Guidance and Technology: An Assessment of Project Intervention and Promoted Technologies

Valerien O. Pede, Justin D. McKinley, Raman Sharma, and Anurag Kumar

***Abstract*— This study used primary data, collected as part of the Cereal Systems Initiative for South Asia (CSISA) project to compare net returns and cost efficiency between farmers who are beneficiaries of the project to farmers who are not beneficiaries. Additionally, non-beneficiary farmers who use the promoted technologies from the project are compared to other non-beneficiary farmers who do not use the promoted technologies. Propensity score matching is used to account for selection bias when comparing the outcomes of beneficiary and control groups. Results indicate higher return for project recipients as well as farmers who use the CSISA promoted resource-conserving technologies (RCTs).**

Keywords- conservation agriculture; India; propensity score matching; resource-conserving technologies; selection bias; zero-tillage

I. INTRODUCTION

Rice and wheat are immensely important crops for India. Rice is a staple crop for 65% of the population and constitutes nearly 55% of the total cereal production in the country. Much of this crop production comes from the study area of this paper, Bihar and eastern Uttar Pradesh (EUP); represent 7.5% and 12.6%, respectively [9]. Wheat represents approximately 35% of India's food grain production. Of this, 90% comes from the plain states of northern India, including Bihar and EUP. Uttar Pradesh was the largest producer of wheat in 2009 with a total of 24.3 million tons [6].

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Valerien O. Pede is with the Social Sciences Division of the International Rice Research Institute, Los Baños, Philippines. (phone: +63(2) 580-5600; fax: +63(2) 580-5699; e-mail: v.pede@irri.org).

Justin D. Mckinley is with the Social Sciences Division of the International Rice Research Institute, Los Baños, Philippines. (e-mail: j.mckinley@irri.org).

Raman Sharma is with the India office of the International Rice Research Institute, New Delhi, India and is working in the CSISA-hub located in Kushinagar, Uttar Pradesh (e-mail: raman.sharma@irri.org).

Anurag Kumar is with the India office of the International Rice Research Institute, New Delhi, India and is working in the CSISA-hub located in Begusarai, Bihar (e-mail: anurag.kumar@irri.org).

These cereal crops are water and labor intensive, two scarce resources in Bihar and EUP. In an effort to alleviate the demands for these resources, as well as decrease hunger and malnutrition while increasing income and food security, the Bill and Melinda Gates Foundation and USAID have funded the Cereal Systems Initiative for South Asia (CSISA) project. This project promotes the use of resource-conserving technologies (RCTs) in rice-wheat cropping systems. These technologies, such as zero-tillage (ZT) and direct-seeded rice (DSR), reduce the amount of water and labor necessary for cereal production. This study evaluated the performance of farmers engaged in the CSISA project in the season of rabi[1] 2011 for wheat. In addition, to evaluate the economic performance of non-beneficiaries who use RCTs compared to those who do not, this study evaluated the difference in net returns and cost efficiency for these farmers

CSISA intervention involves outreach and engagement with farmers through attendance in travelling seminars, trainings, field visits, and technology demonstrations. Farmers who are receiving intervention from the CSISA project also gain access to technologies, and in some cases the farmers will also receive subsidies from CSISA. However, being involved in the project does not guarantee subsidies to a farmer. The effectiveness of CSISA interaction, as well as the use of RCTs are being evaluated through the use of cost and return surveys that have been conducted for every season since 2009. Data for this study is from the cost and return survey for the wheat season of rabi 2011 and is conducted over Bihar and EUP.

II. OBJECTIVE

There were two main objectives to this study. Firstly, this study aimed to evaluate the differences between farmers who received intervention from the CSISA project to a control group of farmers who were not receiving intervention. This helps to measure the effectiveness of participation with the project. Secondly, this study looked only at farmers who were not receiving intervention from the CSISA project but use the CSISA-promoted RCTs compared to a control that doesn't use the RCTs. In the rabi season, the promoted RCT is ZT-wheat compared to conventional tillage. Non-beneficiary farmers will be evaluated to help determine the effectiveness of the RCTs without contact with CSISA. In all situations, the net returns and a stochastic frontier analysis of technical and cost

[1] Rabi/winter season runs from November to March. Wheat is the primary crop grown in this season. Other crops include sugarcane, vegetables, oilseed, and pulses.

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efficiency are used to evaluate the differences in the two groups.

Beneficiary farmers in the CSISA project were selected using a random stratified sampling procedure. However, these farmers were selected from a pre-approved list of farmers in the region. To address selection bias, this study uses propensity score matching (PSM). The propensity score of the comparison groups are compared using 1-to-1 nearest neighbor matching outlined in Caliendo and Kopeinig [1]. Samples that lay outside of the supported region (i.e. vary too much between control and beneficiary groups) are removed. Remaining farmers are then paired 1-to-1 between the beneficiary group and control group.

The remainder of this paper is organized as follows: section III describes the methodology used for cost and return analysis and stochastic frontier cost efficiency, section IV provides a description of the data used and results for the wheat season of rabi 2011, and section V concludes.

III. METHODOLOGY

The first way that this study measured the effectiveness of the guidance and promoted technologies of the project was through a cost and return analysis. The net returns of farmers were determined by taking the gross return minus total variable costs (including imputed costs such as family labor) and subsidies received from the project or other sources. All values are reported per hectare. Costs and returns were computed as follows:

$$NR = P_w Q_w - \left[\sum_{j=1}^{n} r_j q_j + S \right], \tag{1}$$

where NR is net return; P_w is farm-gate price of wheat; Q_w is yield of wheat reported per hectare; r_j is the price of variable input j; q_j is the quantity of variable input j; n is the number inputs and S is the total value of subsidies received by the farmer.

Cost efficiency is derived from Farrell [4], who first illustrated the idea of allocative and technical efficiency in 1957. Figure 1, shows a simple example using two inputs (x_1 and x_2) to produce a single output (P), assuming a constant return to scale.

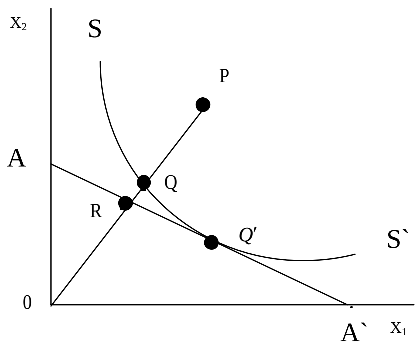

Figure 1. Technical and allocative efficiency from Farrell [4].

In figure 1, SS` represents a frontier isoquant for inputs of production, $x_1$ and $x_2$, such that $f(x_1, x_2) = 1$. Line AA` represents the price relationship of inputs x_1 and x_2. Point Q is technically efficient on the isoquant SS`. However, this point is not allocatively efficient because the cost of production is greater than P = Q', the most allocatively efficient point. Allocative efficiency can then be measured by the ratio 0R/0Q and economic efficiency can be measured by the ratio 0R/0P.

Cost efficiency of a farmer is defined as the ratio of input costs associated with input vectors related with the points P and Q' to output:

$$CE = \frac{OR}{OP}. \tag{2}$$

If the slope of the isocost line, AA`, represents the input to price ratio, then allocative efficiency and technical efficiency measures can also be calculated using the isocost line:

$$AE = \frac{OR}{OQ} \qquad TE = \frac{OQ}{OP}. \qquad (3)\ (4)$$

The distance RQ represents the reduction in production costs that would occur if the farmer produced at the allocatively (and technically) efficient point Q' rather than at the technically efficient, but allocatively inefficient, point Q. Given the measure of technical efficiency, the total overall cost efficiency (CE) can be expressed as a product of technical and allocative efficiency measure:

$$TExAE = (OQ/OP)x(OR/OQ) = (OR/OP) = CE \tag{5}$$

These efficiency measures assume that production technology is known. In practice, this is not the case, and the efficiency isoquant must be estimated for the sample data according to Coelli et al. [5].

The parametric approach for cost efficiency, based on a specific stochastic frontier cost function, is identical to the one proposed by Schmidt and Lovell [6] as follows:

$$C = f(x;\beta)\exp(V+U), \tag{6}$$

where, C is the cost of production of the household; x is a vector representing the input prices and output of the household; β is a vector of unknown parameters; V represents random variables, assumed to be identically distributed as $N(0,\sigma^2)$, and independent from other random variables; U represents random variables that are assumed to account for the inefficiency in production, which in this case is assumed to have a non-negative, normal distribution; and U also defines how far the farmer operates from the cost frontier.

The procedure performed by Ogundari et al. [7], based on Coelli et al. [5], defined cost efficiency in terms of the ratio of observed cost (C) to the corresponding minimum cost (C*) of the most efficient farmer, given the available technology. The cost efficiency is defined as follows:

$$\frac{C}{C^*} = \frac{f(x;\beta)\exp(V+U)}{f(x;\beta)\exp(V)} = \exp(U) \quad , \qquad (7)$$

where C represents the total variable paid-out costs of production and C* represents the level of total frontier production cost. Hence, the cost efficiency level takes a value that is equal to or larger than 1. The most cost efficient farmer will have a cost efficiency level 1 and the higher the value of corresponding farmers, the more cost inefficient they are.

Seven independent variables were included in the cost frontier function. These variables were seed price, labor price, fertilizer price, chemical price, diesel price, and machine price with yield also included in the specification. This study specified the model using a Cobb-Douglas functional form. The Cobb-Douglas form is expressed as:

$$\ln C = \beta_0 + \sum_k \beta_k \ln x_k + (V+U) \qquad (8)$$

where x is a vector of input prices and yield and V and U are as described in equation 6.

The cost inefficiency model is expressed as:

$$U = \delta_0 + \sum_\phi \delta_\phi Z_\phi \quad , \qquad (9)$$

Where δ are unknown parameters, Z is a vector of variables thought to influence cost inefficiency, such as: a dummy variable if the respondent receives CSISA intervention (1: yes; 0: no), a dummy variable for type of irrigation (1: water pump, 0: otherwise), a dummy variable for cropping system (1: rice–wheat, 0: otherwise), years in school, farming experience in years, a dummy variable for production system (1: Irrigated lowland, 0: otherwise), and a dummy variable for geographical location (1: Bihar, 0: EUP).

Similarly to equation 9, technical efficiency was determined using the same variables to account for inefficiency as the cost efficiency model. However, to determine technical efficiency quantities of inputs are used rather than prices of inputs in the case of cost efficiency analysis. The technical efficiency model is expressed as yield determined by inputs: seed, nitrogen (urea or DAP), potassium, zinc, herbicide, diesel, man hours, machine hours for cultivation, machine hours for irrigation, and machine hours for harvest.

IV. DATA AND RESULTS

A. Data

Wheat is the primary crop planted in the study area during the dry season. The primary technology, ZT-wheat provides benefits to many of the farmers during the kharif season, particularly in flood prone regions. Bihar, for example, has over 2 million hectares of flood-prone land. [2, 8], the excessive moisture on these lands prevents farmers from cultivating the fields. As a result, more than 60% of the wheat crop is planted late [2]. This delay in planting reduces yield and water-use efficiency [5]. By engaging in ZT-wheat, farmers no longer need to cultivate their fields prior to planting. This allows them to establish their crops sooner and avoid reductions in yield due to late sowing.

TABLE I
SOCIOECONOMIC CHARACTERISTICS OF WITH- AND WITHOUT- INTERVENTION FARMERS

		Before PSM	After PSM
	Without Intervention (n=124)	**With Intervention (n=242)**	**With Intervention (n=124)**
Gender (%)			
Male	100.00	100.00	100.00
Female	0.00	0.00	0.00
Marital Status (%)			
Married	96.77	95.45	96.77
Single/Widowed	3.23	4.55	3.23
Primary Occupation (%)			
Farming	92.74	88.43*	95.97
Other	7.26	11.57*	4.03
Type of household (%)			
Absolute nuclear	51.61	55.79	54.03
Extended family	48.39	44.21	45.97
Age (years)	51.22	48.91*	50.36
Years in school	9.88	11.63***	9.85
Household size (persons)	7.98	7.79	7.78
Farming experience (years)	28.45	27.84	28.4

Note: a comparison of means t-test was conducted between the with- and without-intervention farmers before and after treatment. *,**, and *** are significant at 10%, 5%, and 1%, respectively.

After removing outlying farmers, the total sample for was 366, of which, 242 had received intervention from the CSISA project and 124 had not. After implementing the PSM 1-to-1 nearest neighbor matching without replacement treatment, the sample was reduced to 124 households with intervention and 124 without intervention. Socioeconomic characteristics of the primary farmers and their households can be seen in table 1. The table shows the correction of observed biases through the use of PSM. After PSM, a comparison of means t-test shows that the variables for primary occupation, age, and years in school no longer significantly different.

TABLE II
SOCIOECONOMIC CHARACTERISTICS FOR ZT-ADOPTERS AND NON-ADOPTERS

	Before PSM		After PSM	
	ZT-wheat group (n=40)	**Control group** (n=84)	**ZT-wheat group** (n=32)	**Control group** (n=32)
Gender (%)				
Male	100.00	100.00	100.00	100.00
Female	0.00	0.00	0.00	0.00
Marital Status (%)				
Married	97.50	96.42	96.88	100.00
Single/Widowed	2.50	3.58	3.12	0.00
Primary Occupation (%)				
Farming	95.00	91.67	93.75	93.75
Other	5.00	8.33	6.25	6.25
Type of household (%)				
Absolute nuclear	47.50	53.57	46.88	50.00
Extended family	52.50	46.43	53.12	50.00
Age (years)	46.53	53.45***	49.72	48.88
Years in school	11.95	8.89***	11.81	11.72
Household size (persons)	6.75	8.57***	7.09	8.34*
Farming experience (years)	25.98	29.63*	28.03	26.43

Note: a comparison of means t-test was conducted between the with- and without-intervention farmers before and after treatment. *,**, and *** are significant at 10%, 5%, and 1%, respectively.

Table 2 illustrates the socioeconomic characteristics farmers who have adopted ZT-wheat versus non-adopters. None of the farmers in this sample are receiving intervention from the CSISA project. Before treatment the sample size was 124, of which, 40 were using ZT-wheat and 84 were not. The PSM 1-to-1 nearest neighbor without replacement treatment was also applied to this group. The matching technique found 8 farmers who used ZT-wheat to be outside of the range of common support and those farmers were consequently dropped from the sample. The end sample was 32 farmers using ZT-wheat and 32 control farmers. The two groups of farmers, prior to treatment, were found to be significantly different in age, level of education, and household size at 1% and farming experience at 10%. Corrections in observable biases are seen in table 2 where age, years in school, household size, and farming experience were found to either not be significantly different, or the level of significance was decreased after the PSM treatment was applied.

B. Results

Farmers who were receiving intervention from the CSISA project were found to have higher net returns than those farmers who did not receive intervention from the project before and after the PSM. In both cases, the average net return for with-intervention farmers is over 9,000 Rs/ha higher than without-intervention farmers. In addition to higher yields, farmers who receive CSISA intervention were found to have lower costs of production, particularly in the case of seed, fertilizer, and machine costs. Cost and return details are presented in table 3 for the with- and without-intervention farmers before and after PSM. Additionally, the difference in net returns after the treatment can be seen in figure 2.

TABLE III

COST AND RETURN RESULTS FOR WITH- AND WITHOUT- INTERVENTION FARMERS

		Before PSM	After PSM
	Without intervention	**With intervention**	**With intervention**
	(n=124)	(n=242)	(n=124)
Production-			
Yield	3.4	3.75***	3.70***
Farm gate price	10,446.77	10,525.70	10,530.09
Value of cereal	35,505.82	39,475.94***	38,964.57***
Paid out costs-			
Seed	3,023.23	2,030.60***	2,035.57***
Fertilizer	3,498.42	3,269.87**	3,188.08***
Insecticide	27.14	25.12	26.29
Herbicide	337.83	287.35	268.32
Fungicide	5.34	4.16	3.01
Non-chemical	891.83	831.38	871.65
Labor	4,627.96	4,277.80	4,260.59**
Machine	7,741.28	5,226.36***	4,916.81***
Total paid out	20,153.03	15,952.65***	15,570.32***
Imputed costs-			
Material subsidies	44.24	338.12***	283.96***
Machine subsidies	-	2.55***	2.808***
Total subsidies	44.24	340.67***	286.77***
Imputed labor	2,276.99	998.79***	1,021.25***
Total imputed	2,365.47	1,339.46***	1,654.23**
Net returns-			
Gross returns - paid out costs	15,352.78	23,523.29***	23,394.25***
Gross returns - total costs	13,031.55	22,183.83***	22,086.23***

Note: a comparison of means t-test was conducted between the with- and without-intervention farmers before and after treatment. *,**, and *** are significant at 10%, 5%, and 1%, respectively.

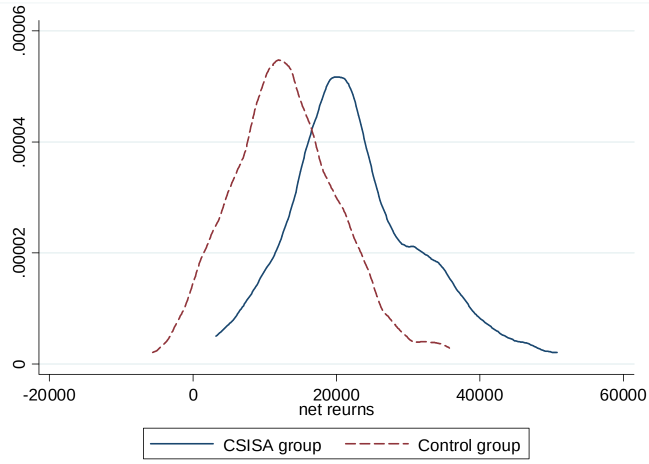

Figure 2. Kernel density distribution of net returns (Rs ha^{-1}) between with- and without-intervention farmers, rabi 2011.

Without-intervention farmers were further divided into those who are engaged in ZT-wheat, and those who are not using the RCT. Famers engaged in ZT-wheat were found to have significantly higher net returns before and after PSM. These results were true even though the control group had higher average yields and consequently, a higher value of cereal crop before and after PSM treatment. A detailed account for cost and return is presented in table 4 for ZT-wheat adopters and non-adopters, before and after PSM. In addition, a kernel density graph of net returns for the after-PSM group of adopters and non-adopters is presented in figure 3.

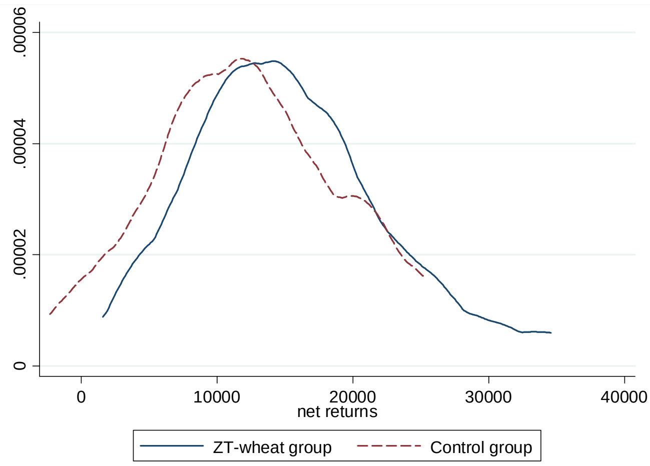

Figure 3. Kernel density distribution of net returns (Rs ha^{-1}) between ZT-wheat adopters and non-adopters, rabi 2011.

The level of cost efficiency was also measured between with- and without-intervention farmers and ZT-wheat adopters and non-adopters. For this analysis, the most cost-efficient farmer has a level of 1 and all other farmers have a level of cost efficiency higher than 1. For example, cost efficiency level of 2.0 means that a farmer spends two times as much as the most efficient farmer for the same level of output. Cost efficiency was measured using the after-PSM group of with- and without-intervention farmers.

Results of the determinants of cost efficiency reveal that farmers who are engaged in the CSISA project are more cost efficient at the 1% level. This result was expected and is likely caused by the use of the promoted technologies and the guidance provided by the project, not only in the use of RCTs but also in best agronomic practices. In addition, using a water pump for irrigation made the farmers less cost efficient at the 5% level. Most likely a result of high diesel costs to run the irrigation pump. Farmers who were located in Bihar were found to be more cost efficient than those in EUP at the 10% level. These results are indistinct and would require a more in-depth study to more accurately ascertain the determinants. Lastly, farmers with more experience farming were found to be more cost efficient at the 10% level; showing that farm experience matters among the sampled farmers in the Bihar and EUP locations.

Farmers receiving intervention from the CSISA project were found to be more cost efficient at the 1% level of significance than the control group. CSISA farmers had a mean level of cost efficiency of 1.64 as compared to the control group's cost efficiency level of 2.15. A kernel density graph of the results is presented in figure 4.

TABLE IV
COST AND RETURN RESULTS FOR ZT-WHEAT ADOPTERS AND NON-ADOPTERS

	Before PSM		After PSM	
	ZT-wheat group (n=40)	Control group (n=84)	ZT-wheat group (n=32)	Control group (n=32)
Production-				
Yield	3.18	3.51***	3.20	3.31
Farm gate price	10,637.50	10,355.95***	10,650.00	10,525.00
Value of Cereal (A)	33,765.94	36,334.33**	34,063.99	34,860.80
Paid out costs-				
Seed	2,534.23	3,256.09***	2,589.46	3,134.46**
Fertilizer	3,315.86	3,585.36*	3,392.78	3,620.34
Insecticide	54.77	13.99**	68.46	21.09
Herbicide	252.62	378.40*	267.35	199.64
Fungicide	16.56	0.00*	20.70	0.00
Non-chemical	2,082.57	324.81***	2,201.27	593.35***
Labor	4,005.20	4,924.51*	4,179.51	5,003.92
Machine	4,600.03	9,237.12***	4941.54	8,142.89***
Total paid out (B)	16,861.83	21,720.27***	17,661.08	20,715.69***
Imputed costs-				
Material subsidies	137.14	-	92.66	-
Machine subsidies	-	-	-	-
Total subsidies	137.14	-	92.66	-
Imputed labor	828.60	2,966.70***	1,012.58	1,939.15**
Total imputed (C)	965.74	2,966.70***	1,105.25	1,939.15*
Gross Returns-				
-paid out costs (A-B)	16,904.10	14,614.06***	16,402.91	14,145.10*
-total costs (A-(B+C))	15,938.36	11,647.36***	15,297.66	12,205.95**

Note: a comparison of means t-test was conducted between the with- and without-intervention farmers before and after treatment. *,**, and *** are significant at 10%, 5%, and 1%, respectively.

The cost efficiency levels of farmers who were not engaged in the CSISA project were also compared. In this situation, ZT-wheat adopters were compared to non-adopters. Farmers who were using the ZT technology in wheat were found to be slightly more cost efficient. The ZT-wheat group had a mean level of cost efficiency of 2.07. The mean level of cost efficiency for the non-adopters was 2.16. However, this difference was not significant. Results of the cost efficiency levels are shown in figure 5.

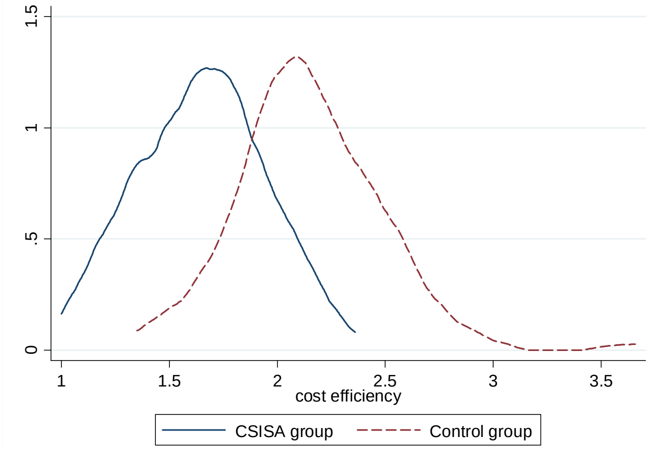

Figure 4. Kernel density distribution of cost efficiency level between with- and without- intervention farmers, rabi 2011

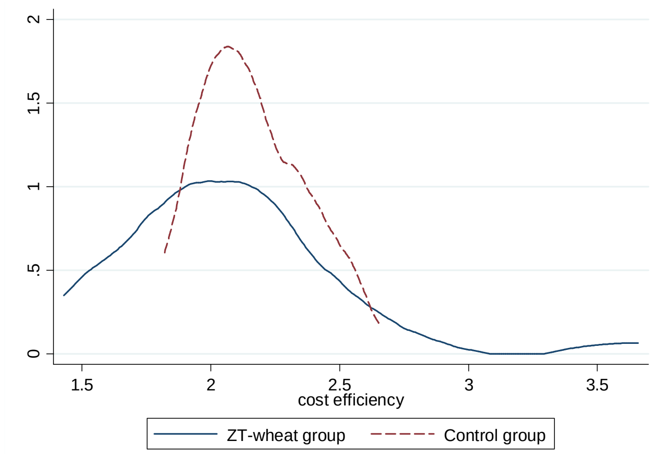

Figure 5. Kernel density distribution of cost efficiency level between ZT-wheat adopters and non-adopters, rabi 2011

Beneficiaries of the CSISA project were also found to be more technically efficient than the control group at the 1% level of significance. Meaning that the CSISA group is producing more outputs with fewer inputs than the control group (see figure 6.). The closer to 1 that a farmer operates, the more output he has with fewer inputs. CSISA farmers had a mean level of technical efficiency of 0.725 and the control group had a mean of 0.636. Beyond receiving intervention from CSISA, farmers were found to be more technically efficient if they had higher levels of education (significant at 1%) and less technically efficient if they use a water pump for irrigation (significant at 10%). Likely a result of increased inputs for irrigation machine rental time and diesel fuel costs associated with water pump irrigation.

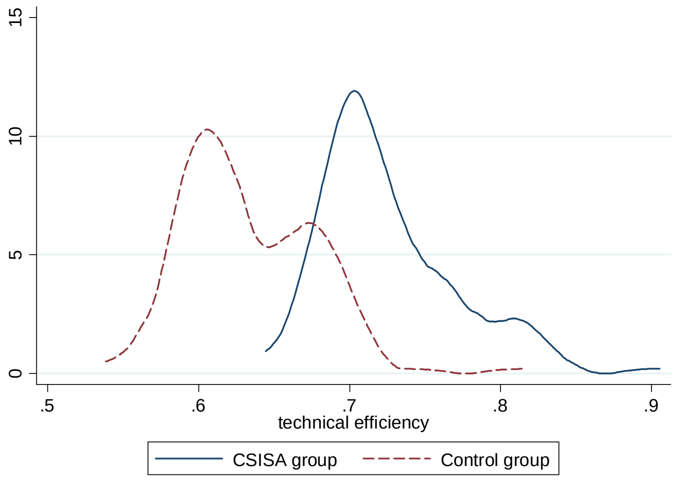

Figure 6. Figure 2. Kernel density distribution of technical efficiency level between with- and without- intervention farmers, rabi 2011

ZT-adopters had mean kevel of technical efficiency of 0.622 as compared to 0.646 in the control group. This differnence was found to be statistically significant at 5%. This difference could be partially explained by the increased inputs of diesel fuel for ZT-adopters. This result is opposite of what was expected and needs further investigation.

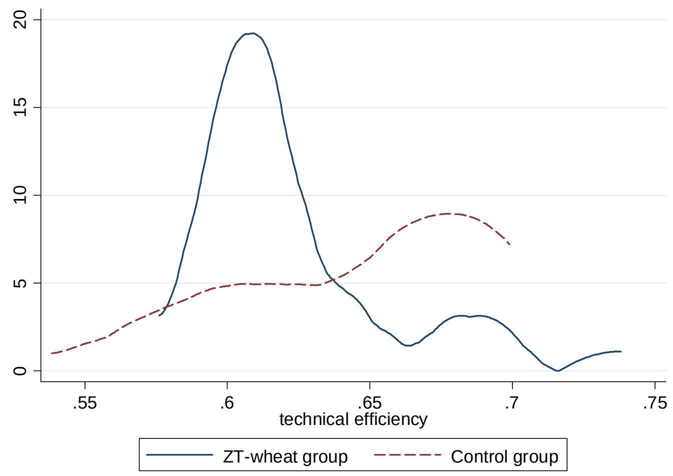

Figure 7. Figure 3. Kernel density distribution of technical efficiency level between ZT-wheat adopters and non-adopters, rabi 2011

V. Conclusion

This study compared beneficiaries of the CSISA project to non-beneficiaries as well as technology adopters and non-adopters of CSISA-promoted ZT-wheat. The purpose was to help determine what aspects of the project are having a larger impact, guidance or technology. The results indicate that farmers who received intervention from the CSISA project had higher net returns than the control group (significant at 1%), were more cost efficient (significant at 1%), and were more technically efficient (significant at 1%). Farmers who adopted the promoted technologies, but were not part of the project, had higher net returns than non-adopters (significant at 5%), a slightly higher level of cost efficiency than non-adopters (no significance), but were less technically efficient (significant at 5%). These results indicate that CSISA-guidance may have a more substantial role in the performance of farmers than the use of the ZT-wheat technology. Meaning, the technology is only as useful as the farmers' understanding of how to use it properly.

The results of this study, particularly between adopters and non-adopters, are limited by a small control group. Results received from a sample of 32 adopters and 32 non-adopters are a good indicator of a potential problem, but more studies should be carried with a larger sample to more adequately address the impact of technology adoption in farmers who are not receiving guidance from the project. In addition, future studies should incorporate more variables to account for best agronomic practices and more consideration should be taken to account for selection bias issues. Even with the use of PSM, it is possible that the effect of the project and the technologies are both being overstated.

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