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Impact of zero tillage adoption on household welfare in Pakistan

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The current study was carried out to estimate the impact of zero tillage technology adoption on household welfare in Pakistan. For the study cross sectional data set was collected from 234 households in the rice-wheat area of Pakistani Punjab. The data was collected through stratified random sampling technique from 3 main districts of rice-wheat area namely Gujranwala, Sheikhupura and Hafizabad. The empirical analysis was carried out by employing the propensity score matching approach to correct for potential sample selection biased ness that may arise due to systematic differences between adopters and non adopters. The empirical result indicates that adoption of zero tillage technology has positive and significant impact on wheat yield and household income while non significant impact on rice yield. Most importantly the adoption of zero tillage technology can help to reduce poverty among rural households in the range of 8-10 percent.

Keywords: Adoption, Impact Evaluation, Zero Tillage, Propensity score matching, Punjab, Pakistan.

Introduction

Rice-Wheat Cropping Zone in Pakistan

In South Asia, rice-wheat cropping systems cover 13.5 million hectares and are source of income and food to many millions of people (Gupta et al., 2003; Timsina and Connor, 2001). The rice-wheat system is primarily irrigated with 85 percent concentrated in the Indo-Gangetic Plains (IGP) (Timsina and Connor, 2001). In the face of increasing competition for water from industrial, domestic and environmental sectors, concerns are being raised about the productivity of water used in agriculture (Kijne *et al*., 2003). Increasing water scarcity is also seen as a major contributor to stagnating productivity in the rice-wheat cropping systems of the IGP (Byerlee et al., 2003; Kumar et al., 2002). In the face of unreliable canal water supplies, many farmers have

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increased their reliance on private tube wells, placing tremendous pressure on groundwater supplies (Abrol 1999; Ahmad *et al*. 2007; Qureshi *et al*. 2003). Negative environmental effects related to irrigation are increasing as overexploitation of groundwater and poor water management lead to the dropping of water tables in some areas and increased water logging and salinity in others (Harrington *et al*., 1993; Pingali and Shah 2001; Qureshi *et al*., 2003). In addition, tube-well irrigation has raised production costs in view of the energy expenses incurred (electricity or diesel) (Qureshi *et al*., 2003). Agricultural technologies that can save water, reduce production costs and improve production are therefore becoming increasingly important (Gupta *et al*., 2002; Hobbs and Gupta, 2003).

The rice-wheat cropping zone of Punjab is the main producer of high-valued and fine quality basmati rice in Pakistan. The rice produced in this area is famous for its grain length and aromatic characteristics. Being an important export item, rice contributes significantly to the national foreign exchange earnings. Wheat is the other major crop of the rice-wheat system and being the staple food is central to national agricultural policies. Rice is grown on a vast area in this zone during *Kharif* mostly followed by wheat in the *Rabi* season. Studies have shown that a large gap exists between the potential and actual yields realized by the wheat growers of the area (Byerlee *et al*., 1984).

Farmers’ practices regarding land preparation for paddy, wheat planting time, and other conflicts endogenous to the rice-wheat based cropping system were identified as the major factors limiting wheat yield in the area. The flooded and puddled soils that are well suited for paddy production as compared to well-drained conditions required for wheat is such an example of the system conflicts. The farmers in the rice-wheat zone of the Punjab predominantly grow basmati varieties, which are late maturing as compared to coarse varieties of rice. Therefore, paddy harvest is generally delayed at most of the farms in this zone. The late paddy harvest coupled with poor soil structure and loose plant residues create problems for preparation of a good seedbed and planting of wheat often gets late (Byerlee *et al*., 1984). The farmers also had to resort to the broadcast method for wheat sowing which results in poor and patchy plant stands. Moreover, the occurrence of rain during land preparation operations may cause a further delay of 2-3 weeks in wheat sowing (Aslam *et al*., 1993). Studies have reported that after the mid-November a day’s delay in planting of wheat results in a yield loss of one percent per hectare.

Adoption of Zero Tillage Technology in Pakistan

Farmers in the Indo-Pak sub continent are rapidly adopting zero-tillage for sowing wheat after rice due to unbelievable benefits from zero tillage i.e.

most important timely sowing of wheat, more yield, cost effectiveness, soil quality and significant saving in water. The conventional tillage practices after rice harvest involve extensive ploughing with common cultivator and deep tillage implements for preparation of a fine seedbed for wheat planting which is time consuming as well as costly. In order to save the sowing time and the tillage costs, a new seed drill was introduced in early 1980s that made it possible to sow wheat in freshly harvested and untilled paddy fields utilizing residual moisture. The drill was named as zero tillage drill and the method of wheat sowing with this drill is called as zero-tillage technology. The results of this experimentation showed that the crop stand is improved for wheat sown with zero-tillage drill as compared to that obtained under conventional system. Based on these findings a comprehensive zero-tillage pilot production program was initiated in 1990s to expand the usage of the technology in the rice-wheat zone of Punjab (Aslam *et al.,* 1993). However, a perceptible use of the drill started by the On-Farm Water Management (OFWM) and got involved in drill promotion efforts. The zero-tillage technology is widely maintained as an integrated approach that can tackle the problem of wheat yield stagnation in the rice-wheat zone by improving planting time and enhancing fertilizer and water use efficiency. It is observed that zero-tillage technology helps in reducing the Phalaris minor weed infestation and also enables timely seeding of the wheat crop. During the past two years substantial wheat acreage was sown with zero-tillage drill. ZT in rice-wheat systems ranges from surface seeding to planting with seed drills drawn by four-wheel tractors (Hobbs *et a*l., 1997). In surface seeding, wheat seeds are broadcasted on a saturated soil surface before or after rice harvest (Tripathi *et al*., 2006). It is a simple technology for resource-poor farmers requiring no land preparation and no machinery, but its use is still largely confined to low-lying fields that remain too moist for tractors to enter, particularly in the eastern IGP. Mechanized ZT has proven more popular in the IGP, but implies the need for a tractor-drawn ZT seed drill. This specialized seeding implement allows wheat seed to be planted directly into unplowed fields with a single pass of the tractor, often with simultaneous basal fertilizer application.

The use of ZT significantly reduces energy costs, mainly by reducing tractor costs associated with CT methods, and also because water savings reduce the time that tube wells must be operated. The use of ZT also allows the wheat crop to be planted sooner than would be possible using CT methods, which significantly reduces turnaround time. This is an important consideration in many parts of the rice-wheat belt, where late planting of wheat is a major cause of reduced yields: terminal heat implies that wheat yield potential reduces by 1-1.5 percent per day if planting occurs after 20th November (Ortiz-Monasterio *et al*., 1994; Hobbs and Gupta, 2003).

The zero-tillage technology is widely maintained as an integrated approach that can tackle the problem of wheat yield stagnation in the rice-wheat zone by improving planting time, reducing weed infestation, and enhancing fertilizer and water use efficiency Hobbs *et al.* (1997).

The current study was carried out with the objective to analyze the impact of zero tillage adoption on household welfare in Pakistan. The welfare is estimated in terms of crop yield, household income, labour demand and input savings. For that the rest of the paper is organized as follows. In section 2 conceptual framework is presented. In section 3 empirical model is presented. In section 4 data and description of variables are presented. In section 5 empirical results are presented and paper finally concludes with some policy recommendation.

Conceptual Framework

Zero Tillage Technology Adoption

Let the adoption of zero tillage technology be a binary choice, where the farmers adopt the new technology when the net benefits from adoption are greater as compared to non adoption. The difference between the net benefits from adoption and non adoption can be denoted as P^* such that $P^*>0$ indicates that the net benefits from adoption are greater as compared to non adoption. Although P^* is not observable, but it can be expressed as a function of observable elements in the following latent variable model

$$P_i^* = \beta X_i + \varepsilon_i \quad , \qquad\qquad P_i = 1[P_i^* > 0] \qquad (1)$$

Where P_i is a binary choice variable that equals 1 for household *i* in case of adoption and 0 otherwise, β is a vector of parameter to be estimated, X_i is a vector of household and plot level characteristics and ε_i is an error term assumed to be normally distributed.

The probability of adoption of new technology can be represented as

$$\Pr(P_i = 1) = \Pr(P_i^* > 0) = \Pr(\varepsilon_i > -\beta X_i) = 1 - F(-\beta X_i) \qquad (2)$$

Where F is the cumulative distribution function for ε_i. Different models like probit and logit normally results from the assumptions, which are made about the functional form of F. As the adoption of zero tillage drill is expected to affect the demand for inputs such as labour demands as well as yields and net returns.

To link the adoption decision with the potential outcomes of adoption, we consider a risk neutral farm that maximizes net returns π, subject to competitive inputs and outputs markets and single output technology that is quasi concave in the vector of variables inputs, W. This can be expressed as

$$\max \pi = RQ(W, X) - Y^{/}W \quad (3)$$

Where R is the output price, and Q is the expected output level, Y is the column vector of input prices, where W is a vector of input quantities and X represent farm and household characteristics. The farm net returns can be expressed as a function of technology choice P, output price, variable inputs and household characteristics as follows.

$$\pi = \pi(P, Y, R, X) \quad (4)$$

Application of Hotelling's lemma to equation (3) yields reduced form equations for input demand and output supply

$$W = W(P, Y, R, X) \quad (5)$$

$$Q = Q(P, Y, R, X) \quad (6)$$

The specification in equation (4)-(6) show that the choice of technology input and output prices, as well as farms and household characteristics tends to influence farm net returns, demand for inputs and level of farm output.

Impact evaluation problem

The discussion in the previous section shows that new agricultural technologies can help increase productivity and farm incomes, and as such, improve the welfare of farm households. Although several other reasons can be advanced to explain why agricultural technology may be crucial in improving the welfare of farm households, it is difficult to simply attribute the differences in welfare between adopters and non-adopters of the technology to adoption. In cases where experimental data are gathered through randomization, information on the counterfactual situation would normally be provided, and as such the problem of causal inference can be resolved. However, when the data available are from a cross-sectional survey, as the one employed in the present study, no information on the counterfactual situation can be obtained. An effective way of addressing the problem is to resort to an investigation of the direct effect of technology adoption by looking at the differences in outcomes among farm households (Blundell and Costa Dias, 2000).

Given that the decision of households to adopt or not to adopt the new technology may be associated with the net benefits of adoption, the issue of self-selection is crucial. To show the significance of self-selection, consider a reduced-form relationship between the technology choice and the outcome variable such as

$$O_i = \alpha_0 + \alpha_1 P_i + \alpha_2 X_i + \mu_i \qquad (7)$$

Where O_i represents a vector of outcome variables for household *i* such as demand for inputs and farm out, X_i represents farm level and household characteristics, μ_i is an error term with $\mu_i \sim N(0,\sigma)$. The issue of selection bias arises if unobservable factors influence both the error term of the technology choice ε_i in equation (1) and the error term of the outcome specification μ_i in equation (7), resulting in a correlation between the two error terms. When the correlation between the two error terms is greater than 0, then OLS regression techniques tends to yield biased estimates. In the current paper to address the sample selection problem, propensity score matching approach is employed.

Propensity Score Matching Approach

The empirical analysis is carried out by employing the propensity score matching approach. It follows that the expected treatment effect for the treated population is of primary significance. This effect may be given as

$$\tau|_{I=1} = E(\tau \mid P=1) = E(O_1 \mid I=1) - E(O_0 \mid P=1) \qquad (8)$$

where τ is the average treatment effect for the treated (ATT), O_1 denotes the value of the outcome for participation in a particular labour category and O_0 is the value of same variable for non participation. A major problem is that we do not observe $E(O_0 \mid P=1)$. Although the difference $[\tau^e = E(O_1 \mid P=1) - E(O_0 \mid P=0]$ can be estimated, it is potentially biased estimator.

In the absence of experimental data, the propensity score-matching model (PSM) can be employed to account for this sample selection bias (Dehejia and Wahba, 2002). The PSM is defined as the conditional probability that a farmer participate in a particular labour category, given pre-adoption characteristics (Rosenbaum and Rubin, 1983). To create the condition of a randomized experiment, the PSM employs the unconfoundedness assumption also known as conditional independence assumption (CIA), which implies that once *X* is controlled for, participation is random and uncorrelated with the outcome variables[i]. The PSM can be expressed as,

$$p(X) = \Pr\{P=1 \mid X\} = E\{P \mid X\} \qquad (9)$$

where I = {0,1} is the indicator for participation and X is the vector of pre-participation characteristics. The conditional distribution of X, given p(X) is similar in both groups of participation and non participation.

Unlike the parametric methods[ii], propensity score matching requires no assumption about the functional form in specifying the relationship between outcomes and predictors of outcome. The drawback of the approach is the strong assumption, of unconfoundness. As argued by Smith and Todd (2005), there may be systematic differences between outcomes of participants and non participants even after conditioning because selection is based on unmeasured characteristics. However, Jalan and Ravallion (2003) pointed out that the assumption is no more restrictive that those of the IV approach employed in cross-sectional data analysis. In a study by Michalopoulos et al. (2004) to assess which non-experimental method provides the most accurate estimates in the absence of random assignment, they conclude that propensity score methods provided a specification check that tended to eliminate biases that were larger than average. On the other hand, fixed effects model did not consistently improve the results.

Average treatment effects

After estimating the propensity scores, the average treatment effect for the treated (ATT) can then be estimated as

$$\tau = E\{O_1 - O_0 \mid P = 1\} = E\{E\{O_1 - O_0 \mid P = 1, p(X)\}\} = E\{E\{O_1 \mid P = 1, p(X)\} - E\{O_0 \mid P = 0, p(X)\} \mid P = 0\} \tag{10}$$

Several techniques have been developed to match adopters with non-adopters of similar propensity scores. In the current paper Nearest Neighbour Matching (NNM) and Mahalanobis Metric Matching (MMM) methods are employed.

Data and Description of Variables

The data and description of variables is presented in table 1. The data was collected from 3 main districts of rice wheat area i.e. Gujranwala, Sheikhupura and Hafizabad. About 46 percent farmers were interviewed from Gujranwala district, 22 percent were interviewed from Sheikhupura district and 32 percent were interviewed from Hafizabad district. In total 234 farmers were interviewed.

The mean distance to the market was about 7 kilometers from the household. The mean age of the farmers was about 45 year and the mean experience was about 24 years. The mean education level was about 6 years of schooling. The average family size was about 7 persons per household. Information regarding a number of household assets was also collected. About 48 percent of the households have own refrigerator and 36 percent of the households have own tractor. About 62 percent of the households have own bicycle. The 30 percent of the households have own motorcycle. Only 8 percent of the households have own zero tillage drill. About 9 percent of the households have own car. About 28 percent of the households have own tube well. About 30 percent of the households have own radio. Similarly 62 percent of the households have own TV. About 58 percent of the households have own washing machine.

About 76 percent of the households have availed credit facility. The area under rice was about 18 acres and average rice yield was 32 maunds[iii]. The area under wheat was about 16 acres per households. The average wheat yield was 27 maunds per household.

Empirical Results

The empirical results regarding technology adoption are presented in table 2. The dependent variable is dummy, i.e. 1 if the farmers have adopted zero tillage technology and 0 otherwise. The distance to market is negative and significant at 10 percent level of significance indicating that more the distance to the market less the adoption of zero tillage technology. The age coefficient is negative and non significant indicating that more the age, less the adoption of zero tillage technology and vice versa. The education coefficient is positive and significant at 5 percent level of significance, indicating that more the education levels more the chances that farmers will adopt the new technology. The family size coefficient is negative and significant at 5 percent levels of significance indicating that large family size households are less willing to adopt the new technology and vice versa.

The farmers' organization membership was also included as dummy variable. The coefficient is negative and non significant. The land holding is positive and highly significant at 1 percent level of significance indicating that large land holders mostly adopt the new technology. A number of different households' assets were also included in the model. The refrigerator ownership is positive and significant at 10 percent level of significance. The tractor ownership is positive and significant at 1 percent level of significance. The bicycle ownership is positive and non significant. The car ownership is negative and non significant. The radio was included as dummy variable to capture impact of information source regarding technology adoption, the coefficient is positive although non significant. The farmers' access to credit is positive and significant at 10 percent level of significance. The agriculture extension services role is positive although non significant.

The district dummies were also included in the model to capture the regional variation. Although individually the district dummies are non significant but collectively they are significantly different from zero. The value of R^2 is 0.69. The high value of R^2 indicates that maximum variation in dependent variables is due to independent variables included in the model. The LR χ^2 is also significant at 1 percent level of significance indicating the robustness of variables included in the model.

After estimating the adoption of zero tillage technology, in order to estimate the extent of adoption of zero tillage technology censored least absolute deviation (CLAD)[iv] model is estimates and the results are presented in table 3. Since in the face of heteroskedaticity or non-normality, the Tobit model produces biased estimates. In contrast, since the censored least absolute deviation (CLAD) estimator does not depend on distributional or homoskedasticity assumptions of the errors and is robust to censoring, it produces consistent estimates even in the face of heteroskedasticity, non-normality and censoring.

As the CLAD estimator imposes the weakest stochastic restrictions on the error terms, it results in the most precise estimates of the policy effects[v].In the model the dependent variable is numbers of acres under zero tillage technology. A set of independent variables are included in the model. The market distance is negative and significant at 5 percent level of significance indicating that as distance to market increases farmers allocate less area under zero tillage technology and vice versa. The results for age coefficient are negative and significant at 10 percent level of significance indicating that mostly the younger farmers allocate more area under zero tillage technology and vice versa. The results for education coefficient are positive and highly significant at 1 percent level of significance. The results for education coefficient indicates that mostly the educated farmers allocate more area under zero tillage technology. The results for family size are positive and non significant. The results for land holding are positive and highly significant at 1 percent level of significance. The results for tractor ownership are also positive and significant at 1 percent level of significance , indicating that households having own tractor allocate more area under zero tillage technology. The results for refrigerator ownership are positive and non significant. The results for zero tillage drill ownership are positive and significant at 1 percent level of significance indicating that households having own zero tillage drill allocate more area under zero tillage technology and vice versa. The results for car ownership are negative and non significant. The results for tube well ownership are positive and non significant. The district dummies were also included in the model to capture the regional variation. The initial sample size was 234 and final sample size was 179. The value of R^2 is 0.350.

Propensity score matching results for average treatment affect for the treated (ATT) are presented in table 4. Two different matching algorithms i.e. Nearest Neighbour Matching (NNM) and Mahalanobis Metric Matching (MMM) are reported. The impact of zero tillage technology is estimated on Rice Yield, Wheat Yield, Labour demand, household income and poverty status. The results for rice yield are positive and non significant both in case of NNM and MMM, indicating that zero tillage technology adoption leads to higher rice yields. The results for wheat yield are positive and significant both in case of NNM and MMM matching algorithms, indicating that zero tillage adoption leads to higher wheat yields. The positive and significant results indicates the importance of zero tillage technology adoption. The results for labour demand are also positive and significant at 10 percent level of significance indicating that zero tillage technology adoption decreases the labour demand. The results for household income are also positive and significant at 1 percent level of significance indicating that zero tillage technology adoption can help to increase household income in the range of rupees 2262 to 2456. The zero tillage technology adoption impact on poverty (head count index) was also estimated. The poverty was negative and significant both in case of NNM and MMM indicating that zero tillage adoption can decrease the household poverty levels from 8-10 percent. The results regarding technology adoption are in line with the previous studies like Ali and Abdulai (2010). Different calipers were employed for estimation of results as table 3 indicates. The critical level of hidden bias is also reported in the table. The critical level of hidden bias ranges from 1.10-1.15 to a maximum of 1.65-1.70. the value of 1.70 indicates that adopters and non adopters differs in their odds of technology adoption upto 70 percent. The number of treated and number of control are also reported in the table.

A number of different balancing tests were employed to check the matching quality like median absolute bias before and after matching and percentage bias reduction and the results are presented in table 5. The bias before matching is quite high both in case of nearest neighbor matching and mahalanobis metric matching. Before matching the bias is in the range of 17.62-25.33. After matching the bias is quite low and is in the range of 6.38-11.52. The percentage bias reduction is in the range of 40.80 to 73.53. The percentage bias reduction indicates that after matching the covariates have been balanced and there is not much difference between adopters and non adopters of zero tillage technology. Another test employed to check the matching quality is the value of R^2 before and after matching. The value of R^2 should be quite high before matching and should be quite low after matching. In the current analysis the value of R^2 before matching quite high in the range of 0.48-0.71.

After matching the value is close to zero indicating that after matching the covariates have been balanced and there is no systematic differences between adopters and non adopters.

The joint significance of covariates is an indicator of covariates balancing. The joint significance of covariates should always be accepted before matching and should always be rejected after matching. In the current analysis the p-value is quite low before matching and is quite after matching hence indicating that after the adopters and non adopters are not systematically different from each other. The results regarding covariates balancing are in line with the previous studies like Faltemier and Abdulai (2009).

Table 1. Data and description of variables

Variable	Description	Mean	Std. Dev
District1 Gujranwala	1 if farmer belongs to Gujranwala district, 0 otherwise	0.457	0.499
District 2 Sheikhupura	1 if farmer belongs to Sheikhupura district, 0 otherwise	0.222	0.416
District 3 Hafizabad	1 if farmer belongs to Hafizabad district, 0 otherwise	0.320	0.474
Market distance	Distance of market in kilometers	6.897	5.417
Age	Age of farmer in number of years	44.918	14.604
Experience	Experience of farmer in number of years	24.008	13.408
Education	Education of farmer in number of years	6.171	4.895
Family size	Total number of family members in the household	6.568	4.340
Refrigerator	1 if household owns a refrigerator, 0 otherwise	0.482	0.500
Tractor	1 if household owns a tractor, 0 otherwise	0.358	0.506
Bicycle	1 if household owns a bicycle, 0 otherwise	0.615	0.487
Motorcycle	1 if household owns a motorcycle, 0 otherwise	0.299	0.458
Zt drill	1 if household owns a Zt drill, 0 otherwise	0.081	0.273
Car	1 if household owns a car, 0 otherwise	0.085	0.280
Tube well	1 if household owns a tube well, 0 otherwise	0.282	0.478
Radio	1 if household owns a radio, 0 otherwise	0.299	0.458
TV	1 if household owns a TV, 0 otherwise	0.619	0.486
Washing machine	1 if household owns a washing machine, 0 otherwise	0.581	0.494
Credit (dummy)	1 if household have access to credit facility, 0 otherwise	0.764	0.434
Extension Contact	1 if farmer have contact with extension services, 0 otherwise	0.273	0.442
Rice area (acres)			
Rice yield (maunds)	Area under rice in acres	18.36	25.205
Wheat area (acres)	Yield of rice in maunds	32.00	7.942
Wheat yield (maunds)	Area under wheat in acres	15.925	24.631
	Yield of wheat in maunds	27.384	12.60

Source: Own Calculations.

Table 2. Propensity score matching estimates regarding zero tillage adoption (Pobit estimates)

Variable	Coefficient	t-values
Market distance	-0.036*	-1.85
Age	-0.039	-0.60
Education	0.207**	2.08
Family size	-0.264**	-2.21
Membership	-0.767	-0.48
Land holding	0.210***	2.52
Refrigerator	0.031*	1.74
Tractor	0.342***	2.43
Zt drill	0.321***	2.68
Bicycle	1.319	1.17
Car	-0.854	-0.58
Tube well	0.331	0.41
Radio	0.584	0.77
Credit	0.055*	1.89
Agri. Extension	0.042	0.88
Constant	-6.850	-0.24
District dummies		
Gujranwala	-2.713	-1.60
Hafizabad	-1.371	-0.83
Number of observations	234	
Pseudo R^2	0.6926	
LR χ^2	91.31	
Prob> χ^2	0.000	

Note: The results are significantly different from zero at ***, **,* 1, 5 and 10 percent levels respectively.

Table 3. CLAD Results for number of acres under zero tillage technology

Variable	Coefficient	t-values
Market distance	-0.314**	-2.16
Age	-0.211*	-1.89
Education	0.275***	2.46
Family size	0.202	0.77
Land holding	0.579***	2.76
Tractor	0.383***	2.54
Refrigerator	0.178	0.90
Ztdrill	0.561***	2.68
Car	-0.215	-0.88
Tube well	0.145	0.82
District Dummies		
Gujranwala	-0.413	-1.20
Hafizabad	-0.201	-0.56
Initial Sample Size	234	
Final Sample Size	179	
Pseudo R^2	0.350	

Note: In CLAD bootstrap replications are 100. The results are significantly different from zero at ***1%, **5% and *10%, respectively.

Table 5. Indicators of covariates balancing before and after matching

Matching bias	Outcome	Median	Median %	Value	Value	p-value	p-value	
Algorithm		absolute bias before matching	absolute bias after matching	reduction before	of R^2 before matching after	of R^2 after matching	of joint significance of covariates matching	of joint significance of covariate matching
NNM	Rice Yield	20.34	7.54	62.93	0.720	0.001	0.033	0.469
	Wheat	22.61	8.20	63.73	0.813	0.009	0.024	0.771
	Yield	25.33	7.21	71.53	0.645	0.003	0.041	0.836
	Labour	24.11	6.38	73.53	0.699	0.002	0.037	0.569
	Demand	18.93	9.72	48.65	0.715	0.004	0.072	0.310
	Household							
	Income							
	Poverty							
MMM	Rice Yield	25.61	7.53	70.59	0.485	0.003	0.051	0.960
	Wheat	24.22	11.52	52.43	0.654	0.004	0.046	0.828
	Yield	21.85	9.42	56.88	0.572	0.002	0.037	0.655
	Labour	20.07	8.39	40.80	0.482	0.003	0.041	0.716
	Demand	17.62	10.37	41.14	0.663	0.000	0.082	0.641
	Household							
	Income							
	Poverty							

Table 4. ATT results for rice yield, wheat yield, labour demand, household income and poverty status of the household

Matching Algorithm	Outcome	Caliper	ATT	t-value	Critical level of of hidden bias	Number of treated	Number of control
Nearest	Rice Yield	0.05	0.85	1.04	-	82	125
Neighbor	Wheat Yield	0.10	0.46*	1.85	1.15-1.20	76	122
Matching	Labour	0.03	-1.34*	-1.69	1.30-1.35	79	114
(NNM)	Demand	0.05	2456.33***	2.43	1.10-1.15	85	112
	Household	0.09	-0.08*	-1.71	1.20-1.25	63	139
	Income						
	Poverty						
Mahalanobis	Rice Yield	0.03	0.66	1.34	-	77	128
Metric	Wheat Yield	0.05	0.53**	2.09	1.65-1.70	92	123
Matching	Labour	0.04	-1.42*	-1.83	1.20-1.25	66	115
(MMM)	Demand	0.05	2261.81***	2.70	1.45-1.50	81	137
	Household	0.10	-0.10**	-1.84	1.35-1.40	72	120
	Income						
	Poverty						

Note: ATT stands for average treatment affect for the treated. The results are significantly different from zero at ***, **,* at 1, 5 and 10 % levels respectively.

Conclusion

This can be concluded from the empirical results that adoption of zero tillage technology has positive and significant impact on household welfare. The adoption of zero tillage technology helps in increasing the crops yield, particularly the wheat crop yield. The increased crops yield leads to higher household incomes which in turn can help in reducing the household poverty levels. As the current study results indicates that household having adopted zero tillage technology were having less poverty levels as compared to non adopters of the technology. Besides this there are many other benefits of zero tillage technology, as the zero tillage adoption can results in water and labour saving. In addition the zero tillage technology is also good for the environment. The adoption of zero tillage technology needs to be encouraged among farming community.

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