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Central America
Environment for Development Program for Central America
Centro Agronómico Tropical de Investigacíon y Ensenanza (CATIE)
Email: centralamerica@efdinitiative.org

China
Environmental Economics Program in China (EEPC)
Peking University
Email: EEPC@pku.edu.cn

Ethiopia
Environmental Economics Policy Forum for Ethiopia (EEPFE)
Ethiopian Development Research Institute (EDRI/AAU)
Email: ethiopia@efdinitiative.org

Kenya
Environment for Development Kenya
Kenya Institute for Public Policy Research and Analysis (KIPPRA)
Nairobi University
Email: kenya@efdinitiative.org

South Africa
Environmental Policy Research Unit (EPRU)
University of Cape Town
Email: southafrica@efdinitiative.org

Tanzania
Environment for Development Tanzania
University of Dar es Salaam
Email: tanzania@efdinitiative.org

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Abstract

The new fertilizer subsidies in sub-Saharan Africa are intended to increase agricultural production and ensure development of a fertilizer market. Fertilizer adoption requires complementary inputs, such as investment in soil and water conservation (SWC), for efficient and optimal nutrient uptake, and many fertilizer subsidy programs implicitly assume that fertilizer subsidies crowd in such investments. The results of our study of the impact of fertilizer subsidies on SWC efforts in Ghana indicate that beneficiaries of the program do not invest significantly more in SWC. This suggests that policies should not expect farmers to respond to fertilizer subsidies with substantial investment in SWC. Thus, in order to achieve increased investment in SWC for sustainable agricultural development, more comprehensive measures that include fertilizer investments explicitly (such as integrated soil fertility management programs) may be needed.

Key Words: soil and water conservation, soil fertility, fertilizer subsidy, endogenous switching

JEL Classification: N57, Q15, Q18

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Godwin Kofi Vondolia, Håkan Eggert, and Jesper Stage*

Introduction

The principal objective of this paper is to empirically evaluate the impact of fertilizer subsidies on investment in soil and water conservation (SWC), looking specifically at smallholder farmers in Ghana. Soil fertility depletion is a fundamental biophysical factor that accounts for the declining agricultural production in sub-Saharan Africa (Scoones and Toulmin 1999). Moreover, the low agricultural production and decreased income reinforce the decline in soil fertility because the degradation of land and water resources also reduces the capacity of farmers to invest in SWC (e.g., Pender and Hazell 2000; Shiferaw and Bantilan 2004; Shiferaw et al. 2009).

Despite the failure of past fertilizer subsidy programs in sub-Saharan Africa, many experts still maintain that fertilizer subsidies are needed to create the demand and supply that develops fertilizer markets and contributes to higher sustainable agricultural production. Although the extent to which these multiple objectives are met depends on investment in SWC, many existing fertilizer subsidy programs implicitly assume that subsidizing fertilizer alone will lead to significant investments in SWC. Thus, the relationship between fertilizer subsidies and investment in SWC is fundamental to the design of new fertilizer subsidy programs. We propose to explore this relationship.

For far too long, the net effect of agricultural production on soil fertility has been negative in sub-Saharan Africa (e.g., Stoorvogel and Smaling 1990; Stoorvogel et al. 1993; de Jager et al. 1998), which is costly to agricultural production (e.g., Alfsen et al. 1997; Biggelaar et

* Corresponding author: Kofi Vondolia, Department of Economics, University of Gothenburg, 405 30 Sweden, (e-mail): Kofi.Vondolia@economics.gu.se ; Håkan Eggert, Department of Economics, University of Gothenburg, Sweden, (email) Hakan.Eggert@economics.gu.se; Jesper Stage, Department of Economics, University of Gothenburg and Department of Social Sciences, Mid Sweden University, Sundsvall, Sweden, (email) jesper.stage@miun.se. Håkan Eggert acknowledges support from the research program Human Cooperation to manage natural resources (Commons). Financial support from Sida (Swedish International Development and Cooperation Agency) to the Environmental Economics Unit of University of Gothenburg is gratefully acknowledged. Jesper Stage is funded by Elforsk. Thanks to Jim Anderson, World Bank, and seminar participants at University of Gothenburg for useful comments on earlier versions of the paper.

al. 2004; Diao and Sarpong 2007). For example, using an economy-wide multi-market model for Ghana, Diao and Sarpong (2007) estimated the impact of agricultural soil loss on agricultural gross domestic product to be 5 percent 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) argued that these same factors should constitute the basis for investment in soil fertility through technological innovations, and recognized 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 SWC, to boost agricultural production and income (Boserup 1965).

It is a paradox that fertilizer adoption in sub-Saharan Africa is low, given the high rate of return with fertilizer use and the high levels of land degradation and nutrient mining related to agricultural production. The fertilizer intensity in Africa in 2000 was 0.8 kgs per hectare, compared to 9.6 kgs per hectare in east and southeast Asia, and 10.1 kgs per hectare in 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) suggested 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 production-enhancing measures. 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 make fertilizer supply unviable. Duflo et al. (2011) invoked systematic behavioral biases 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. 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, particularly if they are offered just after harvest. In addition to the theoretical model, Duflo et al. (2011) also found 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 programs, many agricultural experts still view fertilizer subsidies as a viable means of restoring soil fertility to help ensure food security and eliminate malnutrition and poverty in sub-Saharan Africa (Morris et al. 2007; Denning et al. 2009). Yet, Crawford et al. (2003) noted that the giant fiscal burden of earlier fertilizer subsidy programs contributed to the region's macroeconomic crises. Moreover, Morris et al. (2007) held 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 SWC.

However, the new subsidy programs rely on innovations in implementing them to overcome the shortcomings of the past fertilizer subsidy programs (Banful 2011). For instance, World Bank (2008) and Morris et al. (2007) maintained that the new subsidy programs in sub-Saharan Africa must be temporary and aim at developing fertilizer markets. The new subsidy programs 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 SWC is required in order to stimulate the demand for fertilizer (Place et al. 2003; Morris et al. 2007). This is because SWC increases agricultural productivity and incomes, and consequently raises the demand for fertilizers. Minot and Benson (2009) held that voucher programs provide an opportunity to train farmers and input suppliers on efficient and profitable fertilizer use. Under this system, farmers are given vouchers that let them acquire fertilizer cheaper from private input suppliers. Thus, a voucher is an income transfer, which can promote investment in SWC 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 programs increase fertilizer uptake and, at the same time, crowd in investment in SWC.

Public discussions on the design and implementation of fertilizer subsidies in sub-Saharan Africa 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 is inadequate to address the protracted nutrient mining (e.g., Stoorvogel and Smaling 1990; Stoorvogel et al. 1993; de Jager et al. 1998). As such, integrated soil fertility management (ISFM) programs have been suggested to overcome the protracted land degradation. ISFM programs are comprehensive in the sense that they increase fertilizer adoption and investment in SWC (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 SWC requiring labor. Scoones and Toulmin (1999) suggested that a combination of organic and inorganic materials in agriculture promotes agronomic efficiency and sustainability. Janssen (1998) noted that both uptake efficiency and utilization efficiency depend on such factors as availability of water and other nutrients, and balanced provision of nutrients is the best guarantee for their optimal use. Furthermore, ISFM programs ensure that soil fertility and all possible sources of plant nutrients are optimized, namely, 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 program may be preferable to the wider-reaching programs outlined above. This viewpoint emerged from actual implementations of fertilizer subsidy programs in sub-Saharan Africa. The historical experiences from the 1960s and 1970s suggest that wide-ranging policy packages with a 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 programs attractive.

For these reasons, many governments have chosen to adopt fertilizer subsidy programs that only promote fertilizer adoption. For instance, whereas Malawi and Kenya provide 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 labor-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 fertilizer use provides a strong incentive for farmers to invest in SWC. 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 have evaluated the impact of public programs on investment in SWC and fertilizer adoption. As regards the impact of public programs on investment in SWC, Berg (2002) found that public works and self-employment programs reduce fertilizer use; thus, employment programs should not be used to promote fertilizer adoption. The mechanism is that public employment programs reduce the effect of risk of fertilizer use, and there is thus no component in this program that directly promotes fertilizer adoption.

Gebremedhin and Swinton (2003) analyzed the effects of public programs (e.g., food-for-work programs and mandatory community labor) on investment in soil conservation in northern Ethiopia. The evidence suggests that availability of food-for-work programs increases the adoption of stone terraces, but decreases 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) developed 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 SWC work on the fields, but that this negative effect could be mitigated by linking a conservation requirement to the fertilizer credit. Hagos and Holden (2006) also assessed the relationship between public-led conservation programs and private investment in soil conservation in Ethiopia, and their findings indicate a positive relationship.

Similarly, Holden and Lunduka (2010) evaluated the impact of fertilizer subsidies on agricultural yields and manure use. They found that fertilizer and manure are complements, since the farmers in the study 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 programs on conservation investments is mixed.

We seek to extend the existing literature on the impact of public programs on SWC by evaluating the impact of fertilizer subsidies on investment in SWC. The paper is structured as follows. Section 1 discusses the fertilizer subsidy program as implemented in Ghana. Section 2 presents a brief discussion of the study area and the sampling method. Section 3 explains the econometric models used in the estimation. Sections 4 presents the description and summary statistics of the data, and section 5 discusses the impact of Ghana's fertilizer subsidy program. Section 6 concludes the paper.

1. The Fertilizer Subsidy Program in Ghana

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

The subsidy program employs several implementation innovations to achieve its objectives (Banful 2009). First, the government adopted a region- and product-specific voucher system. The vouchers are distributed by agricultural extension agents to farmers within their so-called operational areas. Involving extension officers in the distribution channel offers added benefits. It facilitates dissemination of information about available extension services. It also creates opportunities for farmers to interact with extension officers about efficient and profitable use of fertilizer, and opportunities for the extension agents to open discussions of investment in SWC (Minot and Benson 2009). In this way, the program nurtures a relationship between farmers and extension officers that could outlast the subsidy program.

To purchase the subsidized fertilizer, farmers present the voucher and a matching amount of cash to private agents. Instead of government officials distributing the fertilizer—which was a major drawback of many fertilizer programs in the past—the current program relies on private agents to supply the fertilizer.

A number of studies have shown that increasing farmers' access to information and extension officers increases investment in SWC (e.g., Place and Dewees 1999; Pender and Gebremedhin 2008; Kassie et al. 2009). However, Ghana's fertilizer subsidy program is not an integrated soil fertility management program: it only provides fertilizer vouchers without any other visible effort to stimulate investment in SWC.

There are elements in Ghana's fertilizer subsidy program that can promote demand for fertilizer and increase its supply, and potentially facilitate fertilizer market development in the long run. The voucher system represents income transfers that promote demand for fertilizer in the short run, which could also sustain the demand for fertilizer beyond the life of the fertilizer subsidy program, due to higher profits and investment in complementary inputs. Farmers using the vouchers must acquire fertilizer from private fertilizer agents in Ghana, which enables the agents to benefit from economies of scale. This provides incentives for them to develop new distribution networks that could remain when the fertilizer subsidy program ends.

2. Study Area and Sampling Method

We administered a questionnaire for this study (to collect cross-sectional data for the analysis) to smallholder rice farmers at the Afife irrigation project in the Volta region of Ghana from February to May 2010. We randomly selected 550 farmers, of which 548 chose to participate. Due to missing responses to some items, the final sample was reduced to 460 farmers, implying a participation rate of 84 percent. A total of 190 farmers in the study took advantage of the fertilizer subsidy program, and the remaining 270 acquired fertilizer on the open market.

The questionnaire included questions about socioeconomic variables, such as the farmer's age; marital status; number, age, and gender of dependents; farming experience; plot characteristics; investment in SWC; fertilizer adoption; and participation in joint work, i.e. joint work with other farmers to maintain the irrigation canals. Also, 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[1] in one month's time, whereas option B would pay the farmer GHS 200 in six months to reflect seasonal decisionmaking. The farmers were also asked to quote a value for option B that would make them indifferent to either program. The discount rate of the farmer was then calculated as the $\log\left(\frac{\eta_2}{\eta_1}\right)$ where η_2 is the value indicated by the farmer and η_1 is the value of option A (150 GHS).

As part of the study, the extension officers at the Afife irrigation project were asked to describe the soil type and rank the fertility, slope, and level of erosion of plots on a scale of 1 to 10 (1 being the lowest). Investment in SWC was measured as the number of days that the farmer engaged in SWC 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.

3. Econometric Model

Many of the stated goals of the new subsidy programs seek to increase the demand for fertilizer in the long run. However, success in this respect depends on the extent to which fertilizer subsidy programs crowd in investments in SWC 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—investment in SWC—is a count data variable. That is, we measure investment in SWC as the number of days a farmer devotes to it per hectare. Thus, models designed for continuous dependent variables are inappropriate.

[1] GHS = Ghana cedis.

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

Terza (1998) outlined 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 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. The 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 SWC 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 SWC 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 $f\left(\cdot\right)$ 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:

$$Sub_i^* = z_i\alpha + u_i, \qquad (2)$$

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:

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

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:

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

where $\Phi^*\left(\varepsilon\right) = \Phi\left(\dfrac{z\alpha + \left(\rho/\sigma\right)\varepsilon}{\sqrt{1-\rho^2}}\right)$ and $f_\varepsilon\left(\varepsilon \mid w\right)$ 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 $f_\varepsilon\left(\varepsilon \mid w\right)$ is normal with zero mean and variance σ^2.

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

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

where n is the sample size; and 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

$\zeta = \left(\frac{\varepsilon}{\sqrt{2\sigma}} \right)$ and rewriting the normal probability distribution function, we can rewrite the likelihood function under the Poisson version of the model as:

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

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

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

The full information maximum likelihood endogenous switching model will estimate both the investment in SWC and the participation in the fertilizer subsidy program. Thus, the above model will capture the effects of the subsidy program on investment in SWC efficiently. Kassie et al. (2010) used the same framework to evaluate the impact of sustainable land management practices on the net value of agricultural production in different agroecological 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 program. Thus, we rely on the distance to the source of information to achieve exclusion restrictions, in other words, 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 program. Hence, we adopt distance to voucher distribution point as the instrument. This follows the findings in the literature that proximity to subsidy programs 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).

4. Description and Summary Statistics

Table 1 presents the description and the summary statistics of the data. Approximately 75 percent of the farmers are male, and this proportion is similar among both the farmers who participated in the fertilizer subsidy program 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 used the fertilizer subsidy program and those who did not is not statistically significant. The average plot size is 2 hectares among both beneficiaries and non-beneficiaries of the program, which implies that our sample consists of smallholder irrigation farmers. Half the sampled households were engaged in alternative employment in addition to farming. The household labor endowment is significantly lower among program beneficiaries.

However, the discount rates are higher among beneficiaries of the subsidy program: the extrapolated average discount rate per six months is 62 percent and 53 percent among the farmers who did and did not participate in the fertilizer subsidy program, respectively. The mean difference in discount rate between beneficiaries and non-beneficiaries is statistically significant (i.e., $p < 0.01$). Holden et al. (1998) suggested 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 percent per season, which is similar to the interest rate charged by money lenders, which is 50 percent per season.

The average ranking for soil fertility is about 5, and the ranking for soil erosion is 2.[2] Also, the rankings indicate that the fertility of the plots is the same among the farmers who benefitted from the program 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 used the program 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 program 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 percent of the total sample holds a lease. Moreover, this share was higher among the farmers who did not participate in the fertilizer subsidy program. 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 program is low.

[2] On a scale of 1 to 10, with 1 as the lowest.

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 GHS)	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 has alternative employment	0.589	0.511	0.078*	0.556
Household labor	Number of household members who work on the farm	3.758	3.427	0.330**	3.621
Hired labor	Hired labor (in days)	10.955	18.883	-7.928***	14.227
Joint work	Number of days a farmer participates in joint 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 of the canal	0.216	0.089	0.127***	0.163
Tail plot	Dummy variable for plot being located at the tail end of the canal	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 a scale of 1 to 10	3.020	2.944	0.076	2.988

Soil fertility	Soil fertility as ranked by extension officers on a scale of 1 to 10	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 hectare	4.854	4.489	0.365	4.704

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

We also counted the number of times farmers participated in joint work related to maintenance of irrigation canals. The level of participation reported is statistically higher among the program participants than among the others. Comparing this public intervention that increases production of land and inputs with private investment in SWC (Ouedraogo and Bertelsen 1997; Kazianga and Masters 2002), on average, farmers participated in community work about three times per season, while the average number of days per season that farmers reported engaging in SWC was almost five. The average number of days is not significantly different between fertilizer subsidy 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 SWC 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 labor hired to work on the plots of the farmers. The hired input will only benefit the farmer. The average amount of labor hired was 14 days, and this value is significantly higher among the farmers who benefitted from the program.

The assumption we used to justify the choice of the instrumental variable appears valid. The farmers who benefitted from the fertilizer subsidy program 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 used subsidized fertilizer is 4.98 km, whereas the distance for the farmers who did not benefit from the fertilizer subsidy program is 6.47 km. The mean difference between the two averages is statistically significant $\left(p < 0.01\right)$.

5. Impact of Ghana's Fertilizer Subsidy Program 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., $p = 0$). The results under model 1 indicate evidence of over-dispersion 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 program does not affect investment in SWC 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.

Table 2. Regression Results of Independent Variables

	Model 1		**Model 2 (Main model)**		**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 labor	0.100***	0.155***	0.092**	0.157***	0.090**	0.145***
	(0.030)	(0.040)	(0.043)	(0.040)	(0.041)	(0.038)
Joint 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 labor 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)
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)
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)
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.

For the gender dummy, zero denotes female and one male. For the plot location dummies, head plots are the the baseline and have zero values for both dummies.

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 $\left(\chi_1^2 = 916.54;\ p < 0.01\right)$. Similarly, the test comparing the exogenous model to model 3 is also statistically significant $\left(\chi_1^2 = 916.64;\ p < 0.01\right)$. These test results imply that participation in the program 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 program does not crowd in investment in SWC. The subsidy dummy is not statistically significant in this specification either.

The regression results identify a number of determinants of investment in SWC. Hired labor and investment in SWC are complementary. Similarly, farmers with a higher household-labor endowment invest more in SWC. Both results reveal that investment in SWC requires labor resources. Also, farmers who participate in joint work with other farmers also invest significantly more in SWC. However, farmers who have extensive experience in farming allocate less days to investment in SWC. The location of plots affects investment in SWC; farmers whose plots are located in the middle of a block of plots spend more days on investment in SWC as compared to the base category.

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 program. This provides a justification for the exclusion restriction, and also supports existing literature that proximity to a welfare program affects participation (Allard et al. 2003). Similarly, participation in joint work with other farmers increases the likelihood of participating in the fertilizer subsidy program. 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 program. Also, farmers with higher rate of time preference are more likely to participate in the fertilizer subsidy program. Furthermore, hired labor affects participation in the fertilizer subsidy program. Farmers who engage in alternative employment are less likely to participate in the fertilizer subsidy program. However, farmers with more years of farming experience in farming are more likely to do so.

6. Conclusions

The main objective of our paper is to evaluate the impact of fertilizer subsidies on investment in SWC. This follows an implicit assumption in many fertilizer subsidy programs that fertilizer subsidies will nudge investment in SWC. We adopted a full information maximum likelihood endogenous switching model that handles unobserved heterogeneity in the selection into the studied subsidy program to simultaneously estimate SWC efforts and participation in the program.

The results indicate that beneficiaries of the fertilizer subsidy program do *not* invest more in SWC efforts, compared to non-beneficiaries. These findings suggest caution on reliance that farmers will respond to fertilizer subsidies with complementary inputs that increase efficient and optimal nutrient uptake for agricultural production and help develop a fertilizer market. The interaction between farmers and extension officers, which was promoted as part of the fertilizer subsidy program in Ghana, does not result in significant investment in SWC. Previous studies of similar programs (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 SWC, but this does not appear to be happening with the fertilizer subsidy program in Ghana.

The results that the participation in the fertilizer subsidy program does not yield significant investment in SWC appear to be consistent with the broader interpretations of the theoretical model and empirical findings of Duflo et al. (2011) 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 SWC to support fertilizer adoptions.

The combination of increased fertilizer use (which can help efficient and optimal nutrient uptake) and SWC investments is seen as a measure to hedge agricultural production in sub-Saharan Africa against climate change. They can mitigate the growing water shortages, worsening soil conditions, drought, and desertification (IPCC 2001; Kurukulasuriya and Rosenthal 2003). Given the importance of investment in SWC to achieve the goals of Ghana's fertilizer subsidies, the government should promote it along with fertilizer subsidies. These measures would increase output and income among the farmers.

Our findings that participation in the fertilizer subsidy program does not lead to such investments show that Ghana's fertilizer subsidy program alone does not nudge Boserup (1965). This suggests that an integrated soil fertility management program, which simultaneously promotes fertilizer adoption and SWC investment, is needed.

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