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Fertilizer subsidy policy and smallholder farmers' crop productivity: The case of maize production in North-Eastern Ghana

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Crop yield enhancing technologies such as inorganic fertilizers present opportunities for improving smallholder farmers' crop yields, food security and incomes. This study examines maize productivity response to Ghana's fertilizer subsidy policy focusing on yield differences between participants and non-participants in the Tempane District in Ghana among smallholder farmers. An Endogenous Switching Regression (ESR) model is employed to simultaneously examine the determinants of participation and its impact on maize productivity. The results show that education, nativity and media access are factors influencing the probability of fertilizer subsidy participation. The study reveals that participation in subsidized fertilizer policy is positively and significantly associated with maize productivity. Other factors such as fertilizer use rate, improved seeds and age enhance maize yield whilst non-farm work engagement negatively influences maize yield. These findings suggest that the impact of subsidized fertilizer on maize productivity can be enhanced with proper targeting and farmer education through field demonstrations.

Key words: Subsidized fertilizer, maize yield, endogenous switching regression, Northern Ghana.

INTRODUCTION

Agriculture is the main source of livelihood for the majority of people in developing countries where crop production methods are dominated by traditional practices. Farmers in Sub-Saharan countries have traditionally cleared virgin lands, grown crops for a few seasons and then moved on to clear more land. This practice left the abandoned land to fallow, allowing it to regain its fertility over time. However, constant population growth has compelled farmers to continually plant crops on the same land giving no time for the soils to replenish the lost nutrients (Mokwunye and Bationo, 2011). The resulting effect has been soil nutrient depletion which has led to declining per capita food production (Mwangi, 1996), increased food insecurity and high poverty rates, especially in African countries. For smallholder farmers to feed themselves and to increase their incomes, then the

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use of modern methods of production that improve and restore soil fertility is paramount.

The use of inorganic fertilizers to restore and maintain soil fertility for increased crop productivity has been generally acclaimed as very necessary among researchers and policy makers (Chapoto and Ragasa, 2013; Duflo et al., 2011; Mokwunye and Bationo, 2011). However, farmers in Africa may not be in the position to optimize fertilizer use because either they cannot afford or that fertilizer may not be readily available. As indicated by Druilhe and Barreiro-Hurlé (2012), while Sub-Saharan African farms are highly deficient in nutrients, fertilizer use is very low, with only 7 kg/ha application rate compared to more than 150 kg/ha in Asia (Fearon et al., 2015). The low rates of use of fertilizers are largely the result of limited smallholder farmers' access, high cost and limited availability of fertilizers in the local community. These circumstances therefore make subsidy programmes economically justified to address the market failures and the poor incentives faced by farmers.

Subsidy programmes were suspended as part of the Structural Adjustment Programme (SAP) and market liberalization policies adopted by African governments in the 1980s and 1990s (Chibwana et al., 2010; Minot and Benson, 2009). The combined effect of production stagnation, declining soil fertility and rising food insecurity however, led to fresh interest in promoting input subsidies as a tosol for addressing food insecurity. The Abuja declaration on fertilizer for a "Green Revolution" which has the objective of increasing fertilizer use to 50 kg/ha by 2015 (AU, 2006) was adopted at the 2006 Africa Fertilizer Summit held in Abuja to address agricultural productivity challenges.

In 2008, Ghana re-introduced the fertilizer subsidy programme with the core objective of raising productivity/production in line with government's commitment to ensure food security and to improve the living standards of Ghanaians. The new programme, per the recommendations of the Abuja Summit, was expected to help increase fertilizer usage to at least 50 kg/ha by 2015. A proper implementation of such a subsidy programme could trigger both short term and long term development, not only in the agricultural sector but in other sectors of the economy. For example, effective subsidies can raise both land and labour productivities, as well as drive down staple food prices, which have the multiplier effect of raising real incomes, enhancing local labour demand and wages and improving the people's nutrition (Kassie et al., 2011). The reintroduction of the fertilizer subsidy programme was, therefore, to address the challenges confronting the development of the agricultural sector generally and specifically to increase crop production and productivity for sustainable food security, with particular attention to smallholder farmers (Benin et al., 2013) cultivating maize, rice, sorghum and millet (Fearon et al., 2015). Between 2008 and 2012, Ghana's annual spending on subsidized fertilizers grew by over 4 folds, amounting to GH₵20.6 million in 2008 and GH₵117.4 million in 2012 (Fearon et al., 2015).

Maize, being the largest and most important staple crop in Ghana, accounts for over 50% of cultivated land in the country with its production being dominated by smallholder farmers who usually rely heavily on rain fed conditions with limited use of fertilizers and other inputs due to high cost of such inputs (MoFA, 2011, 2013). The on-going fertilizer subsidy falls in line with government's commitment to boost the production of staple food crops including maize to cope with the ever growing demand for maize and poverty associated with smallholder farmers (MoFA, 2017). Increasing maize crop productivity can simultaneously release resources for the production of non-staple foods and non-farm goods and services.

While a lot of studies on fertilizer subsidy abound in Ghana and elsewhere (Azumah and Zakaria, 2019; Benin et al., 2013; Chapoto and Ragasa, 2013; Chibwana et al., 2010; Duflo et al., 2011; Imoru and Ayamga, 2015; Mather and Jayne, 2018; Yawson et al., 2010), not much of it has focused on how specifically fertilizer subsidy policy has affected maize production especially in the north-eastern corner of Ghana where possible smuggling activities could render the programme ineffective. Even after some reforms were made to the distribution format for subsidized fertilizers recently, smuggling of subsidized fertilizers from Ghana to neighbouring countries persisted (Benin et al., 2013; Resnick and Mather, 2016). For some reasons including alleged smuggling of subsidized fertilizers, in July 2019 retail distribution of fertilizer was banned in nine districts located in the north-eastern corridors of the country and these included the Tempane District. The study by Azumah and Zakaria (2019) examined the effects of subsidized fertilizers on rice productivity, whilst those of Yawson et al. (2010) and Imoru and Ayamga (2015) centred on subsidized fertilizer use and use intensity. In their study, Azumah and Zakaria (2019) found that the adoption of subsidized fertilizer had a negative and significant impact on rice yield. Some studies on subsidized fertilizer and maize production include Chapoto and Ragasa (2013) for Ghana and Chibwana et al. (2010) for Malawi using different approaches. Previous studies on the effect of fertilizer subsidy on maize yield (Chapoto and Ragasa, 2013) employed Ordinary Least Squares (OLS), a model that fails to account for selection bias The use of OLS to assess the effect of a possible endogenous variable, such as farmers' decision to adopt or not to adopt subsidized fertilizer, on maize productivity could be flawed due to endogeneity problems and selectivity bias. This study therefore examines productivity differences between fertilizer subsidy beneficiaries and non-beneficiaries in the Tempane District, located at the north-eastern corner of Ghana and part of the Upper East Region, among smallholder farmers engaged in maize production.

In assessing the impact of a given policy such as fertilizer subsidy like in the present study requires the use of an appropriate method that is capable of establishing a suitable counterfactual against which the impact can be measured (Asfaw et al., 2012; Kassie et al., 2011; Nonvide, 2018). This study therefore uses an Endogenous Switching Regression (ESR) approach which can help estimate counterfactual outcomes and account for possible endogeneity due to selectivity bias that may be associated with farmers' decision to use subsidized fertilizer and maize productivity.

MATERIALS AND METHODS

Theoretical framework and econometric model

In this study, farmers' decision to adopt/use subsidized fertilizers is modeled based on the expected utility maximization theory. The farmer adopts subsidized fertilizer only if the expected utility derived from adoption exceeds that from not adopting. In this case, the farmer's direct expectation in adopting subsidized fertilizer is better or higher crop (maize) yield. This implies that, adoption of subsidized fertilizer becomes the selection criterion indicating the scenario faced by farmers and following earlier studies on impact analysis (Donkoh et al., 2016; Issahaku and Abdulai, 2019; Mwangi and Crewett, 2019; Nonvide, 2018; Simtowe et al., 2009), subsidized fertilizer adoption function can be represented by:

$$\mathbf{S_i^* = \delta D_i + V_i} \tag{1}$$

where $\mathbf{S_i^*}$ is a latent variable indicating a farmer's subsidized fertilizer adoption status; $\mathbf{D_i}$ is a vector of household and farm characteristics, assumed to affect farmer's decision with respect to subsidized fertilizer adoption; $\boldsymbol{\delta}$ is a vector of parameters to be estimated and $\mathbf{V_i}$ is a random error term. It follows from Equation 1 that a farmer is a beneficiary of subsidized fertilizer given that $\mathbf{S_i^*} > 0$. Farmers are categorized as beneficiaries if they have benefitted from the fertilizer subsidy programme for at least, in the immediate past two years conservatively and non-beneficiaries if they have not used subsidized fertilizers as described. The observable dichotomous variable $\mathbf{S_i}$ indicating whether or not a farmer is a beneficiary of subsidized fertilizer can then be defined as follows:

$$\mathbf{S_i} = \begin{cases} \mathbf{1} \;\; \mathbf{iff} \;\; \mathbf{\delta D_i + V_i} > 0 \\ \mathbf{0} \;\; \mathbf{iff} \;\; \mathbf{\delta D_i + V_i \leq 0} \end{cases} \tag{2}$$

where $\mathbf{S_i = 1}$ indicates that the farmer has benefitted from fertilizer subsidy and $\mathbf{S_i = 0}$ indicates otherwise.

Defining farmers' maize productivity to be a linear function of adoption of subsidized fertilizers along with other observed variables, the linear regression equation can be specified as

$$\mathbf{Y_i = \beta X_i + \delta S_i + U_i} \tag{3}$$

Where $\mathbf{Y_i}$ is maize productivity, $\boldsymbol{X_i}$ is a vector of farmer, household and farm characteristics, $\boldsymbol{\beta}$ is a vector of parameters to be estimated, $\mathbf{U_i}$ is a random error term with $\mathbf{S_i}$, $\boldsymbol{\delta}$ and $\mathbf{V_i}$ as defined earlier.

Applying OLS techniques to estimate the impact of fertilizer subsidy adoption on maize productivity using Equation 3 may produce biased and inconsistent estimates. This might be so because, farmers' decision to use subsidized fertilizer is assumed exogenous by Equation 1, but this could be potentially endogenous (Heckman, 1979) since farmers' decision to adopt or not to adopt subsidized fertilizer may be voluntary and could be based on individual self-selection. Under such cases, the impact of subsidized fertilizer adoption needs be isolated from the observed and unobserved socioeconomic and farm variables that determine maize productivity and subsidized fertilizer adoption status of farmers. For example, unobserved factors influencing the adoption decision which may include farmers' personal traits (ability and skills) $(\mathbf{V_i})$ may correlate with unobserved factors that influence the outcome variable $(\mathbf{U_i})$, maize productivity, resulting in biased and inconsistent coefficient estimates. On the account of the two sub-groups of maize farmers, two outcome scenarios emerge and can be stated as follows:

Scenario 1: $\mathbf{Y_{i1} = \beta X_{i1} + U_{i1}}$ for subsidized fertilizer beneficiaries

Scenario 2: $\mathbf{Y_{i0} = \beta X_{i0} + U_{i0}}$ for non-subsidized fertilizer beneficiaries (4b)

where $\mathbf{Y_{i1}}$ and $\mathbf{Y_{i0}}$ are respectively, maize productivities of beneficiaries and non-beneficiaries of subsidized fertilizer; $\mathbf{X_i}, \boldsymbol{\beta}$ and $\mathbf{U_i}$ are as defined earlier.

Due to the likelihood that some unobserved factors affecting farmers' adoption of subsidized fertilizer decisions could also affect some unobservable factors affecting maize yield (outcome variable), the error term in Equation 1 and the error terms in the outcomes functions (Equations 4a and b) may be correlated as noted earlier. To account for this, a simultaneous equations model of fertilizer subsidy adoption and maize productivity was estimated using an ESR based on a Full Information Maximum Likelihood (FIML) technique following earlier studies (Asfaw et al., 2012; Issahaku and Abdulai, 2019; Nonvide, 2018).

As estimates of expected maize yield of fertilizer subsidy beneficiaries and non-beneficiaries as well as the associated counterfactuals are important for explaining differences in maize yield between the two sub-groups, ESR enables the estimation and comparison of the expected maize yield. In this regard, the expected maize yields of fertilizer subsidy beneficiaries (i) to that of non-beneficiaries (ii). It is also possible to estimate the expected maize yield in the counterfactual cases; (iii) that beneficiaries did not benefit from the subsidy programme and (iv) that non-beneficiaries did benefit from the programme. Reported in Table 1 are the conditional expectations of maize yield in cases (i) through (iv) with cases (i) and (ii) indicating actual maize yield expectations, while the counterfactual expected outcomes are represented by cases (iii) and (iv).

In Table 1, TT is the estimate of the effect of the treatment on the treated, calculated as $\mathrm{TT} = \mathrm{E}(Y_{i1}|S_i = 1) - E(Y_{i1}|S_i = 0)$. TT therefore measures the effect of fertilizer subsidy adoption which is the difference between cases (i) and (iii). The effect of the treatment on the untreated is defined as TU, calculated as $\mathrm{TU} = \mathrm{E}(\mathrm{Y_{i0}}|\mathrm{S_i} = 1) - \mathrm{E}(\mathrm{Y_{i0}}|\mathrm{S_i} = 0)$ and this is the difference between cases (iv) and (ii), reflecting a scenario where non-subsidy beneficiaries did adopt and where they (non-beneficiaries) did not adopt. To segregate the treatments effects from heterogeneity effects arising from the possibility that beneficiaries may have more or less yield than non-beneficiaries, regardless of the fact that they benefitted from subsidized fertilizer, $\mathrm{BH_1}$ is calculated as the base heterogeneity effect using the formula $E(Y_{i1}|S_i = 1) - E(Y_{i0}|S_i = 1)$. Such difference could rather be due to unobservable factors that affect maize productivity. It is the difference between cases (i) and (iv). In contrast, $\mathrm{BH_0}$ is the base heterogeneity effect for farmers that did not benefit and measured as $E(Y_{i1}|S_i = 0) - E(Y_{i0}|S_i = 0)$ which is the difference between cases (iii) and (ii). Finally, to determine

Table 1. Maize yield expectations, treatment effects and heterogeneity effects.

Sub-sample	Decision stage		Treatment effects
	Benefit	Do not benefit	
Beneficiaries	(i) $[Y_{i1}\|S_i = 1]$	(iii) $[Y_{i1}\|S_i = 0]$	TT
Non-beneficiaries	(iv) $[Y_{i0}\|S_i = 1]$	(ii) $[Y_{i0}\|S_i = 0]$	TU
Heterogeneity effect	BH_1	BH_0	TH

Source: Di Falco et al. (2011); Asfaw et al. (2012).

whether or not the effect of fertilizer subsidy on maize yield is greater or less for beneficiary or for non-beneficiary farmers if they did benefit, a transitional heterogeneity effect (TH) was calculated by taking the difference between TT and TU $(TH = TT - TU)$.

Study area, sampling and data

The study was conducted in the Tempane District which is located in the north-eastern part of the Upper East Region and lies between latitude 100 10'N and Longitude 00 10'W. It is bordered to the east by the Republic of Togo, to the north by Burkina Faso, to the west by the Bawku Municipality and to the south by the East Mamprusi District. The district has an area of 1,230 km^2 and a population density of 99 persons per square kilometer. The climate is characterized by a unimodal rainy season which occurs between May/June to September/October with an average amount of rainfall of 800-860 mm per annum. The vegetation is mainly Sahel savannah, consisting of scattered drought resistant trees and grasses. The district is predominantly rural with the main occupation being farming and an estimated total farmer population of 80-90% (GSS, 2012). Farmers in the district engage in the cultivation of cereals, legumes vegetables as well as tree crops.

Sample selection for the study followed a multi-stage procedure. The Tempane District was purposely selected because of its location as the north-eastern most district bounded by two neighboring countries (Togo and Burkin Faso) in the first stage. The second stage involved a random selection of five communities including Nintanbugsuk, Sunugu, Tempane, Gagberi and Busum. In the third stage, a stratified sampling technique was employed to grouped farmers as beneficiaries of subsidized fertilizers and non-beneficiaries of subsidized fertilizer. In the fourth and final stage, a simple random sampling method was used to select 15 respondents from each stratum in each community, giving two sub-samples of 75 subsidized fertilizer beneficiaries and 75 non-beneficiaries of subsidized fertilizer. A total of 150 respondents therefore consisted the sample for the study. A semi-structured questionnaire was used in collecting the relevant data for the study. Data were collected on the socioeconomic characteristics of farmers at both the household and individual levels as well as farm characteristics between November and December 2018.

Descriptive results

Summary statistics of respondents in the study indicate no statistical differences between beneficiary and non-beneficiary farmers of subsidized fertilizer (Table 2) with respect to a number of factors. In particular, beneficiary farmers were not different from non-beneficiary farmers in terms of marital status, level of formal education, access to credit, engagement in non-farm activities, access to extension services, mean distance to the nearest market and non-nativity status of farmers. Significant differences between beneficiaries and non-beneficiaries were however found to include maize yield per unit of land area, farmers' age and gender, household size, farm size, fertilizer use rate, the use of improved maize seeds, community influence and access to media (Table 2).

Overall, the mean yield of maize for all farmers was 10.63 maxi bags per hectare which is approximately 1,063 kg/ha according to the conversion rate used by MoFA [1]. Beneficiaries of fertilizer subsidy had about 1,143 kg/ha compared to their non-beneficiary counterparts who had less (979 kg/ha) than the global mean yield. Beneficiaries were much older than non-beneficiaries indicating that older farmers had better access to subsidized fertilizer in the Tempane District.

Generally, households consist of larger membership (10) compared to national average (4) (GSS, 2014a) and beneficiaries had more household members (13) than non-beneficiary households (7). The small size of farm lands signals a serious challenge of access to land for farming purposes in the Tempane District as on the average, a typical farmer has less than 1.5 ha (1.47 ha). This is far below the Ghana Statistical Service estimate of 2 ha of land size cultivated by smallholder farmers in Ghana (GSS, 2014b). The results however reveal a higher average farm size among fertilizer subsidy beneficiaries (1.67 ha) relative to an average farm size of 1.25 ha among non-beneficiary farmers. The study reveals a generally low fertilizer application rate (6.2 kg/ha) among farmers compared to estimates by earlier studies such as Benin et al. (2013). There were however significant differences between subsidized fertilizer beneficiaries (6.67 kg/ha) and non-beneficiaries (5.58 kg/ha). The use of improved maize seeds for planting appears very scanty as less than 10% of farmers reported using improved seeds during the 2018/2019 farming season. However, there were more beneficiary farmers (14.4%) than non-beneficiaries (4.1%) who used improved seeds. While a little over 10% (11.7%) of beneficiary farmers had influence at the community level, only 4.1% of non-beneficiaries had such influence. There was also significant difference between beneficiary and non-beneficiary farmers with respect to access to media which could make beneficiaries more exposed and well informed of development interventions compared to their non-beneficiary counterparts.

RESULTS AND DISCUSSION

Determinants of subsidized fertilizer participation and maize yield in the Tempane District

Results of the estimates of the ESR (Table 3) show a significant Wald test of independent equations at 1% level, confirming the sample separation and that the model has a good fit with its explanatory variables. The

[1] A maxi bag of maize gains is approximately 100kg according to the Ministry of Food and Agriculture (MoFA).

Table 2. Variables and summary statistics of respondents.

Variable	Total (150)	Beneficiaries (75)	Non-beneficiaries (75)	Mean difference	t-test/χ^2
Maize productivity (kg/ha)	1.063	1.143	979	163	3.42***
Married farmer	0.933	0.935	0.931	0.004	0.087
Age	42.2	47.1	37.1	10	5.83***
Male farmer	0.733	0.792	0.671	0.121	1.68**
Education level	7.64	6.1	9.3	-3.16	-5.35
Household size	10	13	7	6	5.71***
Farm size	1.47	1.67	1.25	0.42	4.8***
Fertilizer application/ha	6.2	6.78	5.58	1.2	3.81***
Improved seeds	0.0933	0.143	0.041	0.102	2.16**
Credit	0.093	0.117	0.068	0.048	1.025
Non-farm activity	0.113	0.078	0.151	-0.073	-1.405
Extension services	0.033	0.026	0.041	-0.0151	-0.513
Farm-Market distance	3.38	3.35	3.41	-0.06	-0.308
Non-Native	0.353	0.377	0.329	0.048	0.609
Community influence	0.08	0.117	0.041	0.076	1.715*
Media	0.307	0.506	0.096	0.411	6.046***

Source: Field Survey November/December 2018. ***, ** and * indicates statistical significance levels of 1, 5 and 10% respectively.

coefficient of correlations of the error terms between the selection equation and each of the two outcome equations, Rho_1 and Rho_0, are both significant at the 1% level. The positive coefficient of Rho_1 signals a negative selection bias, which implies that farmers with maize yields lower than average without the fertilizer subsidy policy actually participated in the fertilizer subsidy programme. The negative and significant coefficient of Rho_0 shows a positive selection bias, meaning that farmers with maize yields more than average without the policy, did not actually adopt subsidized fertilizer (Abdulai and Huffman, 2014; Lokshin and Sajaia, 2004). These results suggest that in the Tempane District, maize farmers who perceive themselves as less productive are more likely to participate in the subsidized fertilizer programme whilst those who consider themselves more productive were more likely not to participate in the programme and this has an implication for programme targeting which is very important for effective input subsidy policy roll outs (Mather and Jayne, 2018).

The derivers of subsidized fertilizer adoption in the Tempane District are reported in the last column of Table 3. Significant factors informing farmers' decisions regarding the use of subsidized fertilizers are education, nativity and access to the media. Whilst education and being a non-native negatively influence farmers' fertilizer subsidy decisions, having access to the media has a positive impact on farmers' decision to use subsidized fertilizers. The inverse relationship between subsidized fertilizer adoption and farmers' education attainment may be as a result of the fact that educated farmers are more endowed and hence can purchase fertilizer at the market price compared to non-educated farmers. It could also be attributed to the fact that educated people might not be doing farming as their main economic activity and hence, their investment on farm operations is less in terms of fertilizer application. The finding on farmers' education finds support in a recent study, Azumah and Zakaria (2019), which analyzed fertilizer subsidy programme participation and rice productivity in northern Ghana.

The results also revealed an inverse relationship between the non-native status of farmers and subsidized fertilizer programme participation. This suggests that farmers who are natives tend to have access to subsidized fertilizers and therefore are more likely than non-natives to adopt the product. This makes intuitive sense as non-native farmers could just be settlers who may face challenges in doing so because they may be treated as outsiders. Similar finding on nativity was reported in Martey et al. (2014). Media access is also an important determinant of subsidized fertilizer programme participation as the coefficient of media is significant and positive at the 1% level. As found in earlier studies, farmers who own communication facilitating equipment such as radio and television are more likely to have information on policy interventions that target farmers and their operations (Azumah and Zakaria, 2019).

The significant determinants of the maize yield among subsidized fertilizer beneficiaries and non-beneficiaries as reported in the second and third columns of Table 3

Table 3. Estimates of the impact of fertilizer subsidy participation on maize yield.

Variable	Maize yield model		Fertilizer subsidy participation model
	Beneficiaries	Non-beneficiaries	
Married farmer	1.074 (0.999)	-0.240 (1.168)	-0.175 (0.439)
Age of farmer in years	0.0705 (0.0409)*	-0.0148 (0.0602)	0.00638 (0.0222)
Male farmer	-0.0392 (0.594)	-0.216 (0.716)	0.350 (0.281)
Household size	-0.0782 (0.0659)	-0.0840 (0.106)	0.0245 (0.0399)
Farm size in hectares	0.278 (0.623)	0.300 (1.153)	-0.232 (0.411)
Fertilizer rate (hectare)	1.078 (0.159)***	0.745 (0.212)***	0.126 (0.0791)
Used improved seeds	3.197 (0.843)***	3.865 (1.532**	0.137 (0.834)
Access to credit	-1.234 (0.813)	-1.895 (1.474)	0.664 (0.408)
Non-farm work	-2.156 (0.869)**	0.343 (0.918)	0.201 (0.372)
Extension advice	1.236 (1.369)	-0.702 (1.418)	0.234 (0.591)
Years of education	0.0674 (0.0852)	0.133 (0.182)	-0.109 (0.0542**
Market distance (km)			-0.0761 (0.0926)
Non-native farmer			-0.476 (0.222)**
Community leadership			-0.259 (0.791)
Access to media			0.784 (0.257)***
Constant	-1.436 (1.976)	4.077 (2.991)	0.0234 (1.073)
Observations	75	75	150
rho_1	0.967 (0.051)***		
rho_2	-0.899 (0.1029)***		
Log likelihood	-373.4605		
Wald Chi^2 (11)	162.91		
Prob>Chi^2	0.0000		
Likelihood test of independent equations			
Chi^2(1)	22.18		
Prob>Chi	20.0000		

Source: Field Survey Data, November/December 2018. ***, ** and * indicates statistical significance levels at 1, 5 and 10% respectively. Standard errors are in parentheses.

are fertilizer application rate and the use of improved maize seeds. For the two regimes of subsidized fertilizer beneficiaries and non-beneficiaries, fertilizer application rate and the use of improved maize seeds contribute significantly to higher output of maize. The results collaborate empirical findings of technological input adoption and crop yield (Chapoto and Ragasa, 2013; Denning et al., 2009; Mwangi, 1996; Scheiterle et al., 2018; Theriault et al., 2018; Yawson et al., 2010). Additional factors that determined maize yield among beneficiary farmers were famers' age and non-farm work. While age had a positive effect on maize yield, participation in non-farm work tends to reduce yield. The finding on age of the farmer implies experience of the farmer is important for increasing maize productivity as older farmers are assumed to have long periods of farming compared to younger farmers (Imoru and Ayamga, 2015) but this is contrary to the findings of Chibwana et al. (2010) that the age of the farmer reduces maize yield in Malawi.

The study, in examining the impact of subsidized fertilizer on famers' maize productivity estimated expected maize yield under the counterfactual scenarios of fertilizer subsidy beneficiaries and non-beneficiaries (Table 4). The observed maize productivities for beneficiaries (11.47 maxi bags/ha or 1,147 kg/ha) and non-beneficiaries (9.81 maxi bags/ha or 981 kg/ha) are indicated in cases (i) and (ii) respectively which were found to be significantly different at the 1% level based on a test of difference of means (t-test). In the counterfactual case (iii), the mean maize yield of beneficiary farmers would have been 6.99 maxi bags/ha or 699 kg/ha of maize, had they not benefited. The results suggest that farmers who benefitted from the subsidy programme are better off as their observed productivity (1,147 kg/ha) is much higher than their

Table 4. Mean expected maize yield per hectare for subsidy beneficiaries and non-beneficiaries.

Sub-sample	Decision stage		Treatment effects
	Benefited	Did not benefit	
Beneficiaries	(i) 11.47 (0.329)	(iii) 6.99 (0.243)	TT=4.48 (0.413)***
Non-Beneficiaries	(iv) 7.15 (0.309)	(ii) 9.81 (0.197)	TU=-2.66 (0.371)***
Heterogeneity effects	BH1=4.32 (0.452)***	BH2=-2.82 (0.313)***	TH=7.14 (0.235)***

Source: Field Survey November/December 2018. ***indicates statistical significance level at 1%.

counterfactual productivity of 699 kg/ha. This is demonstrated by the positive significant difference of the Treatment on the Treated (TT) at the 1% level [4.48 (0.413)].

For non-beneficiaries, the average maize productivity would have been 7.15 maxi bags or 715 kg/ha had they decided to use subsidized fertilizer. When compared with their observed productivity, non-beneficiaries of fertilizer subsidy in this study are better off with their decision not to be part of the programme since their observed maize yield (981 kg/ha) is much higher than their counterfactual mean productivity (715 kg/ha). This result is confirmed by the negative significant difference of -2.66 (0.371) which is an estimate of the effect of the Treatment on the Untreated (TU). This finding suggests that non-beneficiaries of subsidized fertilizer in the Tempane District are rational as they tend to make decisions that help in optimizing returns to their maize production goals. Overall, these findings imply that while fertilizer subsidy policy increased maize productivity among programme beneficiaries, non-beneficiaries are not also worse off for their decision not to join the programme. Furthermore, from the estimated Transitional Heterogeneity (TH) effect, the results show a positive and significant TH (7.14 (0.235) implying that the effect of subsidized fertilizer was greater among beneficiary farmers than their non-beneficiary counterparts. Beneficiary farmers produced 714 kg/ha more than non-beneficiaries, if they (non-beneficiaries) actually benefitted from the policy. While the findings of this study are in line partly with the policy objectives underlying Ghana's fertilizer subsidy programme of raising crop productivity among smallholder farmers (MoFA, 2017) and confirms some previous empirical studies (Chibwana et al., 2010), the findings nonetheless, contradict some earlier studies that produced decreasing effect of subsidized fertilizer use on crop yield (Azumah and Zakaria, 2019) and yet others found that the programme was largely ineffective (Fearon et al., 2015; Imoru and Ayamga, 2015).

CONCLUSION AND RECOMMENDATIONS

The paper analyzed the impact of Ghana's fertilizer subsidy programme on maize productivity in the north-eastern corner of the country. The major determinants of programme participation are education, media access and nativity status of farmers. The study found fertilizer application rate and the use of improved seeds as factors contributing to increased maize yield for both programme beneficiaries and non-beneficiaries. Age and non-farm work participation are additional factors that influence maize yield for programme participants with age affecting maize yield positively and non-farm work having a decreasing effect on maize yields, a finding that suggests a labor loss effect of non-farm work engagement. It is therefore recommended that the goal of the policy on subsidized fertilizer that targets smallholder farmers could be realized if education campaign on the importance of using the right quantity of fertilizer per land area is carried out and as well as making improved crop seed varieties accessible to farmers. The findings on age and non-farm work provide a guide for programme targeting if the objectives of the fertilizer subsidy policy are to be achieved.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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