ATU	ATE
<b>Based on Pooled</b>			
CEff3	-0.053 (0.006)***	-0.026 (0.031)	-0.159 (0.012)***
PEff3	-0.401 (0.063)***	-0.046 (0.026)*	0.022 (0.051)
<b>Based on Sector</b>			
<b>E-Down</b>			
CEff3	-0.094 (na)	0.56 (na)	-0.34 (na)
PEff3	-1.383 (na)	-0.175 (na)	-0.155 (na)
<b>E-Left</b>			
CEff3	-0.047 (0.018)**	-0.022 (0.054)	-0.189 (0.043)***
PEff3	-0.746 (0.154)***	-0.112 (0.046)**	0.030 (0.092)
<b>M-Rice B</b>			
CEff3	-0.051 (0.010)***	0.006 (0.029)	-0.185 (0.021)***
PEff3	0.061 (0.136)	-0.110 (0.028)***	0.083 (0.115)
<b>N-Rice</b>			
CEff3	-0.054 (0.007)***	-0.025 (0.052)	-0.225 (0.020)***
PEff3	-0.39 (0.118)***	-0.024 (0.020)	-0.035 (0.097)
<b>G-Rice B</b>			
CEff3	-0.071 (0.016)***	-0.159 (0.034)***	0.075 (0.015)***
PEff3	-0.284 (0.137)*	-0.037 (0.020)	0.020 (0.131)
<b>Intake C</b>			
CEff3	-0.059 (0.011)***	-0.014 (0.059)	-0.199 (0.048)***
PEff3	-0.631 (0.168)***	-0.10 (0.056)	-0.087 (0.124)
<b>F-Right</b>			
CEff3	-0.063 (0.011)***	0.09 (0.025)***	-0.144 (0.018)***
PEff3	-0.519 (0.176)**	-0.145 (0.021)***	-0.188 (0.154)

\*\*\*<0.01 and \*\*<0.05; CEff3 = Cost efficiency due to technical and allocative inefficiency; PEff3 = Profit efficiency due to technical and allocative inefficiency; na=not available; Values in brackets are standard errors

## CONCLUSION AND RECOMMENDATIONS

The study concluded that price of fertilizer (organic and inorganic), the price of agrochemical, the amount of credit received and the distance to rice plots influenced the



adopters' cost and profit efficiency. Similarly, for non- users, the price of organic fertilizer, the price of agrochemical and the distance to rice plots were the key determinants of the cost and profit efficiency. There was evidence of a positive impact of SRI on cost and profit efficiency through reduction of excess cost of production and profit loss from rice farming among the users. Based on the findings of this study it is recommend that more efforts should be harnessed by the government and research institutes to encourage the testing and promotion SRI technology across other States of the economy in order to significantly reduce the current deficit of rice in the country and extension services should be used extensively in this process as the right link between farmers and other stakeholders such as input dealers and research institutes.

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