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The Effect of Fertilizer Subsidies on Investment in Soil and Water Conservation and Productivity among Ghanaian Farmers Using Mechanized Irrigation

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Abstract: The fertilizer subsidies reintroduced in various sub-Saharan African countries from 2007 aim to increase agricultural production and assist in the development of fertilizer markets. The present study evaluates the impact of a fertilizer subsidy program among farmers in Ghana who employ highly mechanized irrigation systems. The results indicate that farmers who received fertilizer under the subsidy program used 45% more fertilizer. However, they did not use more weedicide and were likely to reduce investment in soil and water conservation. Thus, the income gains resulting from the subsidy programs were not invested in such non-targeted inputs. Moreover, the program beneficiaries' reduced investment in soil and water conservation may explain the finding that the subsidy did not improve their productivity. Thus, since fertilizer subsidy programs alone may not improve productivity, it may be necessary to target spending explicitly on complementary inputs such as investing in soil and water conservation.

Keywords: soil fertility; fertilizer subsidy; nudges; agricultural development; soil and water conservation

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1. Introduction

1.1. Background of the Study

The principal objective of this paper is to empirically evaluate the impact of fertilizer subsidies on investments in soil and water conservation (SWC), on the adoption of commercial inputs, and on productivity among farmers in Ghana using highly mechanized irrigation. We found that, while the program increased fertilizer use, it did not lead to increased use of other commercial inputs; in fact, it led to reduced investment in SWC, with little overall change in productivity.

Although the return on fertilizer use in sub-Saharan Africa (SSA) is high, the use of fertilizer is low (see, e.g., [1,2]). The fertilizer intensity in Africa in general was 0.8 kg/ha in 2000; this compares with 9.6 kg/ha in East and Southeast Asia, and 10.1 kg/ha in South Asia that year [3]. Although the use of modern inputs such as inorganic fertilizer in SSA is low on average, farmers show significant variation in this regard [4]. There is, therefore, a need to assess what this diversity implies for attaining the objectives of fertilizer subsidy programs in SSA.

This study complements existing evaluations of new fertilizer subsidy programs that were introduced in SSA after the food price spike in 2007. [5] review studies on the impact of these new fertilizer subsidies on total fertilizer use, food production, commercial input availability, food prices, wages, and poverty, in addition to measures that could make the input subsidy program more effective. Their review concludes that, whilst input subsidies raised both national and individual grain production in the short term, such subsidies' welfare impacts were negligible. The review also identifies two factors that undermine the effectiveness of fertilizer subsidy programs, namely the crowding out of commercial fertilizer demand, and inadequate increases in crop yields among smallholder farmers. In a subsequent study, [6] review how input subsidies contribute towards the achievement of climate-smart agriculture. They conclude that not only do such subsidies have negative effects on the adoption of climate-smart agricultural practices, but also that, at best, they have no effect on the use of climate-smart agricultural practices among those who have already adopted them.

One important feature of the use of modern inputs by farmers in SSA is that it is not uniformly low [4]. The Living Standards Measurement Study—Integrated Surveys on Agriculture summarized in [4] indicate that the average use of fertilizer in SSA ranges from 1.2 kg/ha to 146 kg/ha. These differences can be explained as being due to farming systems varying in terms of the intensity with which they require modern inputs. For instance, whereas the Food and Agriculture Organization of the United Nations [7] recommends that irrigation and flooded farming conditions require about 300 kg of fertilizer per hectare, the average use of this input in Ghana is about 23.8 kg/ha [8]. Input use may also be affected by a range of other factors, such as input and output prices, market access, past investments in infrastructure, access to and quality of extension services, and gender roles [4,9,10]. These factors are more likely to differ across and within countries and may lead to different input intensities.

The main contribution of the present study is that it focuses exclusively on a group of farmers whose systems are highly mechanized and who use high quantities of fertilizer. This is an important contribution because, in experimental studies, crop yields were more responsive to variation in rainfall under high fertilization treatments, an outcome which could potentially be explained by the inverse relationship between soil water and the extent to which fertilization depletes such water [11]. Thus, the results of the current study could inform the formulation of fertilizer subsidies in SSA, especially in respect of what or whom they target and how they are implemented; this would in turn promote agricultural development and development of markets for modern inputs in Africa.

The remainder of the paper is structured as follows: Section 1 examines the fertilizer subsidy program as implemented in Ghana, while Section 2 briefly discusses the study area and the sampling method, together with the theoretical and econometric models used in the estimation. Section 3 presents the descriptive and summary statistics of the data. Section 4 discusses the impact of Ghana's fertilizer subsidy program, after which Section 5 concludes the paper.

1.2. The Fertilizer Subsidy Program in Ghana

The global food crisis of 2007–2008 drew the attention of several governments in SSA and led to interventions to support domestic agricultural production. The crisis also led to many governments in SSA reconsidering the role that fertilizer subsidies could play in promoting food production. In Ghana, for example, the government implemented a fertilizer subsidy program in 2008 to promote domestic agricultural production. This nation-wide program subsidizes farmers' use of ammonium sulfate, urea, and so-called NPK complex fertilizers (nitrogen/N, phosphorus/P and potassium/K in different proportions, such as NPK 15:15:15 and NPK 23:10:05). According to [12], the program aimed to increase the average application of fertilizer from 8 kg/ha to 20 kg/ha; enhance crop yields and production; raise the profitability of farm production; and support private sector involvement in agricultural input markets. The program is estimated to have subsidized over 700,000 Mt of fertilizer between 2008 and 2015 [13].

Ghana's fertilizer subsidy program adopted several innovations [14]. The program was a region- and product-specific system of vouchers that entitled farmers to a fertilizer subsidy. Extension officers assisted in distributing these vouchers, a program design which was also expected to enhance the dissemination of their services and create opportunities for farmers to interact with these officers to exchange information on the most efficient and profitable use of the fertilizers concerned, and discuss investment in SWC or changes in agricultural practice [15]. As a result, about 94% of farmers in northern Ghana indicated having received training on how to apply fertilizer to increase their agricultural yields [13]. Furthermore, several studies in other areas showed that, when farmers' access to information was increased via extension officers, among other sources, their agricultural development was enhanced by being encouraged to use fertilizer and employ SWC, for instance (e.g., [16,17]). Farmers using these vouchers could acquire fertilizer from private agents in Ghana, who were in turn incentivized to develop new distribution networks that could outlast the subsidy program. Moreover, by transferring valuable vouchers to the farmers, the voucher system represented income transfers to the farmers which could not only promote demand for fertilizer and other commercial inputs, but could also assist in developing input markets due to higher profits and investment in complementary inputs such as weedicide or SWC. It is, however, an open question whether these income gains are in fact invested in other complementary inputs.

The eligibility criteria for receiving subsidized fertilizer in Ghana have changed over time. According to [18], between 2008 and 2009, the initial targets were smallholder food crop farmers. From 2010 to 2012, the definition of *beneficiary* was broadened to include all categories of food crop farmers, i.e., small, medium and large scale. After 2012, smallholder farmers cultivating maize, rice, sorghum, or millet, especially in the savanna agro-ecological area, were prioritized, as were female-headed farms and farmers under out-grower schemes with nucleus farms.

Studies have shown that fertilizer subsidy programs increased fertilization when they targeted farmers using little or no fertilizer [18]. However, when the subsidization eligibility criteria switched from smallholder food crop farmers in 2008–2009 to all categories of such farmers from 2010, it arguably undermined the objective of increasing fertilizer application rates. Evidence from other SSA countries suggests that farmers who had already used fertilizers prior to the implementation of a fertilizer subsidy did not necessarily increase their fertilizer use despite benefiting from the subsidy [19].

Another factor worth considering is that the proportion of price support has changed repeatedly since the fertilizer subsidy program was launched. The average subsidy as a share of market price started at 30% in 2004, increased to 47% in 2012, and fell to 21% in 2015 [13]. This variation in the effective prices facing farmers may have impacted the long-term effectiveness of the program.

2. Materials and Methods

2.1. Study Area and Sampling Method

To collect primary data for our study, we administered a questionnaire among irrigation rice farmers at the Weta/Afife Irrigation Scheme in Ghana's Volta Region from February to May 2010 (data from the same survey have previously been used in [20]). The Scheme was constructed in 1983 with Chinese technical assistance; more than 1000 ha of plots were constructed. The plots are tended using highly mechanized farming, with tractors, harvesters, fertilizers, and weedicides being used. From farming communities surrounding the Scheme and from field visits, we randomly selected 550 farmers (of which 548 chose to participate). Owing to missing responses for some questionnaire items, the final sample was reduced to 460 farmers. A total of 190 farmers in the study received fertilizer under the subsidy program, while the remaining 270 acquired it on the open market.

The questionnaire enquired about the respondents' age; their marital status; the number, age and gender of their dependents; their farming experience; and their plot characteristics. In addition, the farmers' discount rates were estimated, based on their responses to the survey. To determine the individual discount rate, each farmer was presented with two hypothetical work programs from which they had to choose one. The first program (Option A) would pay the farmer GHS 150 (GHS = Ghanaian cedis; at the time of the survey, GHS 1 = USD 0.67) in one month's time, whereas Option B would pay the farmer GHS 200 in six months' time. The farmers were also asked to quote a value for

Option B that would make them indifferent to either program. The discount rate for each farmer was then calculated as $\ln(\eta_2/\eta_1)$ where η_2 is the value indicated by the farmer and η_1 is the value of Option A (GHS 150). We also assessed the respondents' investment in SWC according to how many days of personal effort they allocated to constructing and maintaining bunds (stone or earth embankments) for redistributing water on their plots during the main farming season prior to the survey. In addition, we assessed the amount of weedicide the respondents used, their fertilizer adoption in the previous season, and their adoption of improved seeds in the previous season. Furthermore, we asked whether the respondents had taken advantage of the fertilizer subsidy in the year prior to the survey, and followed that up with a question on how much fertilizer they had used on their plots in the previous season. In addition, we measured the respondents' investment in SWC as the number of days that a farmer engaged in SWC per hectare. We also collected data on the distance that farmers travelled to their plots. Finally, based on this information, we calculated the distance between the farm plot and the fertilizer voucher distribution depot.

2.2. Theoretical and Econometric Models

The effects of fertilizer subsidies can be analyzed with the model presented by [21]. Although the model is a static one, it can be adapted to analyze dynamic decisions such as investment in SWC. For example, when farmers plough their plots after harvesting to prepare them for new vegetable crops, it destroys any previous investment in SWC they may have made. As a result, new investments in SWC have to be undertaken each year.

Following [21], we specify the production function as

$$q(N(F, SWC(L_m)), X) \tag{1}$$

where $q(\cdot)$ is the production function, $N(\cdot)$ refers to soil nutrients which depend on fertilizer F and investments in soil and water conservation $SWC(\cdot)$. The SWC depends on labor use L_m in investment in SWC. The X captures other inputs such as capital.

There is a potential endogeneity in the selection of the fertilizer subsidy program. Such a selection can be determined by unobserved factors which can affect the outcome variables. Ignoring the selection into the endogenous dummy variable could lead to biased and inconsistent estimates of the impacts of the subsidy program, particularly in the presence of unobserved individual heterogeneity [22,23]. In order to deal with this potential endogeneity, we adopt the distance between the place where the farmer resides and the voucher distribution point as an instrumental variable. This choice of instrument is justified because farmers' access to subsidized fertilizer in Ghana is determined largely by their proximity to sale agents/outlets [13].

To estimate the effects of the fertilizer subsidy on investment in SWC, we consider that such investment is measured as a count variable. Consequently, we use a full information maximum likelihood endogenous switching estimation procedure, which, according to [24], provides the statistically most efficient estimator, subject to distributional assumptions.

Formally, by considering investment in SWC as a count variable, we specify the econometric model of the investment in SWC as

$$\begin{aligned} &f(SWC_i|\mathbf{x}_i, sub_i, e_{ii}) = \exp(\mathbf{x}_i\boldsymbol{\beta} + \alpha sub_i + e_{1i}) \\ &sub_i = \begin{cases} 1, \ \mathbf{w}_i\boldsymbol{\gamma} + u_{1i} > 0 \\ 0, \ \text{otherwise.} \end{cases} \end{aligned} \tag{2}$$

where $\mathbf{x}_i$ denotes explanatory variables, with $\boldsymbol{\beta}$ being the corresponding parameter estimates; sub_i refers to participation in the fertilizer subsidy program, with α being the subsidy's effect on investment in SWC; $\mathbf{w}_i$ denotes explanatory variables of the subsidy equation; $\boldsymbol{\gamma}$ refers to the parameter estimates of the subsidy equation; while e_{1i} and u_{1i} are the two error terms.

To estimate the program's effects on the demand for fertilizer and weedicide and on productivity, we use the endogenous treatment model to estimate the average treatment effect. We use the linear counterpart of the investment in SWC model. Our adoption of a linear treatment model here is justified because we are dealing with commercial farmers whose use of modern inputs such as fertilizer and weedicide is usually positive. We specify the model as

$$y_{ki} = \mathbf{x}_i\boldsymbol{\theta} + \alpha_2 sub_i + e_{2i}$$
$$sub_i = \begin{cases} 1, & \mathbf{w}_i\boldsymbol{\gamma} + u_{2i} > 0 \\ 0, & \text{otherwise.} \end{cases} \quad (3)$$

where y_k is the kth input, $\boldsymbol{\theta}$ and $\boldsymbol{\gamma}$ are the parameter estimates, and e_{2i} and u_{2i} are the two new error terms. Finally, to estimate the program's effects on production, we use a simple Cobb-Douglas production function that accounts for the endogeneity of the subsidy variable.

As can be seen from the two formulations of the econometric models, the subsidy variable is predicted from the first-stage estimation and then used in the main equation. In addition, we use a control function approach, also used by [21], to check for the robustness of the results from the endogenous treatment model. The control function approach is more general than the maximum likelihood one, since the first-stage function can either be semiparametric or nonparametric and the joint error terms do not have to be fully parameterized [25].

3. Results

In this section, we present the descriptive statistics of the samples (Table 1) and the estimation results for fertilizer use, weedicide use, investment in SWC, and productivity (Tables 2–5). For the results, given the potential endogeneity of the fertilizer subsidy beneficiaries, we identify the distance from the farm plot to the voucher center to be inversely correlated with the subsidy (but unlikely to explain the use of inputs, investment in SWC, or the level of output). A simple regression estimation shows that increased distance to the voucher center makes being a program beneficiary less probable. This result is statistically significant at a level of less than 1%, while the corresponding F statistic is 19.00. Furthermore, Tables 2–5 show that the results for the variable *Distance to agent* are significant in all the models estimated.

3.1. Descriptive and Summary Statistics

Table 1 presents the descriptive and summary statistics for the relevant variables in the data. Thus, approximately 75% of the respondent farmers were male; this proportion is similar for farmers who received fertilizer under the subsidy program and those who did not. The average farmer had about 17 years of farming experience. The mean difference in years of experience between those who used the fertilizer subsidy program and those who did not is statistically significant. The average plot size was 2 ha among both beneficiaries and non-beneficiaries of the program, which implies that our sample consisted of small-holder irrigation farmers. Half of the sampled households were engaged in alternative employment in addition to farming. The household labor endowment was significantly lower among program beneficiaries, compared with non-beneficiaries.

However, the discount rates are higher among beneficiaries than among non-beneficiaries of the subsidy program: the extrapolated average six-month discount rate was 62% for farmers who received fertilizer under the subsidy program, and 53% for those who did not. The mean difference in the discount rate between beneficiaries and non-beneficiaries is statistically significant (i.e., $p < 0.01$). [26] suggested that high rates of time preference reduced incentives for investment in SWC. One explanation for the higher discount rates could be that beneficiaries used fertilizer to compensate for their low investment in SWC. The average discount rate was 56.5% per season, whereas moneylenders charged 50%, which was very similar. Moreover, a high percentage of farmers perceived their tenure as secure; this percentage was the same whether farmers benefited from the fertilizer subsidy or not.

Table 1. Descriptive and summary statistics of variables.

Variables	Descriptions	Non-Beneficiaries	Beneficiaries	Difference	Pooled
Gender	Dummy variable for gender (1 = Male)	0.743	0.758	−0.015	0.749
Age	Age of the farmer in years	46.55	46.17	0.38	46.39
Experience	Years of farming experience	16.513	17.762	−1250	17.028
Education	Farmer has at least secondary education (1 = Yes)	0.63	0.72	−0.09 **	0.67
Household size	Household size	5.42	5.19	0.23	5.33
Wealth index	An index of total household wealth (Ghanaian cedis, GHS)	3784.02	5451.51	−1667.49 **	4480.61
Discount rate	Discount rate for the farmer for a period of six months	0.532	0.618	−0.086 ***	0.56
Alternative employment	Farmer has alternative employment (1 = Yes)	0.589	0.511	0.078 *	0.556
Secure tenure	Proportions of respondents who see their tenure as secure	0.85	0.86	−0.01	0.85
Household labor use	Number of full-time farmworkers	3.758	3.427	0.330 **	3.621
Joint work	Number of days a farmer participates in joint work per season	2.401	3.049	−0.648 **	2.668
Number of years farming the plot	How long the farmer has been farming the plot	14.45	16.64	−2.19	15.35
Plot size	Plot size (ha)	2.006	2.019	−0.012	2.011
Tail-end plot	Dummy variable for plot being located at the tail end of the canal	0.310	0.281	0.028	0.298
Soil erosion	Soil erosion as ranked by extension officers on a scale of 1 to 10	2.261	2.145	0.116 *	2.213
Soil fertility	Soil fertility as ranked by extension officers on a scale of 1 to 10	4.888	5.005	−0.116	4.936
Clay loam soil	Dummy variable for clay loam soil	0.616	0.564	0.052	0.594
Sandy loam soil	Dummy variable for sandy loam soil	0.142	0.123	0.019	0.134
Distance to plot	Distance between place of residence and plot (km)	3.88	4.38	−0.50 **	4.09
Distance to agent	Distance between place of residence and voucher center (km)	6.466	4.983	1.483 ***	5.856
Output	Quantity of rice harvested during the main season in 2009 (Mt)	1.533	1.717	−0.185 *	1.609
Use of crop residue	Dummy variable for the use of crop residue (1 = Yes)	0.31	0.45	−0.14 ***	0.37
Fertilizer use	Quantity of fertilizer used (kg)	267.957	324.700	−56.713 ***	291.364
Weedicide use	Quantity of weedicide used (cans)	2.693	2.526	0.167	2.62
Soil and water conservation (SWC)	Days of labor devoted to SWC, per hectare	4.854	4.489	0.365	4.704

Statistical significance: * = 10%, ** = 5%, and *** = 1%.

On a scale of 1 to 10, with 1 being the lowest, the average ranking was about 5 for soil fertility and 2 for the extent of soil erosion. The fertility ranking for the plots was the same for farmers that had benefited from the program and for those that had not. Although the average soil erosion ranking for plots was low, the average level of erosion was ranked lower for farmers who had benefited from the program than for those who had not. The soil types were the same for both beneficiary and non-beneficiary groups.

A dummy variable was constructed to capture the location of the plots. This was required because water shortages are a common feature for plots located at the tail end of surface irrigation canals, meaning that farmers have to invest more to access water there (see, e.g., [27]). The proportion of plots located at the tail end of the canal was the same for beneficiaries and non-beneficiaries in the current study.

We also counted the number of times farmers participated in community work related to maintaining the irrigation canals. The level of participation reported was significantly higher among subsidy program participants than among their counterparts.

The average number of days per hectare devoted to SWC was not significantly different between fertilizer subsidy beneficiaries and non-beneficiaries. Despite the mean difference not being statistically significant, we also needed to evaluate the impact of the fertilizer subsidy on the SWC effort per se, since the mean difference does not account for the effects of unobserved heterogeneity in program participation; there could be differences in the frequency distribution, for example. Furthermore, we quantified the amount of labor as being the number of individuals who worked on the plot full-time. The average amount of labor was 3.6 full-time farmworkers. Farmers who did not benefit from the subsidy program needed a significantly higher amount of labor on average, in comparison with program beneficiaries.

3.2. *Impact of Fertilizer Subsidy Program on Demand for Fertilizer*

Table 2 presents the results from the endogenous treatment model (Model 1) and the control function approach (Model 2). The results from both models are very similar and give a good fit. From both estimations, the Subsidy variable is statistically significant. This means that farmers who received fertilizer under the subsidy program used more fertilizer (approximately 45% more) than farmers who did not receive this benefit. Farmers who used crop residues from their plots also tended to use 17% more fertilizer. Farmers whose plots were at the tail end of the canal used 21% more fertilizer than those whose plots were further up. Similarly, the elasticities of Plot size, Wealth index and Years of farming a plot were statistically significant. Farmers with higher discount rates also tended to use more fertilizer on average. The correlations between treatment errors and outcome errors are given as −0.150 and −0.542 for the endogenous treatment and control function estimations, respectively. Furthermore, we computed the variance of the residual to be 0.945.

Table 2. Estimation results for farmers' use of fertilizer.

Variables	Model 1 (Endogenous Treatment)	Model 2 (Control Function)
Fertilizer use equation		
Log of household labor	−0.020	−0.026
	(0.113)	(0.097)
Dummy variable for using crop residues	0.154 **	0.152 *
	(0.073)	(0.078)
Log of plot size	0.320 **	0.310 ***
	(0.149)	(0.104)
Discount rate	0.591 ***	0.588 ***
	(0.126)	(0.116)
Log of wealth index	−0.067 ***	−0.066
	(0.018)	(0.041)
Tail-end plot	0.189 ***	0.180 **
	(0.048)	(0.090)
Gender	−0.063	−0.057
	(0.057)	(0.095)
Age	−0.005 *	−0.005
	(0.003)	(0.004)
Log of number of years farming the plot	0.158 *	0.153
	(0.083)	(0.102)
Interactions between weedicide use and subsidy	0.148 ***	0.161 ***
	(0.028)	(0.044)
Subsidy	0.375 ***	0.483 *
	(0.105)	(0.268)
Constant	5.004 ***	4.673 ***
	(0.117)	(0.347)
Subsidy equation		
Log of distance to agent	−0.374 ***	−0.367 ***
	(0.063)	(0.071)
Constant	0.445 ***	0.434 ***
	(0.096)	(0.133)
Sigma	0.916	0.935
	(0.073)	(0.114)

Statistical significance: * = 10%, ** = 5%, and *** = 1%.

3.3. Impact of Fertilizer Subsidy Program on Demand for Weedicide

The results from the endogenous treatment and control function models in respect of the fertilizer subsidy program's impact on farmers' use of weedicide are presented in Table 3. The elasticities of Household labor and Wealth index were positive and statistically significant. Thus, the use of weedicide increased with household labor and wealth. The interactions between the Subsidy variable and fertilizer use were significant, but the Subsidy variable itself was not significant. Therefore, if one controls for the interactions between the subsidy program and fertilizer use, the use of weedicide is the same among farmers who received fertilizer under the subsidy program and those who did not. Furthermore, the results reveal that farmers who used crop residues on their plot used 18% less weedicide. The correlations between treatment errors and outcome errors are given as −0.845 and −0.588 for the endogenous treatment and control function estimations, respectively. These results imply that the unobservables that determined program participation tended to occur together with unobservables that reduced farmers' use of weedicide.

Table 3. Estimation results for farmers' use of weedicide.

Variables	Model 1 (Endogenous Treatment)	Model 2 (Control Function)
Weedicide use equation		
Log of household labor	0.203 ***	0.166 **
	(0.033)	(0.075)
Dummy variable for using crop residues	−0.196 ***	−0.192 ***
	(0.069)	(0.067)
Log of plot size	0.046	0.038
	(0.079)	(0.075)
Discount rate	−0.158	−0.044
	(0.112)	(0.197)
Log of wealth index	0.041 **	0.043 **
	(0.017)	(0.020)
Tail-end plot	0.051	0.058
	(0.066)	(0.064)
Gender	0.015	0.014
	(0.035)	(0.074)
Age	−0.004	−0.004 *
	(0.007)	(0.002)
Log of number of years farming the plot	−0.018	−0.013
	(0.092)	(0.047)
Interactions between weedicide use and subsidy	0.659 ***	0.567 ***
	(0.155)	(0.182)
Subsidy	−0.044	−0.141
	(0.316)	(0.504)
Constant	0.110	0.278
	(0.183)	(0.324)
Subsidy equation		
Log of distance to agent	−0.282 ***	−0.367 ***
	(0.049)	(0.065)
Constant	0.291 ***	0.434 ***
	(0.074)	(0.116)
Sigma	0.879 ***	
	(0.016)	
Sigma0		0.777 ***
		(0.112)
Sigma1		0.817 ***
		(0.130)

Statistical significance: * = 10%, ** = 5%, and *** = 1%.

3.4. Impact of Fertilizer Subsidy Program on Investment in Soil and Water Conservation

Model 1 in Table 4 presents the impact of the fertilizer subsidy program on investment in SWC without controlling for interactions between either Fertilizer use and Subsidy or Weedicide use and Subsidy. Model 2 in Table 4 shows the impact of the fertilizer subsidy program on investment in SWC, where we control for interactions between Fertilizer use and Subsidy as well as Weedicide use and Subsidy. The estimation results produce a good fit based on the Wald test statistic. In addition, we reject the null hypothesis that there is no correlation between the treatment error and the outcome error. The identified correlation is addressed by the estimation of the endogenous treatment model for count data.

The results presented in Table 4 also indicate that the fertilizer subsidy program actually reduces investment in SWC; the Subsidy variable is negative and statistically significant at the 1% level in both Models 1 and 2. Thus, farmers who received fertilizer under the subsidy program were less likely to invest in SWC measures. Based on the two models' results, the probability that subsidized farmers invested in SWC for five full days was 1.4% lower than for non-program beneficiaries. The probability level increases to 1.5% if we consider the correlations. However, the probability that farmers invested in SWC for five full labor days was 0.4% lower when they did not use crop residues on their farms.

Furthermore, the estimations in Table 4 reveal a number of determinants for SWC investment. For example, the elasticity of the household to SWC investment is 23%. Moreover, the older the farmer, the lower the expected number of full days of labor invested in SWC. Furthermore, a 1% increase in the discount rate increased the expected number of full days of labor a farmer would invest in SWC by 25%.

Finally, we explored the interactions between Subsidy and other explanatory variables to enhance our estimation results. The two interaction terms were not statistically significant. In respect of the correlations between treatment errors and outcome errors, these are 0.667 and 0.694 for the endogenous treatment and control function estimations, respectively.

Table 4. Estimation results for farmers' investment in soil and water conservation.

Variables	Model 1 (Endogenous Treatment)	Model 2 (Control Function)
SWC equation		
Log of household labor	0.228 **	0.168
	(0.108)	(0.124)
Dummy variable for using crop residues	−0.255 ***	−0.260 ***
	(0.095)	(0.093)
Log of plot size	0.078	0.096
	(0.088)	(0.098)
Discount rate	0.253 **	0.244
	(0.113)	(0.223)
Log of wealth index	0.036	0.022
	(0.027)	(0.030)
Tail-end plot	0.116	0.171 **
	(0.091)	(0.079)
Log of number of years farming the plot	0.034	0.000
	(0.074)	(0.081)
Gender	−0.019	−0.027
	(0.082)	(0.084)
Age	−0.007 **	−0.008 *
	(0.004)	(0.005)
Interactions between fertilizer use and subsidy		0.331
		(0.247)
Interactions between weedicide use and subsidy		0.219
		(0.147)
Subsidy	−1.299 ***	−2.235 ***
	(0.137)	(0.484)
Constant	1.139 ***	1.463 ***
	(0.378)	(0.432)
Subsidy equation		
Log of distance to agent	−0.216 ***	−0.213 ***
	(0.072)	(0.070)
Constant	0.190	0.173
	(0.144)	(0.141)
Sigma	1.371 ***	1.386 **
	(0.068)	(0.074)

Statistical significance: * = 10%, ** = 5%, and *** = 1%.

3.5. Impact of Fertilizer Subsidy Program on Productivity

The estimation results for the impact of fertilizer subsidy program on productivity are presented in Table 5. The results show that the fertilizer subsidy did not affect productivity, as the Subsidy variable was not statistically significant. Thus, farmers who received fertilizer under the subsidy program did not produce more than non-beneficiary farmers. This finding is consistent with an evaluation of input subsidy programs in different African countries, which concluded that the costs of such programs outweighed their benefits [28]. Table 5 also reveals that the elasticity of household labor and investment in SWC were positive and statistically significant. In respect of erosion, whereas clay loam soils were 10% more productive, plots that were eroded produced 7% less output on average. Sandy loam soils produced 17% more output. Tail-end plots yielded approximately 32% less output. Fertilizer use was found to be statistically significant, but with decreasing marginal productivity. Similarly, Plot size and Wealth index affected output levels. The correlations between treatment errors and outcome errors are given as 0.046 and 0.416 for the endogenous treatment and control function estimations, respectively.

Table 5. Estimation results for the production function.

Variables	Model 1 (Endogenous Treatment)		Model 2 (Control Function)	
	Coefficient	**Robust Standard Error**	**Coefficient**	**Robust Standard Error**
Output equation				
Log of household labor	0.079 ***	(0.020)	0.078 *	(0.043)
Log of fertilizer use	0.567 ***	(0.126)	0.565 ***	(0.145)
Log of investment in SWC	0.046 *	(0.026)	0.046 **	(0.022)
Tail-end plot	−0.384 ***	(0.130)	−0.385 **	(0.160)
Clay loam soil	0.099 ***	(0.026)	0.100 **	(0.050)
Soil eroded	−0.070 ***	(0.027)	−0.067 **	(0.026)
Sandy loam soil	0.173 ***	(0.034)	0.171 **	(0.073)
Log of plot size	0.978 ***	(0.116)	0.997 ***	(0.174)
Log of wealth index	0.983 ***	(0.132)	1.001 ***	(0.192)
Interactions between plot size and wealth index	−0.941 ***	(0.125)	−0.960 ***	(0.181)
Interactions between plot size and tail-end plot	0.447 ***	(0.134)	0.446 ***	(0.155)
Log of fertilizer use squared	−0.100 ***	(0.021)	−0.100 ***	(0.026)
Log of experience	−0.023	(0.035)	−0.025	(0.031)
Log of weedicide use	−0.031	(0.055)	−0.033	(0.038)
Interactions between fertilizer use and subsidy	−0.091 *	(0.051)	−0.088	(0.125)
Interactions between weedicide use and subsidy	0.080	(0.069)	0.083	(0.057)
Subsidy	0.108	(0.168)	0.082	(0.278)
Constant	0.543 ***	(0.150)	0.482 **	(0.209)
Subsidy equation				
Log of distance to agent	−0.385 ***	(0.054)	−0.385 ***	(0.081)
Constant	0.452 ***	(0.118)	0.453 ***	(0.150)

Statistical significance: * = 10%, ** = 5%, and *** = 1%.

4. Discussion

Three findings in particular deserve further comment. The first is that participation in the subsidy program appears to be associated with reduced investment in SWC. Secondly, while participation in the program is associated with increased fertilizer use, this is not associated with increased use of other modern inputs, such as weedicide. The third finding is that, despite program participants' increased fertilizer use, their productivity does not appear to be higher than that of non-participants. This third result is somewhat surprising, but it may be connected to the first two. For example, SWC investments and fertilizer use both enhance productivity; thus, if participation in the program leads to reduced SWC investment in parallel with increased fertilizer use, the loss in productivity associated with reduced SWC investment may offset the improvement in productivity associated with the increased use of fertilizer. At any rate, judging from these results, it is not obvious that the program—at least in the way it has been implemented—has in fact improved its beneficiaries' productivity.

5. Conclusions

The objective of this study was to evaluate the impact of fertilizer subsidies on the targeted input use of fertilizer and the non-targeted input use of weedicide and investment in SWC and on productivity. We adopted endogenous treatment model and control function estimations to evaluate the impact of the fertilizer subsidy on fertilizer use, productivity, and the use of weedicide. To simultaneously estimate soil and water conservation efforts and program participation, we adopted a full-information, maximum likelihood endogenous treatment model for count data to deal with any unobserved heterogeneity in selection into the program under study.

The results from the endogenous treatment model and control function estimations consistently indicate that farmers who received fertilizer under the subsidy program used more fertilizer than non-beneficiaries, but were less likely to invest in SWC. However, the subsidy program did not significantly impact the beneficiaries' use of weedicide. Furthermore, the productivity levels among farmers who received fertilizer under the subsidy program were not significantly different from those of farmers who were not part of the program. These findings suggest caution in respect of program expectations that farmers will respond to fertilizer subsidies by using complementary inputs to increase efficient and optimal nutrient uptake for agricultural production. Moreover, the interaction between farmers and extension officers, promoted as part of the fertilizer subsidy program in Ghana, did not result in significant investment in SWC. Previous studies on similar programs have indicated that access to information and extension officers can have complementary impacts on other forms of agricultural development, but this does not appear to be happening with the fertilizer subsidy program in Ghana.

The fact that participation in the subsidy program crowds out important investment in other agricultural development appears to be consistent with the broader interpretations of the theoretical model and empirical findings by [1], namely that farmers may not undertake profitable fertilizer investments. The behavioral biases that prevent profitable fertilizer investment (e.g., hyperbolic discounting) are also likely to account for the lack of other investments to complement fertilizer adoption. The combination of increasing fertilizer use and investments is seen as a measure for agricultural production in sub-Saharan Africa to hedge against climate change. Such measures can mitigate the growing water shortages, worsening soil conditions, drought, and desertification already being observed [29,30]. Thus, given the importance of other investments for achieving the goals of Ghana's fertilizer subsidies, the government should promote such investments in their subsidy programs and, in so doing, increase not only farmers' output, but also their income.

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