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Impact of Off - Farm Income on Hybrid Maize Adoption and Productivity of Maize Farmers across Various Agro Ecological Zones of Ghana

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Abstract
This study analyzed the impact of off-farm income on hybrid maize adoption and productivity of farmers across various agro ecological zones of Ghana. This study uses cross-sectional data collected from 453 maize farmers across various agro ecological zones of Ghana in 2010. We utilize propensity score matching to compare the average yield and adoption of hybrid maize of farmers with and without off-farm income. The approach assumes exogenous off-farm income and similar farm technology across farmers in the various agro ecological zones.
The mean yield of farmers was 686.34kg/ha for those without off-farm work compared to the 693.91kg/ha for an average farmer with off-farm income. The result from the study shows that there is no significant impact of off-farm income on hybrid maize adoption and productivity of maize farmers across the various agro ecological zones of Ghana. This suggests that off-farm opportunities, while inducing increased use of improved seed, due to competition for labor time, may undermine the productivity gains from adoption of improved seed. The findings from this study support diversification of household income as a strategy for increasing capital availability to increase uptake of the modern purchased inputs.
Keywords: off-farm, income, productivity, propensity, score, adoption, hybrid

1. Introduction

Sustainable agriculture requires farmers' adoption of new technologies and practices that sustain the environmental quality, while providing the agricultural output. Farmers are expected to adopt various technologies and practices, such as energy crops, genetically modified (GM) crops, and conservation practices. Off-farm income has been analyzed in technology adoption studies, due to its increasing share in agricultural household income (Gedikoglu et al., 2011); Gedikoglu & McCann, 2007). Off-farm income opportunities have been widely documented as an important strategy for overcoming credit constraints faced by the rural households in many developing countries (Iiyama et al., 2008; Reardon et al., 1994). Worldwide, the literature on the effect of off-farm income on the farm sector presents mixed conclusions. One strand of literature shows that off-farm income is a substitute for borrowed capital in rural economies where credit markets are either missing or dysfunctional (Ellis & Freeman, 2005). In addition, off-farm work may serve as collateral to facilitate access to credit by small-scale farmers (Reardon et al., 1994; and Barrett et al., 2001). In summary, off-farm income is expected to provide farmers with liquid capital for purchasing productivity enhancing inputs such as improved seed and fertilizers. On the other hand, pursuit of off-farm income by farmers may undermine their adoption of modern technologies (especially labor intensive technologies) by reducing the amount of household labor allocated to farming enterprises (McNally, 2002; Goodwin & Mishra, 2002).

This study analyzes the premise that off-farm income for Ghanaian smallholder farmers leads to the adoption of improved technologies, translating into increased productivity. We use maize production as a case study. To determine the productivity effects of off-farm earnings, the study establishes the effect of off-farm earnings on yield. It is hypothesized that investment of off-farm income in crop yield-enhancing inputs leads to crop productivity gains through improved production efficiency.

2. Relevance of the Maize Subsector in Ghana

Maize is Ghana's most important cereal crop (Alderman & Hingis, 1992). It is grown by a majority of rural households in all parts of the country (Morris et al, 1999). In the forest agro ecological zone, maize is cultivated on scattered plots, usually as intercropped with cassava, plantain, and cocoyam. Although maize is consumed extensively in the forest zone, it is not a major food staple as much of the crop is sold. In the transitional zone, maize is grown in both major (March) and minor (September) seasons usually as a monocrop or in association with yam and/ or cassava. In savannah zone, sorghum and millet are dominant cereals, but maize is cultivated together with small grains, groundnut, and/or cowpea (Morris et al, 1999). A major constraint to maize production in the savannah zone of Ghana however is soil infertility as a result of the hostile agro ecological environment (NAES, 1984).

Morris et al, (1999) argue that improved maize technology adoption is linked to farmer's productivity and real incomes. A study by International Maize and Wheat Improvement Center (CIMMYT) in 1998 revealed

that factors such as farmer's characteristics, resource ownership and access to technology in terms of extension contacts tend to influence improved maize adoption in Ghana.

3. Methodology

3.1 Study Area

In Table 1, we compare the three agro ecological zones in Ghana being the forest, transitional and savannah zones representing the study areas.

Table 1: A General Description of the Characteristics of the Various Study Areas

General characteristics	Forest Zone (Bekwai Municipal)	Transitional Zone (Nkoranza South District)	Savannah Zone (Gushegu District)
Location	Southern part of Ashanti Region	Middle portion of the Brong Ahafo region.	North eastern corridor of Northern Region.
Total land area	633sqkm	2300sqkm	5796sqkm
Topology	Within the forest dissected plateau.	Low lying and rising gradually.	Fairly undulating.
Climate	Semi-equatorial type.	Wet semi-equatorial region	Tropical continental climate.
Vegetation	Semi-deciduous forest zone	Savannah woodland and a forest belt.	Guinea savannah type.
Rivers /drainage	Drained by the Oda River and its tributaries.	Fairly drained by several streams and rivers.	Strewn with several streams.
Geology	Underlain by three geological formations.	Characterized by soils developed over Voltaian sandstones.	Lies entirely within the Voltaian sandstone basin
Soils	Clay, sand and gravel deposits	The geological feature together with vegetation influences and gives rise to two distinct soil categories.	Coarse lateritic upland soils and soft clay.
Rainfall	1600– 1800mm.	800-1200mm.	950-1300mm
Temperature	Fairly high and uniform temperature ranging between 32ºC in March and 20º C in August.	Average annual temperature is about 26°C.	Normally high above 35^0C

Source: MLGRD (2006)

3.2 Theoretical Framework

This section presents a discussion on the prediction of productivity and adoption of hybrid maize of the farmers with the stochastic frontier model, probit adoption model, propensity score matching and average treatment effects.

3.2.1 Stochastic Production Frontier

This study investigates the possibility of productivity gains and hybrid maize adoption from off-farm income by maize farmers. Following the Aigner et al 1977, Battese 1992 and Rahman 2003, we specify the stochastic production function for a given farmer as:

$$Q = f(X;\beta) + v - u \quad (1)$$

Where Q, X and β are vectors of maize output (kg/ha), input levels used in the maize production and estimated parameters, respectively. The inputs include land (ha), labour (man-days/ha), seed (kg/ha) and fertilizer (kg/ha). The term v is the two sided normally distributed random error $[v \approx N(0,\sigma_v^2)]$ that captures the stochastic effects outside the farmer's control, measurement errors, and other statistical noise. The term u is a one –sided $(u \geq 0)$ efficiency component that captures the technical inefficiency of the farmer. Thus, u measures the shortfall in the output Q from its maximum value given by the stochastic frontier $f(X_{ik};\beta_k) + v_i$. We study assume that u follows a half-normal distribution $[u \approx N(0,\sigma_u^2)]$. The two components v and u are also assumed to be independent of each other. In both cases v_i and u_i cause actual

production to deviate from the frontier. Following the Bravo-Ureta & Pinheiro (1997), technical efficiency of a farmer is empirically measured using the adjusted output as

$$Q_i^* = f(X_{ik}, \beta_k) - u_i \quad (2)$$

Where the conditional mean of u_i, given $\varepsilon_i = v_i - u_i$, is calculated as

$$E(u_i / \varepsilon_i) = \frac{\sigma_i \gamma_i}{1+\gamma_i^2}\left[\frac{f^*(\varepsilon_i \lambda_i / \sigma_i)}{1 - F^*(\varepsilon_i \lambda_i / \sigma_i)} - \frac{\varepsilon_i \lambda_i}{\sigma_i}\right] \quad (3)$$

From equation (3) f^* (.) and F^* (.) are the normal density and cumulative distribution functions, respectively, $Y = \sigma^2 / \sigma_v^2$ and $\sigma^2 = \sigma_u^2 + \sigma_v^2$. Q^* is observed output, adjusted for statistical noise.

3.2.2 Probit Adoption Model

In this study, farm-related and individual determinants for the adoption of hybrid maize seed among maize farmers are identified and estimated. This research question was tested empirically by the model:

$$P\{Y_i = 1 | X_i\} = F\{X_i, \beta\} \quad (4)$$

This binary choice probit model describes the probability that Y_i = 1, the vector X_i containing individual and farm level characteristics, and where F is a cumulative distribution function which is bound by the {0, 1} interval i.e. $0 \le F(X_i, \beta) \le 1$. So, the probability that a farmer has adopted hybrid maize seed depends on specified characteristics.

3.2.3 The Propensity Score Matching Technique

To examine this causal effect of participating in an off-farm work on the productivity and adoption of hybrid maize seed by smallholder maize farmers, the p -score matching approach is employed.

The propensity score $p(Z)$ is the conditional probability of participating in off-farm work given pre-participating in off-farm work characteristics (Rosenbaum and Rubin, [16]). Thus,

$$p(Z) \equiv \Pr\{D = 1 | Z\} = E\{D | Z\} \quad (5)$$

Where $D = \{0,1\}$ the indicator of exposure to participating in in off-farm works and Z is vector of pre- participating in off-farm work characteristics. The estimated propensity scores are then used to estimate the Average Treatment Effect on the Treated (ATT) which is the parameter of interest as

$$\delta \equiv E\{Y_i^1 - Y_i^0 | D_i = 1\} = E\{E\{Y_i^1 | D_i = 1, p(Z_i)\} - E\{Y_i^0 | D_i = 0, p(Z_i)\} | D_i = 1\} \quad (6)$$

Where $p(Z_i)$ is the p -score, Y_i^1 and Y_i^0 are the potential outcomes (yield and adoption of hybrid maize seed) in the two counterfactual situations of receiving treatment (participating in in off-farm work) and no treatment (non- participating in off-farm work).

Two important properties of the p -score matching are the balancing property and conditional independence assumption (CIA). Testing for this property is important to ascertain if maize farmers' behavior within each group is actually similar. Related to the balancing of p -score is CIA, which states that participating in in off-farm work is random and uncorrelated with the maize yield or adoption of hybrid maize seed by the farmer, once the set of observable characteristics, Z are controlled for. A further requirement is the common support condition which requires that persons with the same values of covariates Z have positive possibilities of being both participant and non-participants (Heckman, et al., 1999). Thus, all individuals in the common support region actually can exist in all states $(0 < P(D = 1 | Z < 1)$.

3.3 Survey Design and Sampling Method

The research employed primary data. The primary data employed was obtained through a cross-sectional survey conducted in three different agro-ecological zones in Ghana.

Farm level data were collected from 453 maize producers across the three agro-ecological zones of Ghana in the 2010 calendar year. The choice of the whole calendar year is on the premise that maize can be produced throughout the year.

In the second stage of the sampling design, a district each was selected from each of the three agro ecological zones purposively. The districts are Gushiegu District (Savannah zone), Nkoranza South District (Transitional zone) and Bekwai Municipality (Forest zone). These districts were selected based on their

agricultural potential, accessibility and high level of maize production in their agro-ecological zone. In the third stage, villages or communities from operational areas of MOFA were randomly selected from each of the districts representing the agro-ecological zones.

The final stage involved random selection of maize farmers proportionately according to the sizes of the various communities. A total of 151 maize farmers were sampled in the Savannah zone (Gushiegu District), 151 maize farmers were sampled in the Transitional zone (Nkoranza South District) and 151 maize farmers were sampled in the Forest zone (Bekwai Municipality).

4. Results and Discussion

Table 2 presents summary statistics of maize farmers with and without off-farm income across the various agro ecological zones of Ghana. From the total maize farmers considered, 18.3 percent of the farmers are with off-farm income (treatment group) and the remaining (81.7%) are found to be without off-farm income. Most of the farmers are males and belong to the most active age group. Maize farmers with off-farm income mostly use hybrid seed and have high mean yield compared to those without off-farm income.

Table 2: Summary statistics of farmers with and without off-farm income

Variables	With off-farm Income (N=83) 18.3%		Without off-farm Income (N=370) 81.7%		Diff in Mean
	Mean	SD	Mean	SD	
Gender (1=male;0=female)	0.57	0.5	0.84	0.37	-0.2743***
Age (years)	38.07	9.27	44.32	10.84	-6.2493***
Household size (number)	7.06	4.91	9.74	6.39	-2.6749***
Education (years)	5.96	3.49	4.61	3.72	1.353***
Farmer based organization (1=Yes,0=No)	0.16	0.37	0.14	0.35	0.0188
Hybrid seed (1=Yes,0= No)	0.51	0.5	0.44	0.5	0.0655
Extension contact (1=Yes,0= No)	0.42	0.5	0.47	0.5	-0.0486
Access to credit (1=Yes,0= No)	0.34	0.47	0.28	0.45	0.0415
Yield (kg/ha)	693.91	436.6	686.34	498.72	7.5742
Forest zone (1=Yes, 0=otherwise)	0.40	0.49	0.32	0.47	0.0787
Transitional zone (1=Yes, 0=otherwise)	0.48	0.50	0.30	0.46	0.1819***
Savannah zone (1=Yes, 0=otherwise)	0.12	0.33	0.38	0.49	-0.2606***

Source: Survey data, 2010

Table 3 reports the summary statistics of the impact indicator variable and the probability of having off-farm income used for the matching. The descriptive statistics show a higher level of maize yield among farmers with off-farm income. The average yield of farmers with and without off-farm income are 693.91and 686.34 respectively. However, mean difference between farmers with and without off-farm income is not statistically significant. This means that there is no real difference in the yield of farmers with and without off-farm income. However the propensity score indicates a difference among farmers with and without off-farm income and is statistically significant at 1 percent.

Table 3: Hybrid maize, yield and estimated probability of having off-farm income

Indicators	With off-farm income N (83) 18.3%		Without off-farm income N (370) 81.7%		Diff in mean
	Mean	SD	Mean	SD	
Hybrid maize	0.51	0.5	0.44	0.5	0.0655
Yield	693.91	436.6	686.34	498.72	7.5742
Estimated probability score	0.29	0.16	0.16	0.12	0.1259***

Source: Survey data, 2010 *** indicates significance at 1%,

From Table 4, hybrid maize seed adoption varied according to the various agro ecological zones. Maize farmers in the forest zone had the highest adoption rate (95.36%), whereas maize farmers in the transitional zone had the lowest adoption rate (16.56%). However, the pooled zone had an adoption rate of 45.26 percent which is lower than the adoption rate in the forest zone.

Table 4: Hybrid maize adoption in Ghana by agro ecological zones in 2010 agricultural year

Agro ecological zone	Number of farmers	Number of adopters	Adoption rate (%)
Pooled Zone	453	205	45.26
Forest Zone	151	144	95.36
Transitional Zone	151	25	16.56
Savannah Zone	151	36	45.26

Source: Survey data, 2010

4.1 Factors Associated With the Adoption of Hybrid Maize Seed

Table 5 indicates the factors influencing the adoption of hybrid maize across various agro ecological zones The effect of the farmer's gender is not statistically significant, but positively associated with the likelihood of maize farmers adopting hybrid maize variety. Education is not statistically significant, but positively related to adoption of hybrid maize.

Age was found positive and significant(1 percent) which is consistent with the findings of Etoundi & Dia (2008) which reported positive and significant relation between age group and improved maize variety. Adesina & Forson (1995) suggest that old farmers may have a higher likelihood of adoption, relative to young farmers because old farmers may have accumulated capital or have greater access to credit, due to their age.

The negative relation between household size and adoption of family size plays a role on labour provision. Adoption of new technology requires more labour inputs (Feder et al., 1985).

Farmer based organization had a positive and significant effect on adoption of hybrid maize. This leads credence to the findings of Bandiera & Rasul (2005) who reported that the likelihood of adopting new technologies is high among farmers who have access to paved road, markets, and farmer associations because they are more likely to be exposed to information about the potential benefits of new technologies, contact with extension agents, as a result of market exposure, and from interactions with other association members.

As expected access to extension services is statistically significant at one percent and is positively related to the adoption of hybrid maize. This is consistent with the hypothesis that extension programs help farmers to understand the potential benefits of improved maize -- thereby increasing the likelihood of adoption.

This study hypothesizes that access to credit is associated with the maize farmer's adoption decision. Feder et al. (1985) argue that capital in the form of either accumulated saving or access to capital markets is necessary for households to purchase or finance new agricultural technologies. Furthermore, they suggest that access to credit and farmers' new technological adoption decision are positively associated. Access to credit is positively and statistically significant (5% level)

Transitional and savannah zone negatively influence the adoption of hybrid maize and is statistically significant at 1 percent whereas the forest zone is positively related to adoption but no statistically significant. These findings are leads credence to the findings of Mishra, et al (2009) who indicated that technology adoption is affected by the geographical location of the farm.

Table 5: Factors influencing the adoption of hybrid maize across various agro ecological zones

Variable	Coefficient	Standard Error	Z-value	Marginal Effect
Gender	0.304	0.242	1.26	0.121
Age	0.022***	0.009	2.58	0.009
Household size	-0.055***	0.019	-2.85	-0.022
Education	0.028	0.026	1.07	0.011
Farmer based organization	0.682***	0.247	2.76	0.259
Extension contact	0.522***	0.186	2.81	0.206
Credit access	0.441**	0.211	2.09	0.174
Forest zone	0.620	0.475	0.13	0.025
Transitional zone	-2.218***	0.446	-4.98	-0.701
Savannah zone	-1.799***	0.433	-4.15	-0.611
Log likelihood	-157.368			
Pseudo R	0.496			
Observations	453			

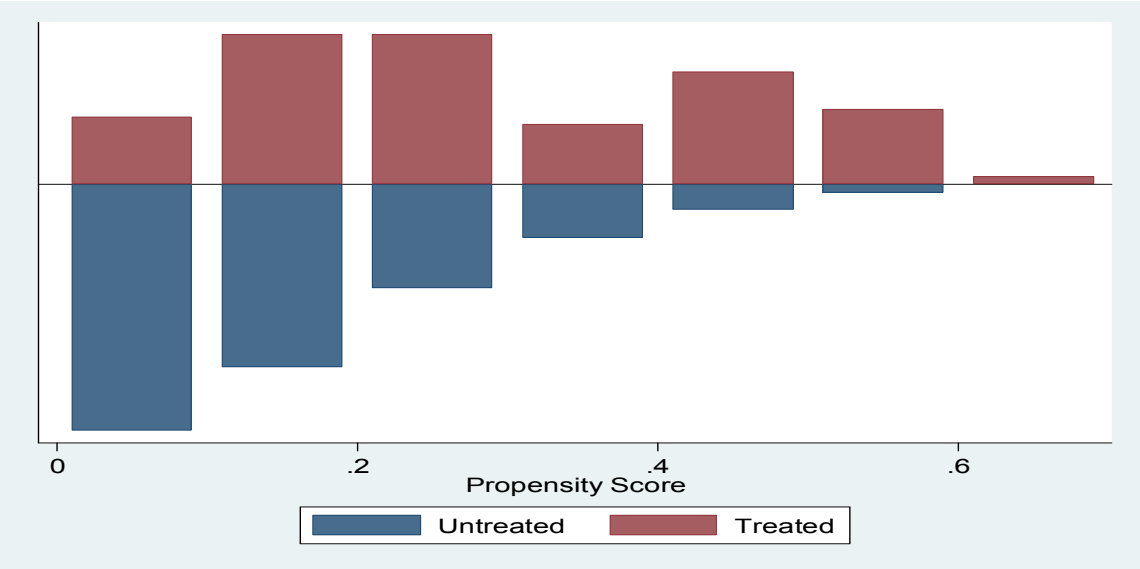
Source: Survey data, 2010

4.1 Impact of off-farm income on hybrid maize adoption and productivity

Figure 1 shows the distribution of propensity scores and the region of common support. The bottom half of the figure shows the propensity scores distribution for the untreated, while the upper-half refers to the treated individuals. The densities of the scores are on the y-axis. The figure indicates that the common support condition

is satisfied as there is overlap in the distribution of the propensity scores of both treated and untreated groups.

Figure 1: Distribution of propensity scores for unmatched and matched samples



Source: Survey data, 2010

The results of the average treatment effect for the treated for participation in farmer based organization are computed by the nearest neighbor matching technique are presented in Table 7. It was observed that this matching technique produced a consistent estimate of the treatment effects on the membership of farmer based organization. The results from this matching technique, generally indicates that the results are robust to the matching algorithm used. The matching results indicate that there is no significant impact of farmer based organization on the technical efficiency and yield of maize farmers.

Table 6: Effect of off-farm income on hybrid maize adoption and yield of farmers

Treatment indicator	Outcome variables	ATT	S. E.	T-value	Treated
Off- farm income	Hybrid maize seed	0.506	0.0918	1.18	83
	Yield	693.9127	76.4865	-0.51	83

Source: Survey data, 2010

Table 7 reports the sensitivity analysis of the models, using Rosenbaum bounds. The purpose is to test the selection bias necessary to invalidate the results of the estimates. As formulated by Diprete & Gangl (2004), the method starts with estimating the effect of the treatment on the treated, assuming the hypothesis of no selection bias. Then this assumption is relaxed. According to the potential impact of the omitted variable on the probability of the participating in farmer based organization (expressed in terms of the odds ratio) becoming stronger, the confidence interval of the estimated effects increases, and the level of significance of the null hypothesis. – that *D* does not affect Y – diminishes (that is, the *p*-value falls). The results for the model appear to be less robust to the presence of unobservable factors, given that their critical values are nearer one.

Table 7: Rosenbaum bounds sensitivity analysis for hidden bias

Critical Value of Hidden Bias (Γ)	Upper Bound Significance level
1	.099271
1.1	.170178
1.2	.257184
1.3	.353502
1.4	.45195
1.5	.546428
1.6	.632626
1.7	.708096
1.8	.771972
1.9	.824527
2	.866752
2.1	.9
2.2	.925731
2.3	.945351
2.4	.960119
2.5	.97111
2.6	.979211
2.7	.985129
2.8	.989419
2.9	.992508
3	.994719

Γ measures the degree of departure from random assignment of treatment or a study free of bias (i.e., Γ=1)

5. Conclusions

This study analyzed the impact of off-farm income on hybrid maize adoption and productivity of farmers across various agro ecological zones of Ghana. The mean yield of farmers was 686.34kg/ha for those without off-farm work compared to the 693.91kg/ha for an average farmer with off-farm income. The result from the study shows that there is no significant impact of off-farm income on hybrid maize adoption and productivity of maize farmers across the various agro ecological zones of Ghana. Adoption of improved maize seed was positively and significantly related to age of the farmer, farmer based organization, extension contact and access to credit. On the contrary, household size, transitional and savannah zone are negatively and significantly related to adoption of hybrid maize seed across the various agro ecological zones of Ghana.

This suggests that off-farm opportunities, while inducing increased use of improved seed, due to competition for labor time, may undermine the productivity gains from adoption of improved seed. The findings from this study support diversification of household income as a strategy for increasing capital availability to increase uptake of the modern purchased inputs.

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