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in soil and water conservation

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Abstract

The new fertilizer subsidies in Sub-Saharan Africa are intended to increase agricultural production and ensure fertilizer market development. Fertilizer adoption requires complementary inputs such as investment in soil and water conservation for efficient and optimal nutrient uptake, and many fertilizer subsidy programmes implicitly assume that fertilizer subsidies crowd in such investments. The present study, therefore, evaluates the impact of fertilizer subsidies on the provision of soil and water conservation efforts in Ghana. The results indicate that beneficiaries of the studied fertilizer subsidy programme do not invest significantly more in soil and water conservation, which advises against excessive reliance on farmers to respond to fertilizer subsidies with substantial investment in soil and water conservation. Thus, in order to achieve increased investment in soil and water conservation for sustainable agricultural development, more comprehensive measures that include these investments explicitly (such as integrated soil fertility management programmes) may be needed.

Keywords: soil and water conservation, soil fertility, fertilizer subsidy, endogenous switching

JEL Classification: N57, Q15, Q18

1.0: Introduction

The principal objective of this paper is to empirically evaluate the impact of fertilizer subsidies on investment in soil and water conservation. Specifically, the study evaluates the extent to which fertilizer subsidies nudge soil and water conservation efforts among smallholders in Ghana. Soil fertility depletion is a fundamental biophysical factor that accounts for the declining agricultural production in Sub-Saharan Africa (SSA) (Scoones and Toulmin, 1999). Moreover, the low agricultural production and income reinforce the decline in soil fertility as the degradation of land and water resources also reduces the capacity of farmers to undertake investments in soil and water conservation (see e.g. Pender and Hazell, 2000; Shiferaw and Bantilan, 2004; Shiferaw et al., 2009). Despite the failure of past fertilizer subsidy programmes in SSA, many experts still maintain that fertilizer subsidies are needed to create demand and supply for fertilizer market development and higher sustainable agricultural production, and in the end facilitate development. Although the extent to which these multiple objectives are met depends on investment in soil and water conservation, many of the existing fertilizer subsidy programmes implicitly assume that subsidizing fertilizer alone will lead to significant investments in soil and water conservation. Therefore, the relationship between fertilizer subsidies and investment in soil and water conservation is fundamental to the design of new fertilizer subsidy programmes, and the purpose of this study is to explore this relationship.

For far too long, the net effect of agricultural production on soil fertility has been negative in SSA (see e.g. Stoorvogel and Smaling, 1990; Stoorvogel et al., 1993; de Jager et al., 1998), and this is costly to agricultural production (see e.g. Alfsen et al., 1997; Biggelaar et al., 2004; Diao and Sarpong, 2007). For example, using an economy-wide multimarket model for Ghana, Diao and Sarpong (2007) estimate the impact of agricultural soil loss on agricultural gross domestic product to be 5% from 2006 to 2015 (i.e. about US$4.2 billion). The reasons for land degradation include population growth and inappropriate land practices (Scoones and Toulmin, 1999). However, Boserup (1965) argues that these same factors should constitute the basis for investment in soil fertility through technological innovations and recognizes the role of public policies in nudging these technological innovations. Specifically, land scarcity and degradation provide farmers with incentives to invest in technological innovations and cultivation practices such as soil and water conservation to boost agricultural production and income (Boserup, 1965).

It is a paradox that fertilizer adoption in SSA is low given the high rate of return to fertilizer use and the high levels of land degradation and nutrient mining related to agricultural production. The fertilizer intensity in Africa in 2000 was $8\,kgha^{-1}$ as compared to 96 $kgha^{-1}$ for East and Southeast Asia and 101 $kgha^{-1}$ for South Asia (Morris et al., 2007). Explanations for this seeming anomaly range from market imperfections to systematic biases in dynamic decisions. Holden et al. (1998) suggest that credit market imperfections and a high rate of time preference could generally hinder investment in soil fertility, and provide a basis for public intervention. For instance, if farmers cannot obtain credit, they may not be able to invest in profitable investments. Specifically, the market imperfections and high rate of time preference generate inter-temporal externalities that distort investment decisions. In addition to these demand-side factors, problems could also come from the supply of fertilizer (Crawford et al., 2003; Morris, et al., 2007). For instance, poor infrastructure, high transaction costs and a non-competitive marketing system can also make fertilizer supply unviable. Duflo et al. (2010) invoke systematic behavioural biases involved in investment decisions to explain the low adoption of fertilizer despite its high rate of return. Their model predicts that some farmers will plan to buy fertilizer, yet will fail to follow through on these plans. Therefore, fertilizer subsidies should increase fertilizer use among farmers who are hyperbolic and lead to overuse of fertilizer among those who are time-consistent. The model also implies that fertilizer subsidies need not be huge to induce farmers to use fertilizer when they are offered just after harvest. In addition to the theoretical model, Duflo et al. (2010) also find that a significant proportion of the farmers in Kenya are present-biased.

The primary role of input subsidies in agricultural development should be to promote adoption of new technologies and accelerate agricultural production (Ellis, 1992). Despite the failure of past fertilizer subsidy programmes, many agricultural experts still view fertilizer subsidies as a viable means to restore soil fertility and hence ensure food security and eliminate malnutrition and poverty in SSA (Morris et al., 2007; Denning et al., 2009). Yet, Crawford et al. (2003) note that the huge fiscal burden of the earlier fertilizer subsidy programmes contributed to the macroeconomic crises. Moreover, Morris et al. (2007) hold that the past efforts to promote fertilizer in Africa were too narrowly concentrated on stimulating increases in fertilizer use without crowding in other complementary inputs such as investment in soil and water conservation.

However, the new subsidy programmes rely on innovations in programme implementations to overcome the shortcomings of the past fertilizer subsidy programmes (Banful, 2011). For instance, World Bank (2008) and Morris et al. (2007) maintain that the new subsidy programmes in SSA must be temporary and help develop fertilizer markets. The new subsidy programmes serve as mechanisms to provide subsidized inputs and services designed both to promote market development and to enhance the welfare of the poor. Investment in soil and water conservation is required in order to stimulate the demand for fertilizer (Place et al., 2003; Morris et al., 2007). This is because it increases agricultural productivity and incomes and consequently increases the demand for fertilizers. Minot and Benson (2009) hold that voucher programmes provide an opportunity to train farmers and input suppliers on efficient and profitable fertilizer use. Under a voucher system, farmers are given vouchers to be sent to private input suppliers to acquire fertilizer cheaper. Thus, a voucher is an income transfer which can promote investment in soil and water conservation if credit is a binding constraint to such investments. The vouchers are also a way to guarantee a demand for fertilizer, which in turn ensures a reliable fertilizer supply. To a large extent, these objectives will be met if the subsidy programmes increase fertilizer uptake and at the same time crowd in investment in soil and water conservation.

Public discussions on the design and implementation of fertilizer subsidies in SSA can be linked to two different viewpoints. The first is based on the premise that soil resources have been so extensively degraded that fertilizer adoption alone will be inadequate to address the protracted nutrient mining (see e.g. Stoorvogel and Smaling, 1990; Stoorvogel et al., 1993; de Jager et al., 1998). As such, Integrated Soil Fertility Management (ISFM) programmes have been suggested to overcome the protracted land degradation. ISFM programmes are comprehensive in the sense that they increase fertilizer adoption and investment in soil and water conservation (Conway, 1997; Heerink, 2005; Misiko and Ramisch, 2007; Place et al., 2003). Each of the components in ISFM relies on a different household resource endowment, with fertilizer requiring financial resources and investment in soil and water conservation requiring labour. Scoones and Toulmin (1999) suggest that a combination of organic and inorganic materials in agriculture promotes agronomic efficiency and sustainability. Janssen (1998) notes that both uptake efficiency and utilisation efficiency depend on factors such as availability of water and other nutrients, and balanced provision of nutrients is the best guarantee for their optimal use. Furthermore, ISFM programmes ensure that soil fertility and plant nutrient supply from all possible sources of plant nutrients are optimized, i.e. that soil

fertility is achieved through a balanced use of mineral fertilizers and biological sources of plant nutrients.

The second viewpoint is that a well-designed, fertilizer-only, programme may be preferable to the wider-reaching programmes outlined above. This viewpoint emerges from actual implementations of fertilizer subsidy programmes in SSA. The historical experiences from 1960s and 1970s suggest that wide- ranging policy packages with large number of different components can be distortionary, and that more limited interventions are likely to be successful in practice. There are also fiscal constraints which make more targeted programmes attractive. For these reasons, many governments have chosen to adopt fertilizer subsidy programmes that only promote fertilizer adoption. For instance, whereas Malawi and Kenya have adopted the provision of fertilizer with improved seed, Ghana and Nigeria only subsidize fertilizer. Thus, in reality, the current fertilizer subsidies dwell on the provision of fertilizer and there is little attempt to promote labour-intensive sustainable land management directly (Heerink, 2005). The promotion of fertilizer only through fertilizer subsidies can be a cost effective way of investing in soil fertility for sustainable agricultural production especially if the fertilizer use provides a strong incentive for farmers to invest in soil and water conservation. There will then be an indirect promotion of the required complementary inputs, without any need for the government to be actively involved in promoting these inputs directly.

A number of studies evaluate the impact of public programmes on investment in soil and/or water conservation and fertilizer adoption. As regards the impact of public programmes on investment in soil and/or water conservation, Berg (2002) finds that public works and self-employment programmes reduce fertilizer use; thus, employment programmes cannot be used to promote fertilizer adoption. The mechanism is that public employment programmes reduce the effect of risk on fertilizer use, and there is thus no component in this programme that directly promotes fertilizer adoption. Gebremedhin and Swinton (2003) analyze the effects of public programmes (i.e. existence of food-for-work programmes and mandatory community labour) on investment in soil conservation in Northern Ethiopia. The evidence suggests that availability of food-for-work programmes increases the adoption of stone terraces but decrease the adoption of soil bunds. Moreover, direct public involvement in constructing soil conservation structures on private lands undermines incentives for private conservation investments; however, public conservation activities on public lands encourage private soil conservation through demonstration effects. Holden and Shiferaw (2004) develop a bio-

economic model with market imperfections to evaluate the impact of hypothetical seed and fertilizer credits on adoption of sustainable soil and water management strategies in Ethiopia. The model results indicate that fertilizer credits reduce soil and water conservation work on the fields, but that this negative effect could be mitigated through linking a conservation requirement to the fertilizer credit. Hagos and Holden (2006) also assess the relationship between public-led conservation programmes and private investment in soil conservation in Ethiopia, and their findings indicate a positive relationship. Similarly, Holden and Lunduka (2010) evaluate the impact of fertilizer subsidies on agricultural yields and manure use. They find that fertilizer and manure are complements, since the studied farmers who applied more fertilizer also used more manure. However, the subsidy dummy is not statistically significant. As can be seen, the existing evidence on the impacts of public programmes on conservation investments is thus mixed.

The present paper seeks to extend the existing literature on the impact of public programmes on soil and water conservation by evaluating the impact of fertilizer subsidies on investment in soil and water conservation. The remainder of the paper is structured as follows. Section 2 discusses the fertilizer subsidy programme as implemented in Ghana. Section 3 presents a brief discussion of the study area and the sampling method. Section 4 explains the econometric models used in the estimation. Section 5 presents the results, and Section 6 concludes the paper.

2.0: The Fertilizer Subsidy Programme in Ghana

The global food crisis of 2007/2008 was a source of major concern all over the world and politically destabilized a number of governments. Governments responded to the crisis in many different ways. In Ghana, the government implemented a fertilizer subsidy programme in 2008 to promote the domestic production of agricultural output.

The subsidy programme involves a number of innovations in programme implementation in order to achieve its objectives (Banful, 2009). First, the government adopted a voucher system where the government prints region-specific and product-specific vouchers. The vouchers are then distributed by agricultural extension agents to farmers within their so-called operational areas. Subsidized fertilizer can be purchased upon presentation of a voucher and a matching cash amount. Instead of allowing government officials to distribute fertilizer – which was a major drawback of many fertilizer programmes in the past – the current programme relies on

private agents to distribute fertilizer vouchers. Secondly, an advantage of the new system noted by e.g. Minot and Benson (2009) is that it creates an opportunity for farmers to interact with extension officers regarding efficient and profitable use of fertilizer and investment in soil and water conservation.

In this way, the programme nurtures a relationship between farmers and extension officers that could outlast the subsidy programme. According to Banful (2009), the involvement of extension officers in the distribution channel offers additional benefits as it facilitates dissemination of information regarding extension services. Moreover, by interacting with extension officers, farmers gain access to information on the adoption of sustainable agriculture practices. These new measures have the potential to promote investment in soil and water conservation. However, the fertilizer subsidy programme in Ghana is not an integrated soil fertility management programme since it only provides fertilizer vouchers without any other visible effort to stimulate investment in soil and water conservation.

There are elements in the fertilizer subsidy programme that could promote demand for and supply of fertilizer and hence facilitate fertilizer market development in Ghana in the long run. For instance, the adoption of the voucher system could have this effect. Voucher systems represent income transfers that promote demand for fertilizer in the short run, but this could sustain the demand for fertilizer beyond the duration of the fertilizer subsidy programme because of higher profits and investment in complementary inputs. That the vouchers are used to acquire fertilizer from private fertilizer agents in Ghana enables the fertilizer agents to benefit from economies of scale, and provides incentives for fertilizer agents to develop new distribution networks that could remain after the fertilizer subsidy programme. Also, as previously mentioned, the interaction between farmers and extension officers permits extension officers to educate farmers on fertilizer use and sustainable land management. A number of studies have found that access to information and extension officers increase investment in soil and water conservation (see e.g. Place and Dewees, 1999; Pender and Gebremedhin, 2008; Kassie et al., 2009).

3.0: Study Area and Sampling Method

The questionnaire for this study was administered among smallholder farmers at the Afife Irrigation Project in the Volta Region of Ghana in February-May of 2010. The Afife Irrigation

Project is located in one of the rice growing districts in the country. The cross-sectional data for the analyses was collected through a survey of smallholder rice farmers. We randomly selected 550 farmers, of which 548 chose to participate. Due to item non-responses, the final sample was reduced to 460 farmers, implying a participation rate of 84%. A total of 190 farmers benefitted from the fertilizer subsidy programme, and the remaining 270 acquired fertilizer from the open market.

The questionnaire includes questions about socio-economic variables such as age of the farmer; marital status; number, age and gender of dependents; farming experience; plot characteristics; investment in soil and water conservation; fertilizer adoption; and participation in collective work. Also, to determine the individual discount rate, each farmer was presented with two hypothetical work programmes from which they had to choose one. The first programme (Option A) involved a programme that would pay the farmer 150 GHS (Ghana cedis) in one month's time, whereas Option B would pay the farmer 200 GHS in six months to reflect seasonal decision making. The farmer was also asked to quote a value for Option B that would make him/her indifferent between the two programmes. The discount rate of the farmer was then calculated as the $\log\left(\dfrac{\eta_2}{\eta_1}\right)$ where η_2 is the value indicated by the farmer and η_1 is the value of Option A (i.e. 150 GHS).

As part of the study, the extension officers at the Afife Irrigation Project were asked to rank the fertility, slope, soil type and level of erosion of plots. Soil fertility, slope and degree of soil erosion were ranked on a 1-10 scale. Investment in soil and water conservation was measured as the number of days that the farmer engaged in soil and water conservation activities per hectare. Also, we collected data on the distance that farmers travelled to their plots. Based on this information, we also calculated the distance to the fertilizer voucher distribution depot.

4.0: Econometric Model

Many of the stated goals of the new subsidy programmes seek to increase the demand for fertilizer in the long run. However, the success in this respect depends on the extent to which fertilizer subsidy programmes crowd in investments in soil and water conservation for higher productivity and income, since such investments help farmers afford fertilizer inputs in the future. Two factors determine the choice of the econometric model.

The first one is that the dependent variable, i.e. investment in soil and water conservation, is a count data variable. That is, we measure investment in soil and water conservation as the number of farm days a farmer devotes to investing in soil and water conservation per hectare. Thus, models designed for continuous dependent variables are inappropriate.

The second factor to consider is the potential problem of endogeneity of participation in the fertilizer subsidy programme. Selection into the programme can be determined by unobserved factors, and these factors can also affect investments in soil and water conservation. Ignoring the selection into the endogenous dummy variable could thus lead to biased and inconsistent estimates of the impact of the subsidy programme on investment in soil and water conservation, especially in the presence of unobserved individual heterogeneity (Heckman, 1979; Mullahy, 1997).

Terza (1998) outlines three estimation methods to address the endogenous dummy explanatory variable problem in count data models. In the first alternative, a two-stage method of moments could be used, following the Heckman's sample selection model. In this procedure, a probit model constitutes the first stage, and it is estimated for the endogenous dummy dependent variable. The second stage involves the estimation of a regression model with the multiplicative correction factor by non-linear least squares. A second alternative is estimation of non-linear weighted least squares. A third alternative is to use a full information maximum likelihood endogenous switching estimation procedure which, according to Terza (1998) provides the statistically most efficient estimator subject to distributional assumptions. Monte Carlo simulations also show that this estimation procedure provides the smallest standard deviation (see Oya, 2005).

Here, we use the full information maximum likelihood endogenous switching model to evaluate the impact of fertilizer subsidy on soil and water conservation effort. The derivation of the econometric model in this section follows Terza (1998), Miranda (2004) and Miranda and Rabe-Hesketh (2006). Conditional on a set of explanatory variables denoted as x_i in this instance, an endogenous dummy variable denoted Sub_i and an error term denoted ε_i, the investment in soil and water conservation effort follows a standard Poisson distribution:

$$f\left(SWC_i \mid \varepsilon\right) = \frac{\exp\left\{-\exp\left(x_i'\beta + \gamma Sub_i + \varepsilon_i\right)\right\}\left\{\exp\left(x_i'\beta + \gamma Sub_i + \varepsilon_i\right)\right\}^{SWC_i}}{SWC_i!}, \qquad (1)$$

where $f(\cdot)$ is the conditional probability distribution and SWC_i represents the investment in soil and water conservation for the i:th farmer. The unobserved latent variable Sub_i^* is defined by the process

$$Sub_i^* = z_i\alpha + u_i, \tag{2}$$

where z is a vector of exogenous variables, α are the corresponding unknown parameters and u is the error term. The latent variable is related to the endogenous variable through the process defined as

$$Sub_i = \begin{cases} 1 & \text{is observed if } Sub_i^* > 0 \\ 0 & \text{otherwise} \end{cases}. \tag{3}$$

Assuming that the two error terms are jointly normal with zero mean, the covariance matrix (Σ) is given as

$$\Sigma = \begin{pmatrix} \sigma^2 & \sigma\rho \\ \sigma\rho & 1 \end{pmatrix}. \tag{4}$$

There is exogenous switching (i.e. Sub_i is exogenous) if $\rho = 0$. In this case, consistent estimates of β and γ can be obtained by estimating only the investment equation. However, if $\rho \neq 0$, there is endogeneity.

The conditional joint probability density function is given as

$$f(SWC, Sub \mid w) = \int_{-\infty}^{\infty} f(SWC \mid w, Sub, \varepsilon)\left(d\Phi^*(\varepsilon) + (1 - Sub_i)(1 - \Phi^*(\varepsilon))\right)f_\varepsilon(\varepsilon \mid w)\,d\varepsilon, \tag{5}$$

where $\Phi^*(\varepsilon) = \Phi\left(\dfrac{z\alpha + (\rho/\sigma)\varepsilon}{\sqrt{1-\rho^2}}\right)$ and $f_\varepsilon(\varepsilon \mid w)$ is the conditional distribution of ε given the exogenous variables, which are represented by w. The joint normality of the two error terms ε and u conditional on w indicates that $f_\varepsilon(\varepsilon \mid w)$ is normal with zero mean and variance σ^2.

Given the functional form of $f(SWC_i \mid w, Subsidy_i, \varepsilon)$, the log-likelihood is specified as

$$L(\mu \mid w) = \sum_{i=1}^{n} \ln f\left(SWC_i, Subsidy_i \mid w_i\right) \tag{6}$$

where n is the sample size, μ is the set of parameters to be estimated including variance and covariance of the two error terms. One notable problem with maximizing equation (6) is that $f\left(SWC_i, Sub_i \mid w_i\right)$ cannot be evaluated in closed form (Terza, 1998). However, by defining $\zeta = \left(\dfrac{\varepsilon}{\sqrt{2}\sigma}\right)$ and rewriting the normal probability distribution function, we can rewrite the likelihood function under the Poisson version of the model as

$$f\left(SWC_i \mid w_i, Sub_i, \varepsilon\right) = \frac{\exp\left\{x_i'\beta + \gamma Sub_i + \varepsilon\right\}^{SWC} \exp\left\{-\exp\left\{x_i'\beta + \gamma Sub_i + \varepsilon\right\}\right\}}{SWC_i!}, \tag{7}$$

and with the change in variable by replacing ε with $\sqrt{2}\sigma\zeta$, the $f\left(\bullet\right)$ can be re-written as

$$f\left(SWC_i \mid w_i, Sub_i, \sqrt{2}\sigma\zeta\right) = \frac{\exp\left\{x_i'\beta + \gamma Sub_i + \sqrt{2}\sigma\zeta\right\}^{SWC} \exp\left\{-\exp\left\{x_i'\beta + \gamma Sub_i + \sqrt{2}\sigma\zeta\right\}\right\}}{SWC_i!}. \tag{8}$$

The full information maximum likelihood endogenous switching model will estimate both the investment in soil and water conservation and the participation in the fertilizer subsidy programme. Thus, the above model will capture the effects of the subsidy programme on investment in soil and water conservation efficiently. Kassie et al. (2010) use the same framework to evaluate the impact of sustainable land management practices on the net value of agricultural production in different agro-ecological areas in Ethiopia.

The main identifying assumption used here is that access to information and the mode of voucher distribution determine the participation in the fertilizer subsidy programme. Thus, we rely on the distance to the source of information to achieve exclusion restrictions, i.e. the distance between the farmer's place of residence and the voucher distribution point. This means that we implicitly assume that farmers who live farther away from the distribution point are less likely to access information about the vouchers and thus less likely to participate in the programme. Hence, we adopt distance to voucher distribution point as the instrument. This follows the findings in the literature that proximity to subsidy programmes enhances

participation (e.g. Allard et al., 2003). As regards the elements in the x_i vector, we follow the empirical studies on investment in soil and/or water conservation, e.g. Berg (2002), Gebremedhin and Swinton (2003), Holden and Shiferaw (2004), Hagos and Holden (2006), Solis et al. (2007), Kassie, et al. (2010).

5.0: Results

5.1: Description and summary statistics

Table 1 presents the description and the summary statistics of the data. Approximately 75% of the farmers are male, and this proportion is similar among both the farmers who participated in the fertilizer subsidy programme and those who did not. An average farmer had about 17 years of farming experience, and the mean difference in years of experience between those who received fertilizer under the fertilizer subsidy programme and those who did not is not statistically significant. The average plot size is 2 ha among both beneficiaries and non-beneficiaries of the programme, which implies that our sample consists of smallholder irrigation farmers. Half of the sampled households were engaged in alternative employment in addition to farming. The household labour endowment is significantly lower among programme beneficiaries.

However, the discount rates are higher among beneficiaries of the subsidy programme: The extrapolated average discount rate per six months is 62% and 53% among the farmers who did and did not participate in the fertilizer subsidy programme, respectively. The mean difference in discount rate between beneficiaries and non-beneficiaries is statistically significant $(i.e.\ p < 0.01)$. Holden et al. (1998) suggest that high time preferences reduce incentives for investment in soil conservation. Thus, one potential explanation could be that the beneficiaries may want to compensate for the low investment in soil conservation with fertilizer use. The average discount rate is 56.5% per season, which is similar to the interest rate charged by money lenders, which is 50% per season.

The average ranking for soil fertility is about 5, and the ranking for soil erosion is 2. Also, the rankings indicate that the fertility of the plots was the same among the farmers who benefitted from the programme and those who did not. Soil erosion is also quite low. However, the level of erosion of the plots was ranked lower for farmers who benefitted from the programme than for those who did not. Two dummy variables were constructed to capture the locations of the

plots. The proportion of plots located at the tail end of the canal is the same for the two groups. However, the proportion of plots located in the middle of the canal is lower among the farmers who benefitted from the fertilizer subsidy programme than among those who did not. The soil types are the same for both groups.

Lease holding is not common among the farmers: Only 8% of the total sample were lease holders. Moreover, this share was higher among the farmers who did not participate in the fertilizer subsidy programme. One possible explanation for the low share is that since lease holders are not registered with the authorities, the probability of being considered for the fertilizer subsidy programme is low.

TABLE 1: DESCRIPTION AND SUMMARY STATISTICS OF VARIABLES

Variables	Descriptions	Non-beneficiaries	Beneficiaries	Difference	Pooled
Gender	Dummy variable for farmer gender (= 1 if 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	-1.250	17.028
Household wealth	Total household wealth (in Ghana cedis)	3784.02	5451.51	-1667.49**	4480.61
Discount rate	Discount rate of the farmer for a period of six months	0.532	0.618	-0.086***	0.56
Alternative employment	Farmer being in alternative employment	0.589	0.511	0.078*	0.556
Household labour	Number of household members who work on the farm	3.758	3.427	0.330**	3.621
Hired labour	Hired labour (days)	10.955	18.883	-7.928***	14.227
Collective work	Number of days a farmer participates in collective work per season	2.401	3.049	-0.648**	2.668
Other soil conservation	Dummy variable for other soil conservation measures	0.313	0.251	0.062	0.287
Plot size	Plot size (in hectares)	2.006	2.019	-0.012	2.011
Middle plot	Dummy variable for plot being located in the middle	0.216	0.089	0.127***	0.163
Tail plot	Dummy variable for plot being located at the tail end	0.310	0.281	0.028	0.298
Leasehold contract	Dummy variable for leasehold (=1 if the farmer was leasing the plot)	0.102	0.057	0 .045*	0.084
Soil erosion	Soil erosion as ranked by extension officers on 1-10 scale	2.261	2.145	0.116*	2.213
Plot slope	Slope of plot as ranked by extension officers on 1-10 scale	3.020	2.944	0.076	2.988
Soil fertility	Soil fertility as ranked by extension officers on 1-10 scale	4.888	5.005	-0.116	4.936
Clayey-loam soil	Dummy variable for clayey-loamy soil	0.616	0.564	0.052	0.594
Sandy-loam soil	Dummy variable for sandy-loamy soil	0.142	0.123	0.019	0.134
Distance to agent	Distance between place of residence and voucher point (in km)	6.466	4.983	1.483***	5.856
SWC	Days devoted to soil and water conservation per ha	4.854	4.489	0.365	4.704

Statistical significance: * = p<0.10, ** = p<0.05, *** = p<0.01.

We also counted the number of times farmers participated in collective work related to maintenance of irrigation canals. The level of participation reported is statistically higher among the programme participants than among the others. On average, farmers participated in this type of work about 3 times per season, while the average number of days per season that farmers reported engaging in soil and water conservation was almost 5. These investments in soil and water conservation entail construction of bunds and are interventions that increase productivity of land and inputs in SSA (Ouedraogo and Bertelsen, 1997; Kazianga and Masters, 2002). The average number of days is not significantly different between beneficiaries and non-beneficiaries. Despite the fact that the mean difference in terms of soil and water conservation effort is not statistically significant, we still need to empirically evaluate the impact of the fertilizer subsidy on the soil and water conservation effort since the mean difference does not account for the effects of unobserved heterogeneity in the participation in the fertilizer subsidy. Also, there could be differences in the frequency distribution. We also quantified the amount of labour hired to work on the plots of the farmers. The hired input will only benefit the farmer. The average labour hired was 14 days, and this value is significantly higher among the farmers who benefitted from the programme.

The assumption we used to justify the choice of the instrumental variable appears valid. The farmers who benefitted from the fertilizer subsidy programme on average live closer to the fertilizer voucher distribution point: The average distance between the farmer's place of residence and the fertilizer distribution point among farmers who took fertilizer under the subsidy programme is 4.98 km, whereas the distance for the farmers who did not benefit from the fertilizer subsidy programme is 6.47km. The mean difference between the two averages is statistically significant $(p < 0.01)$.

5.2: Evaluation of the Impact of the Fertilizer Subsidy Programme on Soil and Water Conservation Efforts

The results for three different models are presented in Table 2. Models 2 and 3 are the results for the endogenous switching model while Model 1 is for the exogenous model. The results of the exogeneity assumption in Model 1 are presented for comparison purposes; our main results are presented under Model 2. Plot characteristics such as plot slope, soil fertility and soil type are unlikely to affect the distribution of vouchers. We therefore exclude these

variables from the subsidy equation in Model 3 to check the robustness of our results to different model specifications. The results in Model 3 are similar to those in Model 2.

Model 1 reports the results under the assumption of exogeneity. That is, the results of Model 1 are estimated under the restriction that there is no correlation between the error terms of the investment equation and the subsidy equations $(i.e. \ \rho = 0)$. The results under Model 1 indicate evidence of overdispersion and unobserved heterogeneity since σ is positive and statistically different from zero $(p < 0.01)$. These results provide a justification for the estimation of the full information maximum likelihood endogenous switching model, which is presented in Model 2. It is also important to highlight the fact that participation in the fertilizer subsidy programme does not affect investment in soil and water conservation in Model 1. This is because the subsidy dummy is not statistically significant. The coefficient for the subsidy dummy is negative, though not statistically significant.

The log-likelihood ratio test was used to test for the null hypothesis that $\rho = 0$ in Models 2 and 3. The log-likelihood ratio test comparing the exogenous model to Model 2 is statistically significant $(\chi_1^2 = 916.54; \ p < 0.01)$. Similarly, the test comparing the exogenous model to Model 3 is also statistically significant $(\chi_1^2 = 916.64; \ p < 0.01)$. These test results imply that participation in the programme is endogenous, which justifies the adoption of the endogenous switching models.

Models 2 and 3 present the results for the full information maximum likelihood endogenous switching model, which relaxes the exogeneity assumption and caters for unobserved heterogeneity found in Model 1. The results for Model 2 indicate that participation in the programme does not crowd in investment in soil and water conservation. The subsidy dummy is not statistically significant in this specification either.

Independent variables	MODEL 1		MODEL 2		MODEL 3	
	Investment	Subsidy	Investment	Subsidy	Investment	Subsidy
Subsidy	-0.087		0.264		0.318	
	(0.095)		(0.354)		(0.340)	
Natural logarithm of age of farmer	-0.027	-0.225	-0.025	-0.221	-0.029	-0.154
	(0.197)	(0.275)	(0.268)	(0.299)	(0.269)	(0.283)
Natural logarithm of household wealth	0.022	0.097**	0.023	0.098**	0.022	0.095**
	(0.035)	(0.046)	(0.043)	(0.046)	(0.043)	(0.045)
Other investments in soil conservation	-0.078	-0.169	0.033	-0.171	0.041	-0.201
	(0.112)	(0.154)	(0.141)	(0.158)	(0.140)	(0.151)
Gender	0.023	0.060	0.022	0.068	0.021	0.057
	(0.108)	(0.156)	(0.147)	(0.164)	(0.147)	(0.156)
Discount rate	0.591***	0.883***	0.420	0.887***	0.411	0.832***
	(0.169)	(0.259)	(0.262)	(0.262)	(0.257)	(0.254)
Natural logarithm of hired labour	0.100***	0.155***	0.092**	0.157***	0.090**	0.145***
	(0.030)	(0.040)	(0.043)	(0.040)	(0.041)	(0.038)
Collective work	0.071***	0.031*	0.053***	0.031	0.052***	0.032*
	(0.009)	(0.019)	(0.017)	(0.019)	(0.017)	(0.018)
Natural logarithm of labour endowment	0.285**	-0.190	0.297**	-0.183	0.309**	-0.245*
	(0.117)	(0.148)	(0.123)	(0.149)	(0.125)	(0.140)
Middle plot	0.566***	-0.611***	0.614***	-0.628***	0.629***	-0.655***
	(0.153)	(0.220)	(0.193)	(0.223)	(0.193)	(0.210)
Leasehold contract	0.331*	-0.279	0.203	-0.265	0.206	-0.255
	(0.169)	(0.261)	(0.219)	(0.252)	(0.219)	(0.237)
Tail plot	-0.019	-0.277*	0.031	-0.278*	0.024	-0.180
	(0.106)	(0.148)	(0.144)	(0.149)	(0.140)	(0.142)
Alternative employment	0.058	-0.282**	0.133	-0.280**	0.138	-0.280**
	(0.098)	(0.141)	(0.129)	(0.140)	(0.128)	(0.134)
Plot slope	-0.053	0.067	-0.094	0.069	-0.086	
	(0.081)	(0.115)	(0.098)	(0.111)	(0.098)	
Soil erosion	-0.001	-0.139	0.117	-0.141	0.102	
	(0.085)	(0.123)	(0.103)	(0.116)	(0.101)	
Soil fertility	0.081*	0.120	0.052	0.115	0.064	
	(0.046)	(0.074)	(0.063)	(0.077)	(0.064)	
Clayey-loam soil	-0.164	-0.045	-0.252	-0.050	-0.258	
	(0.137)	(0.208)	(0.178)	(0.208)	(0.175)	
Sandy-loam soil	-0.237	0.120	-0.254	0.102	-0.245	
	(0.178)	(0.274)	(0.224)	(0.269)	(0.222)	
Natural logarithm of experience	-0.330***	0.260*	-0.379***	0.261*	-0.384***	0.263**
	(0.098)	(0.144)	(0.127)	(0.141)	(0.128)	(0.133)
Natural logarithm of plot size	-0.022	-0.357**	0.084	-0.358**	0.081	-0.281*
	(0.124)	(0.166)	(0.149)	(0.158)	(0.147)	(0.151)
Natural logarithm of distance to agent		-0.374***		-0.376***		-0.299***
		(0.102)		(0.102)		(0.087)
Constant	0.566	-0.643	0.594	-0.660	0.555	-0.477
	(0.818)	(1.092)	(1.048)	(1.176)	(1.051)	(1.054)
Sigma		1.035***		1.004***		1.008***
		(0.049)		(0.063)		(0.065)
Rho				-0.202		-0.234
				(0.204)		(0.194)
Wald χ^2	162.55***		157.72***		149.13***	
Number of observations	460		460		460	

Standard errors in parentheses. Statistical significance: * = p<0.1, ** = p<0.05, *** = p<0.01.

The regression results identify a number of determinants of investment in soil and water conservation. Hired labour and investment in soil and water conservation are complementary. Similarly, farmers with higher household labour endowment invest more in soil and water conservation. Both results reveal that investment in soil and water conservation requires labour resources. Also, farmers who participate in joint work with other farmers also invest significantly more in soil and water conservation. However, farmers who have extensive experience in farming allocate less days to investment in soil and water conservation. Farming experience could endow farmers with higher labour quality for investment in soil and water conservation. The location of plots affects investment in soil and water conservation in that farmers whose plots are located in the middle of blocks spend more days on investment in soil and water conservation as compared to the base category, the farmers with head plots.

The results also indicate a number of factors that determine participation in the fertilizer subsidy in Ghana. First, farmers who live farther away from the fertilizer voucher distribution point are less likely to participate in the fertilizer subsidy programme. This provides a justification for the exclusion restriction, and also supports existing literature that proximity to a welfare programme affects participation (Allard et al., 2003). Similarly, participation in joint work with other farmers increases the likelihood of participating in the fertilizer subsidy programme. These two determinants of participation could be interpreted to mean that access to information is relevant for participation. Farmers with higher household wealth are more likely to participate in the fertilizer subsidy programme. Also, farmers with higher rate of time preference are more likely to participate in the fertilizer subsidy programme. Furthermore, hired labour affects participation in the fertilizer subsidy programme. Farmers who engage in alternative employment are less likely to participate in the fertilizer subsidy programme. However, farmers with more years of farming experience in farming are more likely to do so.

6.0: Conclusions

The main objective of the present paper is to evaluate the impact of fertilizer subsidies on investment in soil and water conservation. This follows an implicit assumption in many fertilizer subsidy programmes that fertilizer subsidies will nudge investment in soil and water conservation. We adopt a full information maximum likelihood endogenous switching model that handles unobserved heterogeneity in the selection into the studied subsidy programme to

simultaneously estimate soil and water conservation efforts and participation in the programme.

The results indicate that beneficiaries of the fertilizer subsidy programme do not invest more in soil and water conservation efforts as compared to non-beneficiaries. These findings suggest caution on reliance on farmers to respond to fertilizer subsidies with complementary inputs to ensure efficient and optimal nutrient uptake for agricultural production and fertilizer market development. The interaction between farmers and extension officers that was promoted as part of the fertilizer subsidy programme in Ghana does not result in significant investment in soil and water conservation. Previous studies of similar programmes (see e.g., Place and Dewees, 1999; Pender and Gebremedhin, 2008; Kassie et al., 2009) have indicated that access to information and extension officers can increase investment in soil and water conservation, but this does not appear to be happening with the fertilizer subsidy programme in Ghana.

The results that the participation in the fertilizer subsidy programme does not yield significant investment in soil and water conservation appear to be consistent with the broader interpretations of the theoretical model and empirical findings of Duflo et al. (2010) that farmers may not undertake profitable fertilizer investments. It is likely that the behavioral biases that prevent profitable fertilizer investment (e.g. hyperbolic discounting) could also account for lack of investments in soil and water conservation to support fertilizer adoptions.

The combination of increased fertilizer use with soil and water conservation investments would not only help ensure efficient and optimal nutrient uptake but could also offer a protection of agricultural production in SSA against climate change. The investment in soil and water conservation is seen as a measure to hedge agricultural production in SSA against climate change since these soil and water conservation investments will mitigate the growing water shortages, worsening soil conditions, and drought and desertification (IPCC, 2001; Kurukulasuriya and Rosenthal 2003). Given the importance of investment in soil and water conservation for achieving the stated objectives of the new fertilizer subsidies, efforts should be made to promote investment in soil and water conservation in addition to the fertilizer subsidies. These measures would increase output and income among the farmers. The finding from the study that participation in the fertilizer subsidy programme does not lead to such investments thus suggests that further intervention may be needed.

Thus, the fertilizer subsidy programme alone does not nudge Boserup (1965). This suggests that for the programme to crowd in investments in soil and water conservation, comprehensive measures that promote fertilizer adoption and investment in soil and water conservation simultaneously, such as an integrated soil fertility management programme, may be preferable.

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