Hybrid Maize Seed Adoption and Impact on Livelihood: Empirical Evidence from Maize Growers in Pakistan

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Abstract:

The price of the maize hybrids in Pakistan is one of the highest in the world. The current study is based on comprehensive data set collected through field survey from 822 maize growers across Pakistan. The data was collected all the four major provinces of Pakistan i.e. Punjab, Sindh, Khyber Pakhtunkhwa (KPK) and Balochistan including Azad Jammu and Kashmir (AJK) and Gilgit Baltistan (GB). The propensity score matching analysis was employed for empirical analysis and four different matching algorithms i.e. Nearest Neighbour Matching (NNM), Kernel Based Matching (KBM), Radius Matching (RM) and Mahalanobis Metric Matching (MMM) to check the robustness of results. The empirical results indicated that maize hybrid adopters have higher yields in the range of 2.35-3.11 maunds per hectares as compared to non adopters. Similarly household income levels are higher in the range of 2176-3518 Pakistani rupees. The poverty levels are less in the range of 2-3 percent. The reduction in the maize hybrid seed price will leads to increase in adoption of hybrid seed, hence will help to increase the wellbeing of the farmers as currently, only 30 percent of maize area is under hybrids mainly due to lack of affordability.

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JEL Codes: Q16, Q16

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Abstract

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Keywords: Maize hybrids; Household income, Poverty levels, Propensity score matching; Pakistan.

JEL Classification:

Introduction

Maize (Zea mays L.) is a member of the grass family *Poaceae* and it is a valuable grain crop which is cultivated throughout the world under varied agro ecological conditions. It is often called as the *"queen of cereals*" and a staple food in several areas of the world. As far as nutritive value of the maize is concerned, it contains amply higher level of energy density of 365 Kcal/100g with about 72% starch, 10% protein and 4% fat (Nuss and Tanumihardjo, 2010).

The utilization of maize for food as well as feed is ever increasing and it has been projected that the global demand for maize will rise further in the coming years. Maize is the third important cereal crop of the world after wheat and rice. It is grown extensively in temperate, subtropical and tropical regions of the world. USA, China, Brazil, Mexico, Yugoslavia, Rumania, Argentina and Italy are the leading maize producing countries in the world. Maize is produced primarily as an energy source crop, but specialized versions for protein oil, wax, sweet corn and popcorn are also available (Akbar & Taj, 1998). Maize is successfully grown from sea level in plains to as high as 3300 meter above sea level in the highlands as a multi-purpose crop in temperate, subtropical regions of the world (Ihsan et al., 2005).

Agriculture is the mainstay of Pakistan's economy as it provides raw material to many industries, contributes to forex earnings and helps in poverty alleviation. Agriculture contributes 19.8 percent to GDP and employs about 42.3 percent of the country's total labour force. Pakistan's agriculture community consists of small farmers who are facing various challenges and limitations in their day to day farming practices. The government of Pakistan is focusing on improving agricultural productivity, competitiveness and profitability of the farming sector and ensuring environmental sustainability by increasing crops yield, systematic application of better

inputs and scaling of advance technology among farming community (Economic Survey of Pakistan 2015-16).

Maize is the third largest cereal after wheat and rice in Pakistan and is among the top 30 maize producers of the world. In Pakistan, the bulk (99.81%) of the total production is produced by the two provinces, Punjab and Khyber Pakhtunkhwa. Maize contributes 2.2 percent to the value addition in agriculture and 0.4 percent to GDP. During 2015-16 cultivated area under maize crop has increased to 1.144 million hectares. Maize crop production stood at 5.2 million tonnes (Economic Survey of Pakistan, 2015-16). Demand in production of corn is increasing day by day because of its multi-usages. Maize grain is an important food grain and produces a variety of products as raw material for multi products and value additions. Pakistan is among the top 30 maize producers of the world.

Seed is the key input in all crop production. All cultural practices are designed to exploit the full genetic potential of the seed sown. No agricultural practices like tillage, weeding, fertilizer and pest and disease control can increase crop yields beyond the limit set by the seed quality (Pula Imvula, 2011).

As compared to other Asian maize producing countries Pakistan still mostly depends on open pollinated varieties as the price of the hybrid in Pakistan is among the highest in the world. In Pakistan the hybrid seed prices is highest as compared to other Asian countries.. In Pakistan the price of hybrid maize is $7.5 per kg, while in India its $3.6 , Bangladesh $4.2 and in Thailand its $3.2 per kgs. No doubt in the past a number of studies have documented the positive and

significant impact of hybrids in comparison to OPV varieties (Kevin, 2001; Setimela et al., 2017; Westengen et al. (2014).

The purpose of the current paper is to estimate the adoption of the maize hybrids and its impact on maize yields and household income levels; For that the rest of the paper is organized as follows; in section 2 brief review of literature is presented; in section 3 data and description of variables is presented; in section 4 empirical results are presented and paper concludes in section 5 with some policy recommendations.

Review of Literature

Studies have documented the positive impact of the hybrid on yields (Manasseh *et al.* (2016); Khonje et al. (2015); Kutke (2011). Hence the adoption of the hybrid leads to improvement of the livelihood of the farm households, but the availability and resources constrain the adoption. To exert the full potential of hybrids when planted and encourage farmers to buy hybrids seed irrespective of the cost of the seeds, it is recommended that all seed companies producing hybrid seed should adhere to all technicalities involved in hybrid seed production and the selection of their inbred lines (Manasseh *et al.*(2016).

In Malawi, as study found that hybrids are adopted by the farmers who are interested in higher yields as well as drought attributes etc. while OPVs are mostly adopted by the farmers who are interested in early maturity (Lunduka et al. (2012)). Adoption of hybrid is driven by the ability of the seed to survive drought besides yield. Applying propensity score matching as well as endogenous switching regression on the 800 farm household data in Zambia, it was found that hybrid adopters have higher yield, higher food security levels as well as higher consumption expenditures (Khonje et al. (2015)).

The maize crop has great potential in Nigeria and hybrid adoption mainly depends on average costs and returns from production. No doubt hybrid adoption is viable and profitable in Nigeria (Olaniyan and Lucas(2004)). The drought-tolerant maize is more profitable as compared to open-pollinated varieties and also offers resistance against changing climatic conditions (Setimela *et al.* (2017)).

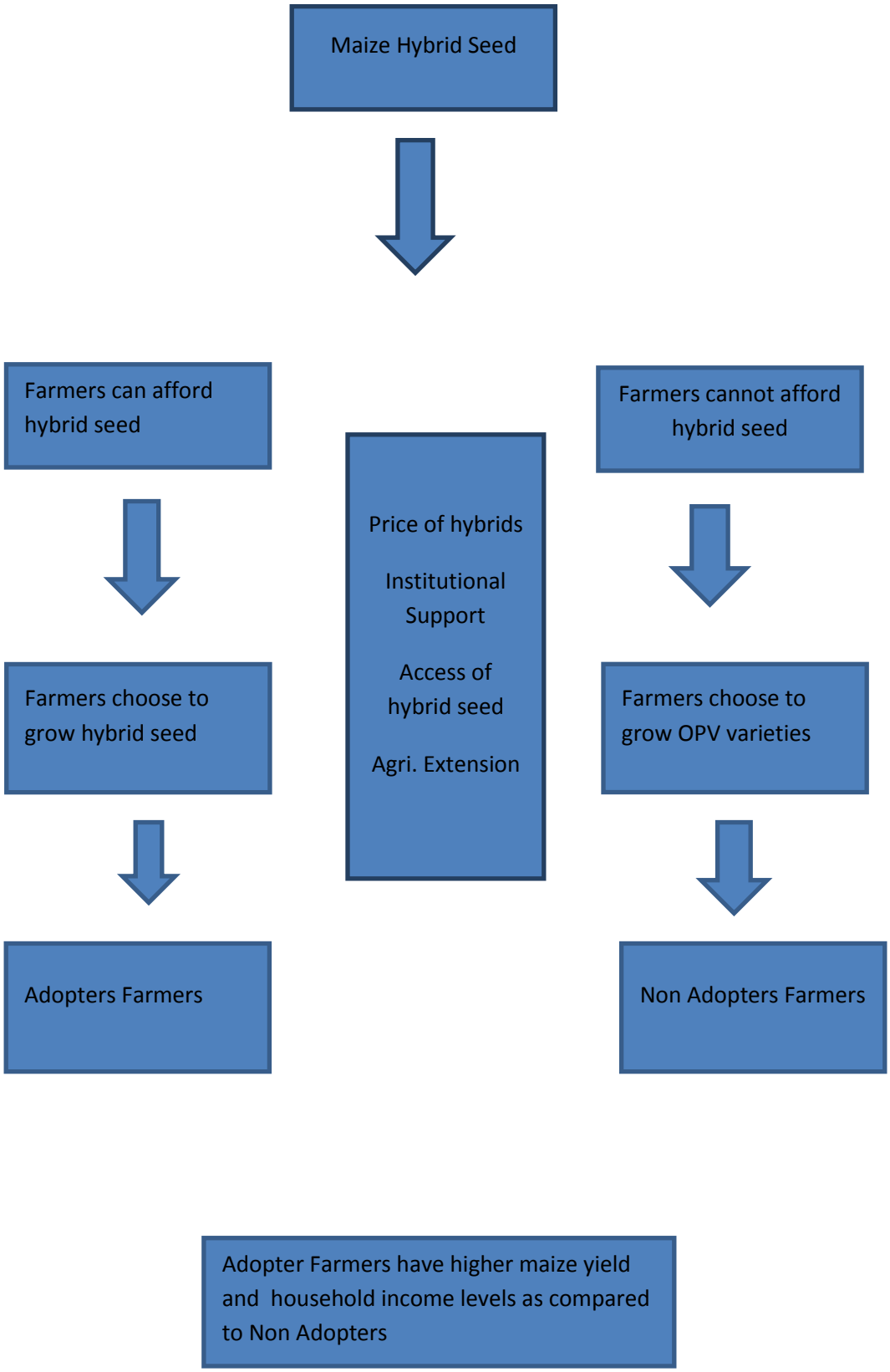
Drought tolerant maize (DTM) brings enormous benefit and it was found that by 2016 DT maize will provide a cumulative benefit of US$590 in 13 countries of East, South and West Africa (Kostandini et al. (2013)). They found that in 13 African countries, approximately 32 percent of

all the cultivars were hybrids, 23 percent were improved open-pollinated varieties and 46 percent were hybrids (Abate et al. (2017).

The maize hybrids provide higher yield as compared to OPV varieties but there are several barrier to adoption of the maize hybrids like high prices of seed and non-availability of the seed (Karim *et al.* (2010). In Oaxaca and Chiapas in Mexico, Becerril and Abdulai (2010) examined the adoption of the improved maize germplasm in Oaxaca and Chiapas in Mexico and found a positive impact of the maize hybrid adoption on household welfare in Mexico.

Although a number of studies have documented the impact of the hybrid maize, however in Pakistan not much studies have documented the impact of hybrid maize, its really important to document the impact of hybrid maize in Pakistan.

Conceptual Framework



The conceptual framework shows that price of the hybrid seed, agricultural extension services are the constraints in adoption of the hybrid seed. Those farmers who adopt the hybrid seed able to over come the constraints while the others who cannot overcome the constraints don't adopt hybrid seed. Finally, those farmers who adopt the hybrid seeds have higher yields and wellbeing as compared to those who did not adopt.

Propensity Score Matching

For estimation of the impact, we used propensity score matching (PSM). The impact of hybrid maize is estimated on maize yield, household income and poverty levels. The significance of the PSM arises from the fact that it accounts for sample selection bias when experimental data are not available (Dehejia and Wahba, 2002). In the absence of the experimental data, PSM creates the condition of the randomized experiment (Rosenbaum and Rubin, 1983).

It follows that the expected treatment effect for the treated population is of primary significance. This effect may be given as

$$\tau|_{I=1} = E(\tau \mid I=1) = E(R_1 \mid I=1) - E(R_0 \mid I=1) \qquad (1)$$

where τ is the average treatment effect for the treated (ATT), R_1 denotes the value of the outcome for adopters of the new technology and R_0 is the value of same variable for non-adopters. As noted above, a major problem is that we do not observe $E(R_0 \mid I=1)$. Although the difference $[\tau^e = E(R_1 \mid I=1) - E(R_0 \mid I=0]$ can be estimated, it is potentially biased estimator.

The PSM is defined as the conditional probability that a farmer adopts the new technology, 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 Z is controlled for, technology adoption is random and uncorrelated with the outcome variables[i]. The PSM can be expressed as,

$$p(Z) = \Pr\{I = 1 \mid Z\} = E\{I \mid Z\} \qquad (2)$$

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

Unlike the parametric methods mentioned above, propensity score matching requires no assumption about the functional form in specifying the relationship between outcomes and predictors of outcome. The draw back of the approach is the strong assumption of unconfoundness. As argued by Smith and Todd (2005), there may be systematic differences between outcomes of adopters and non-adopters even after conditioning because selection is based on unmeasured characteristics. However, Jalan and Ravallion (2003) point 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

$$\tau = E\{R_1 - R_0 \mid I = 1\} = E\{E\{R_1 - R_0 \mid I = 1, p(Z)\}\} = E\{E\{R_1 \mid I = 1, p(Z)\} - E\{R_0 \mid I = 0, p(Z)\} \mid I = 0\} \quad (3)$$

Several techniques have been developed to match adopters with non-adopters of similar propensity scores.

The advantage of the PSM is that as against the parametric approach, propensity score matching does not entail assumption about the functional form in stipulating the relationship between outcomes and forecasters of the outcome. The downside of the approach is the heavy assumption of unconfoundness. It may be possible to notice systematic differences between outcomes of adopters and non-adopters even after conditioning because selection is based on unmeasured features (Smith and Todd, 2005). Nonetheless, (Jalan and Ravallion, 2003) mentioned that the supposition is no more restrictive than those of the instrumental variable approach engaged in cross-sectional data analysis In the current paper, four different matching algorithms i.e. nearest neighbour matching and kernel based matching and mahalanobis metric matching are employed. Also after matching a number of balancing tests are employed to check the matching quality like median absolute bias before and after matching, the value of R-square and joint significance of covariates before and after matching.

Data and Sample

In 2016, using a detailed questionnaire comprehensive data was collected from 822 farm households from all the four major provinces of Pakistan i.e. Punjab, Sindh, KPK and

Balochistan. In total data was collected from 822 maize farmers. Detailed comprehensive questionnaire was prepared for data collection. In the questionnaire information on number of household and farm level characteristics was included. Detailed information regarding maize seed source, quality of seed and maize production practices was included in the questionnaire.

Data and Description of Variables

The description of variables is presented in table 1.The mean age of the surveyed farmers was about 43 years and education was about 10 years of schooling. The mean farming experience was 19 years while maize growing experience was a little less i.e. 17 years. About 86 percent of the respondents were living in the joint family system as in joint family system farmers can carry out the farming operations/practices jointly. About 81 percent of the respondents were married. The mean land owned by the farmers was about 14 acres. The average land rent in the area was rupees 32935 per acre. The land rent varies depending upon crop yield and climatic conditions. About 60 percent of the farmers have access to laser land leveling technology. About 41 percent reported fragmented land holding. Only 20 percent have included legumes in crop rotation. Majority of the farmers about 90 percent have information about the macro nutrient and only 20 percent have information about micro nutrient.

The total number of family members was 11.09. The total numbers of workers working at farm were 3.48. The highest education in the family was about 10.7 years of schooling. The education level of the household head was 9.32 years of schooling.

The village infrastructure indicates that about 88 percent of the households have metal road in the village, 36 percent have basic health unit in the village and 41 percent have veterinary center

in the village. About 7 percent have access to agricultural extension office, 94 percent have access to boys school and 86 percent have access to girls school. About 4 percent have access to commercial bank and 70 percent have access to transport. About 99 percent have access to electricity. About 46 percent have access to pesticide dealer. About 45 percent of the villages have implement repair shop and 49 percent have input dealer in the village. About 32 percent have output dealer in the village. About 7 percent have on farm water management office at village level. About 11 percent have agricultural research station in the village. About 5 percent have soil fertility lab in the village.

The information regarding assets ownership indicates that about 46 percent of the households have tractor ownership. About 38 percent have trolley ownership. About 33 have tube well ownership. About 1 percent has zero tillage drill ownership. Only 3 percent of the households have laser land levelling ownership.

The cost of production of OPV was 25890 while cost of production of hybrid was 34981. The cost of hybrid is high mainly due to expensive seed cost, the rest operational costs are almost same both for OPV and hybrids. The gross revenue for the OPV varieties cultivation 54452 while from the hybrid varieties was 87500. The cost benefit ratio from OPV varieties was 2.10 while for the hybrids was 2.51. The per acre net profits from the OPV cultivation are 28562 while from the cultivation of the hybrids are 52519 rupees per acre. These are very much in line with the other Asian countries as reported by the Kumar et al. (2014).

The comparative economics of the maize cultivation is presented in table 3. In Pakistan the cost of production of production of the hybrid maize is high mainly due to higher prices of hybrids.

Empirical Results

The determinants of the hybrid adoption are presented in table 4. The dependent variable is dummy i.e. 1 for adoption and 0 for non adoption. A set of household and farm level variables were included as independent variables as presented in table 4. The farmer status was included as dummy variable i.e. 1 for the owner and 0 for the tenant. The farmer status was included as dummy variable and the coefficient is positive and significant indicating that owners mostly adopt hybrid maize as compared to tenants. The age coefficient is negative and significant indicating that mostly the young farmers have adopted the hybrids as compared to aged farmers. The education coefficient is positive and highly significant at 1 percent level of significance indicating that mostly the educated farmers adopted hybrids technology as compared to less educated farmers. The family system was included as dummy variable i.e. 1 for the joint family and 0 for the nuclear family and the coefficient of family system is positive and highly significant at 10 percent level of significance. The marital status is negative and non significant. The own land holding coefficient is positive and highly significant at 1 percent level of significance indicating that farmers having large land holdings mostly adopt hybrids as compared to small land holdings. The family size coefficient is positive and significant at 10 percent level of significance. The metal road, basic health unit and veterinary center are non significant. The agricultural extension is positive and significant at 5 percent level of significance.

The transport facility coefficient is positive and significant at 10 percent level of significance. The electricity coefficient is negative and significant at 5 percent level of significance. The OFWM is positive and significant at 5 percent level of significance. The tractor and tube well ownership is positive and significant indicating positive role of asset ownership in technology adoption. The zero tillage drill, car, motorcycle and TV are non significant. The R-square value

is 0.37 indicating that 37 percent variation in dependent variable is due to independent variables included in the model The LR chi square is highly significant at 1 percent level of significance.

The censored least absolute deviation (CLAD) model was estimated for the numbers of hectares under hybrid maize. A set of independent variables were included in the model. The farmer status is non significant while the age and education coefficients are positive and significant. The family system is positive and non-significant. The marital status coefficient is negative and non significant. The land holding coefficient is positive and highly significant at 1 percent level of significance. The family size coefficient is positive and significant at 10 percent level of significance. The metal road, basic health unit and veterinary center are non significant. The agricultural extension services are positive and highly significant at 1 percent level of significance. The other coefficients like transport, electricity and OFWM, tube well, motorcycle are non significant, while tractor, Zero tillage drill ownership, car and TV are positive and significant. The R-square value is 0.53 indicating that 53 percent variation in dependent variable is due to independent variables included in the model. The LR Chi square is highly significant at 1 percent level of significance indicating the robustness of the variables included in the model.

The impact of the hybrid adoption was estimated by employing the propensity score matching approach and the results are presented in table 6. Propensity score matching creates the condition of randomized experiment and then matches similar individuals in the opposite groups i.e. matches similar adopters with similar non-adopters. The current analysis was carried out by employing four different matching algorithms i.e. nearest neighbor matching, kernel based matching, radius matching and mahalanobis metric matching. In case of PSM analysis the

Average treatment affect of the treated (ATT) indicates the difference in outcomes of the similar adopters with similar non-adopters that is attributed mainly due to adoption of the hybrids.

The ATT results for yield are positive and significant indicating that adopters of the maize hybrids have higher yields in the range of 2.35-3.1 maunds per hectare as compared to non-adopters. The household income levels are higher in the range of rupees 2176-3518 per season. The poverty was estimated through head count index. The results for the poverty are negative and significant indicating that poverty is less in the range of 2-3 percent for the adopters as compared to non-adopters.

The critical level of hidden bias indicates the difference in outcomes of the adopters and non adopters due to unobservable. The critical level of hidden bias in the current analysis indicates that results are not sensitive even in the presence of higher levels of hidden bias. The numbers of treated and numbers of control are also presented in table 6.

As the main purpose of the propensity score matching is to balance the covariates across different groups for that a number of balancing tests are employed like median absolute bias before and after matching and percentage bias reduction as well as value of R-square before and after matching as well as joint significance of covariates before and after matching.

The median absolute bias is quite high before matching and is quite low after matching. The percentage bias reduction is also reported. Similarly value of R-square is also quite high before matching and is quite low after matching. The value of joint significance of covariates indicates that joint significance should be accepted before matching and should always be rejected after matching that after matching there are no systematic differences between adopters and non-adopters.

Conclusions

The current study is among the few studies having focused on maize hybrid adoption in Pakistan. The empirical results indicates that human capital like education, institutional support, agricultural extension services as well as household assets leads to the adoption of the hybrid maize. The land holding is one of the key indicators leading to adoption. The impact of adoption was estimated on maize yield, household income and poverty levels. The empirical findings indicate that hybrid adoption has positive and significant impact on household welfare.

Cost benefit analysis also indicates clear advantages of hybrids over OPVs.

Similarly the comparison of the economics of the hybrid with other countries indicates that hybrid cost of production in Pakistan is highest as compared to other South Asian countries mainly due to high prices of the hybrid seed. The wider adoption can only be ensured through reduction in hybrid prices.

Table 1: Data and Description of Variables

Characteristics	Description	Mean	Std. Dev.
Farmer Status	1 if the farmer is beneficiary farmer, 0 otherwise	0.51	0.50
Age	Age of the farmer in number of years	42.53	10.54
Education	Mean number of years of the education of the farmer	9.70	4.42
Farming Experience	Farming experience in number of years	19.10	10.21
Maize growing experience	Maize growing experience in number of years	16.64	9.24
Family system	1 if the households are living in the joint family	0.86	0.39
Marital status	1 if the respondent is married, 0 otherwise	0.81	0.35
Own Land	Number of acres owned by the farmer	14.23	30.54
Land rent	Average land rent in rupees per acre per year	32935	8080
Land Fragmentation	1 if the land holding is fragmented, 0 otherwise	0.41	0.28
Legumes	1 if included legumes in crop rotation, 0 otherwise	0.20	0.35
Macro Nutrient	1 if the farmer have information about macro nutrient, 0 otherwise	0.91	58
Micro Nutrient	1 if the farmer have information about micro nutrient, 0 otherwise	0.75	0.34
FYM	1 if have applied farm yard manure, 0 otherwise	0.80	0.22
Total Family Size	Total Number of Family members in the family	11.09	4.25
Total farm worker	Total number of family members working at farm	3.48	4.06
Highest Education in family	Years of highest education in the family	10.7	4.38
Education level of household head	Education level of household head in number of years	9.32	4.27
Metal Road	1 if there is metal road in the village, 0 otherwise	0.88	0.32
Basic Health unit	1 if there is basic health unit in the village, 0 otherwise	0.36	0.39
Veterinary Center	1 if there is veterinary center in the village, 0 otherwise	0.41	0.48
Agri. Extension Office	1 if there is agricultural extension office in the village, 0 otherwise	0.07	0.12
OFWM	1 if there is OFWM in the village, 0 otherwise	0.07	0.73
Agri. Research	1 if there is agricultural research center, 0 otherwise	0.11	0.32
Soil fertility	1 if there is soil fertility office in the village, 0 otherwise	0.05	0.55
Tractor	1 if the tractor is owned by the household, 0 otherwise	0.46	0.51
Tube well	1 if the tube well is owned by the household, 0 otherwise	0.33	0.38
Zt drill	1 if the zero tillage drill is owned by the household, 0 otherwise	0.01	0.11
Laser Leveler	1 if the laser leveler is owned by the household, 0 otherwise	0.03	0.08
TV	1 if the household have TV ownership, 0 otherwise	0.91	0.28

Table 2: Comparison of the Cost of Production

Operation	OPV	Hybrid	Difference
Cost of Production	25890	34981	-9091
Average Yield	5.7	7.6	-1.9
Revenue Per acre	54452	87500	-33048
Net Profit	28562	52519	-23957
Cost Benefit Ratio	2.10	2.51	-0.41

Table 3: Economics of Maize Cultivation

Country	Cost of Cultivation (US$/ha)	Cost of Production (US$/ton)	Net Profit (US$/ha)
Bangladesh	1014-1242	130-180	200-460
China	2197	297	470
India	307-866	142-254	(-96)-544
Indonesia	412-487	73-97	742-1323
Pakistan	560-1282	201-250	105-391

Source: Kumar et al. (2014).

Table 4: Determinants of the Hybrid Adoption (Probit estimates)

Variable	Coefficient	t-values
Farmer Status	0.02***	2.56
Age	-0.01**	2.23
Education	0.01***	2.45
Family system	0.02*	1.83
Marital status	-0.03	-1.25
Own Land	0.02***	2.86
Family size	0.01*	1.70
Metal Road	-0.03	-1.55
Basic Health unit	-0.01	-1.34
Veterinary Center	0.02	1.17
Agri. Extension	0.02**	2.04
Transport	0.01*	1.83
Electricity	-0.02**	-2.03
OFWM	0.03**	1.97
Tractor	0.01***	2.57
Tube well	0.02*	1.68
Zt drill	-0.03	-1.53
Car	0.02	1.44
Motorcycle	-0.01	-1.23
TV	-0.02	-1.38
Constant	0.031	1.42
R-square	0.37	
LR-Chi square	128.34	
Prob>Chi square	0.000	
Total Number of Observations	822	

Note: Results are significant at ***,**,* 1,5 and 10 percent levels respectively.

Table 5: Number of acres under Hybrid (CLAD estimates)

Variables	Coefficient	t-values
Farmer Status	-0.01	-1.32
Age	0.02*	1.84
Education	0.01**	2.36
Family system	0.01	1.43
Marital status	-0.05	-1.20
Own Land	0.11***	2.49
Family size	0.03*	1.71
Metal Road	-0.01	-1.44
Basic Health unit	-0.03	-1.26
Veterinary Center	-0.01	-1.37
Agri. Extension Office	0.02***	2.65
Transport	0.11	1.25
Electricity	0.03	1.27
OFWM	-0.03	-1.26
Tractor	0.04***	2.34
Tube well	-0.17	-1.23
Zt drill	0.03*	1.91
Car	0.01**	2.16
Motorcycle	0.31	1.45
TV	0.01**	2.04
Constant	0.03	2.12
R-square	0.53	
LR-Chi square	286.34	
Prob>Chi square	0.000	
Total Number of Observations	822	

Note: Results are significant at ***, **,* 1, 5 and 10 percent levels respectively.

Table 6: Impact of Hybrid Adoption on Maize Yield, Household Income and Poverty Levels

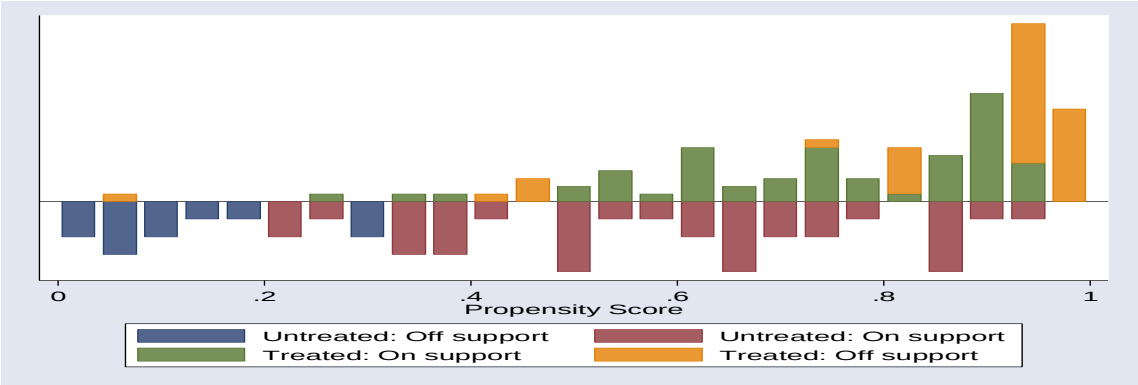
Matching Algorithms	Outcome	Caliper	ATT	t-values	Critical level of hidden bias	Numbers of Treated	Numbers of Control
NNM	Yield	0.01	2.41**	2.37	1.25-1.30	234	467
	Household Income	0.03	2176*	1.92	1.50-1.55	234	467
	Poverty	0.08	-0.03**	2.14	1.05-1.10	234	467
KBM	Yield	0.05	2.35***	2.50	1.30-1.35	316	425
	Household Income	0.001	3122**	2.13	1.65-1.70	316	425
	Poverty	0.003	-0.02*	1.87	1.25-1.30	316	425
RM	Yield	0.002	3.11**	2.62	1.15-1.20	289	403
	Household Income	0.003	3518***	2.66	1.20-1.25	289	403
	Poverty	0.002	-0.03	1.22	-	289	403
MMM	Yield	0.004	2.62***	3.05	1.35-1.40	240	367
	Household Income	0.002	2936**	2.04	1.25-1.30	240	367
	Poverty	0.07	-0.03**	2.15	1.25-1.30	240	367

Note: NNM stands for the nearest neighbor matching, KBM stands for the kernel based matching, RM stands for the radius matching, MMM stands for the Mahalanobis metric matching. ATT stands for the average treatment affect for the treated. The results are significant at ***,**,* 1, 5 and 10 percent levels respectively.

Table 7: Indicators of the Covariates Balancing before and After Matching

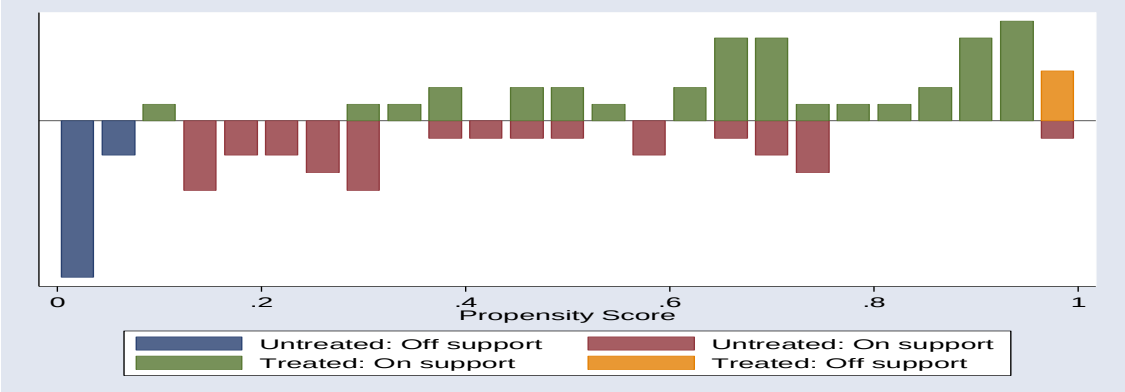
Matching Algorithm	Outcome	Median Absolute Bias (Before Matching)	Median Absolute Bias (After Matching)	Percentage Bias Reduction	Value of R-square before Matching	Value of R-square after Matching	Joint Significance of Covariates Before Matching	Joint Significance of Covariates After Matching
NNM	Yield	18.04	6.38	65	0.284	0.001	0.002	0.334
	Household Income	21.19	7.24	66	0.369	0.003	0.002	0.285
	Poverty	20.12	5.33	74	0.245	0.001	0.002	0.276
KBM	Yield	17.39	6.28	64	0.317	0.003	0.002	0.294
	Household Income	18.22	5.35	71	0.296	0.004	0.003	0.283
	Poverty	17.20	5.29	69	0.234	0.002	0.001	0.247
RM	Yield	19.17	4.28	78	0.189	0.003	0.002	0.230
	Household Income	20.37	7.21	65	0.243	0.001	0.001	0.217
	Poverty	22.67	5.94	74	0.238	0.001	0.002	0.238
MMM	Yield	18.32	6.02	67	0.276	0.003	0.001	0.364
	Household Income	16.38	5.24	68	0.314	0.001	0.002	0.294
	Poverty	19.36	6.27	68	0.297	0.001	0.002	0.287

Figure 1: Indicators of Covariates Balancing



Impact on Maize Yield

Impact on Household Income



Impact on Poverty Levels

Literature Cited

Government of Pakistan. 2015-16. Economic Survey of Pakistan 2004-05, Finance Division, Islamabad, Pakistan

Banziger, M., K.V. Pixley, B. Vivek, and B.T. Zambezi. 2000. Characterization of elite maize germplasm grown in eastern and southern Africa

Kutka, F. 2011. Open-Pollinated vs. Hybrid Maize Cultivars, Sustainability, 3(4), 1531-1554.

Bercill, J., A. Abdulai. 2010. The Impact of Improved Maize Varieties on Poverty in Mexico: A Propensity Score-Matching Approach, World Development, 38(7): 1024-1035.

Dehejia, R.H., Wahba, S., 2002. Propensity score-matching methods for nonexperimental causal studies. Review of Economics and statistics 84, 151-161.

Khonje, M., J. Manda, A. Arega and M. Kassei. 2015. Analysis of Adoption and Impacts of Improved Maize Varieties in Eastern Zambia, World Development.66: 659-506.

Jalan, J., Ravallion, M., 2003. Does piped water reduce diarrhea for children in rural India? Journal of econometrics 112, 153-173.

World Bank (1997) Expanding the Measure of Wealth: Indicators of Sustainable Development, ESD Series No. 17, Washington D.C.: World Bank.

Mannaseh, E. A., S. E. Abimiku., P. O. Ojo and O. K. Ishiak. 2015. Comparism of Yield Potential of Hybrids and Open Pollinated Varieties of Maize Seeds in Northern Guinea Savanna Alfisols, North-West Nigeria, Agricultural Science, 4(1):01-08.

K. Genti, R. L. Rovere and T. Abdoulaye.2013. Potential impacts of increasing average yields and reducing maize yield variability in Africa. Food Policy. 43:213-226.

Karim, M. R., Moniruzzaman and Q. M. Alam. 2010. Economics of hybrid maize production in some selected areas of Bangladesh. Bangladesh J. Agricultural Research. 35(1) : 83-93

Olaniyan, A.B. and E.O. Lucas. 2004. Maize hybrids cultivation in Nigeria - A review. Journal of Food, Agriculture & Environment. 4(2): 177-181

R. Lunduka, M. Fisher and S. Snapp (2012): Could farmer interest in a diversity of seed attributes explain adoption plateaus for modern maize varieties in Malawi. Food Policy: 37(5): 504-510

Bellon M.R., and J. Hellin. 2011. Planting hybrids, keeping landraces: agricultural modernization and tradition among small-scale maize farmers in Chiapas, Mexico. World Development. 8(39):1434–1443

Abate, T., M. Fisher, T. Abdoulaye , G.T.Kassie, R.Lunduka, P. Marenya and W.Asnake. 2017. Characteristics of maize cultivars in Africa: How modern are they and how many do smallholder farmers grow. Agriculture and Food Security.6(1).

Smith, J.A., Todd, P.E., 2005. Does matching overcome LaLonde's critique of nonexperimental estimators? Journal of econometrics 125, 305-353.

Setimela, P.S., C.Magorokosho, R. Lunduka, E.Gasura, D.Makumbi, A.Tarekegne, J.E.Cairns, T.Ndhlela, O.Erenstein and W. Mwangi. 2017. On-farm yield gains with stress-tolerant maize in eastern and Southern Africa . Agronomy Journal. 2(109): 406-417

Westengen, O.T, K.H.Ring, P.R.Berg and A.K.Brysting.2014. Modern maize varieties going local in the semi-arid zone in Tanzania. BMC Evolutionary Biology. 1(14)