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Effect of Nigeria's e-voucher input subsidy program on fertilizer use, rice production, and household income

By

Yoko Kijima

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National Graduate Institute for Policy Studies
7-22-1 Roppongi, Minato-ku,
Tokyo, Japan 106-8677

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Yoko Kijima*

Abstract

Nigeria introduced an e-voucher fertilizer subsidy program that distributes vouchers directly to a beneficiary's mobile phone for enhancing agricultural productivity and food security by changing land use from extensive to intensive farming. By using panel data on rice-growing households in 2012 and 2014 and applying a household fixed effects approach and inverse probability weighting methods, we assess whether and how much the e-voucher program increases fertilizer application on rice production. We do not find evidence that the program results in higher fertilizer application. This is because there is a strong crowding-out effect in the study areas in which the private fertilizer market is active. This finding suggests that introducing a potentially innovative device is not sufficient to boost agricultural production and food security.

Keywords: e-voucher, fertilizer subsidy, rice production, Nigeria

C23, Q12, Q13, Q18

*National Graduate Institute for Policy Studies (GRIPS)

1. Introduction

The expansion of information and telecommunication technologies (ICTs) has been key to providing new opportunities for rural households in sub-Saharan African countries (SSA), whose livelihoods largely depend on agriculture (Aker 2011). ICTs offer low-cost and timely information, such as on new agricultural technologies and output prices in markets, which helps enhance the adoption of technology and increase income (Aker *et al*. 2016a). Furthermore, ICTs have significant potential for improving efficiencies in implementing programs by providing financial services such as mobile money transfers, thus decreasing the administrative and time costs for program beneficiaries (Aker *et al*. 2016b). However, despite the significant potential of ICTs, most government programs are yet to utilize them.

In SSA, where a need exists to enhance agricultural productivity and food security, agricultural input subsidy programs (ISPs) have been a major agricultural policy. Even though a large share of fiscal budget has been spent on ISPs, agricultural productivity in SSA has stagnated because ISPs do not reach small farmers in need given alleged abuse by agricultural extension office staff and politicians (Jayne *et al*. 2013). To maximize the program's effectiveness, a new development has emerged in the last 10 years that distributes either subsidized inputs or paper voucher for accessing to subsidized inputs directly to targeted beneficiaries (Jayne *et al*. 2018). However, only a few countries have implemented ICTs for such an effort by, for example, sending vouchers directly to beneficiaries' mobile phones (e-vouchers). In addition, because few studies exist on subsidized fertilizer programs that use e-vouchers,[1] whether the use of ICTs to deliver e-vouchers, for example, has improved the efficiency of these programs and has increased fertilizer use among smallholder farmers is unclear.

Thus, to fill this knowledge gap, this study uses household panel data collected in Nigeria before and after the implementation of an ISP using e-vouchers (Growth Enhancement Support Scheme; GESS) and estimates the effect of the GESS on fertilizer use, farm productivity, and welfare of rice growing households. Nigeria is currently the largest rice-producing and consuming country in SSA and has been implementing rice development strategy under Coalition for African Rice Development (CARD). It is, therefore, an important policy issue whether GESS is effective for increasing rice productivity or not. The decision to participate in the program is not random; thus, a household fixed effects (HHFE) model is combined with inverse probability weighting (IPW) to mitigate biases.[2] The estimation results show no evidence that program beneficiaries increase the quantity of the fertilizer

[1] The exception is Wossen *et al*. (2017), who analyze the same program as this study's (Nigeria's e-voucher input subsidy program) for maize yield and household income by using cross-section data. They show that program beneficiaries significantly increased their income. However, they did not examine whether or not the program increased the quantity of fertilizer applied. Therefore, how income could have increased through the program was unclear.

[2] Previous non-experimental studies on the impacts of government ISPs in SSA rely on either panel data (Mason

applied and that farm productivity is improved. Further analyses indicate that receiving 100 kg of subsidized fertilizer decreases the quantity of purchased fertilizer from commercial sources by approximately 80 kg. This finding suggests that the GESS crowds out commercial fertilizer demand.

This study contributes to the recently growing literature on ISPs in SSA by adding the case in which the commercial fertilizer market is more developed and fertilizer has been used even without access to subsidized fertilizer. Similar to our results, subsidized fertilizer crowded out commercial fertilizer demand in Malawi, Zambia, and Kenya (Mason *et al*. 2017; Sheahan *et al*. 2014). In contrast, existing studies have mixed results of ISP on income and poverty (Ricker-Gilbert & Jayne 2017; Mason & Smale 2013; Mason et al. 2020; Wossen *et al*. 2017). The degree of market development and quantity of fertilizer used even before the ISPs were implemented seem to affect the size of the crowding-out effect. When ISPs are implemented in countries with a more developed commercial fertilizer market, commercial fertilizer is replaced by subsidized fertilizer, and total fertilizer application does not increase much, thereby weakening the rationale for any ISP.

The remainder of this paper is structured as follows. Section 2 provides an overview of subsidized fertilizer programs in SSA and Nigeria. Section 3 describes the data and the empirical framework. Section 4 presents the estimation results. The last section provides the conclusions.

2. Subsidized Fertilizer Schemes in SSA and Nigeria

2.1 Fertilizer Subsidy in SSA

Studies that have analyzed targeted subsidized fertilizer programs using paper-based vouchers have suggested that such programs still suffer from poor targeting. Recipients of subsidized fertilizer in Tanzania tend to be non-farmers, and those who have connections to politicians purchase fertilizer at subsidized prices and sell it at higher prices in local markets (Pan & Christiaensen 2012); in addition, such recipients in Malawi, Zambia, and Kenya tend to be wealthier (Lunduka *et al*. 2013; Mason & Jayne 2013). In the pilot program in northern Nigeria through which subsidized fertilizer was distributed at the farmer group level, the quantity of subsidized fertilizer received by each household was determined by closeness to the group leader (Liverpool-Tasie 2014a). Furthermore, in Ghana, vouchers were more targeted to districts in which the ruling party had lost in the previous presidential election (Banful 2011).

The problem with fertilizer subsidies is not limited to poor targeting. Government involvement in

et al. 2017; Ricker-Gilbert & Jayne 2017) and instrumental variables (IV) methods (Jayne *et al*. 2013; Mason et al. 2013) or cross-section data and the propensity score matching (PSM) method (Richer-Gilbert et al. 2011; Liverpool-Tasie 2014b; Wossen *et al*. 2017). The panel IV methods can correct the endogeneity of program participation if valid IVs are available.

distributing fertilizer tends to hinder private sector development by depressing commercial fertilizer demand. Some studies have supported this argument, showing that providing subsidized fertilizer tends to decrease commercial fertilizer demand (Xu *et al*. 2009; Ricker-Gilbert *et al*. 2011; Mason & Jayne 2013; Takeshima & Nkonya 2014).[3] In addition, recent empirical studies on SSA have indicated that the effect of subsidized fertilizer on agricultural productivity—particularly in major cereal production—is negligible.[4]

Input distribution systems differ across countries. In Kenya, subsidized fertilizer is redeemed at accredited agro-dealers using voucher coupons, whereas fertilizer vouchers in Malawi had to be redeemed at government depots; in Zambia, subsidized fertilizer was distributed by the government without the use of vouchers (Lunduka *et al*. 2013). Electronic systems also differ by country. In 2017, Zambia introduced an e-voucher program that does not issue an "e-voucher" electronically, unlike Nigeria. Instead, voucher scratch cards are issued to registered farmers who can purchase agricultural inputs and even livestock in the credited amounts at registered agro-dealers (Kuteya & Chapoto 2017).

2.2 Fertilizer Subsidy in Nigeria

In the subsidy program (Federal Market Stabilization Program, or FMSP) prior to GESS,[5] the Nigerian government directly procured and distributed subsidized fertilizer via the state government. In each state, subsidized fertilizer was sold mainly through agricultural extension offices (namely, agricultural development projects, or ADP) (Liverpool-Tasie & Takeshima 2013). As the total quantity of subsidized fertilizer allocated to each state and each local government area (LGA, the lowest administrative unit in Nigeria) was limited by budget constraints, most farmers did not have access to the subsidized fertilizer (Takeshima & Nkonya 2014). Meanwhile, recipients of the subsidized fertilizer tended to be politically well connected, and some were not even actual farmers (Banful & Olayide 2010).

The GESS started in 2012 with a plan to register five million farmers every year and distribute vouchers for 100 kg of fertilizer. The number of farmers who benefited from the subsidy under the GESS increased from 0.7 million in 2012 to 7.2 million in 2014, and the quantity of fertilizer distributed was 749,000 tons in 2014 (Olomola 2015). All adult farmers have the right to apply to the GESS. As registration is not at the household but

[3] One exception (Liverpool-Tasie 2014b) is when fertilizer vouchers were successfully targeted for areas in which private commercial markets were weak and for poor households, and beneficiaries of subsidized fertilizer *increased* commercial fertilizer demand.
[4] See Liverpool-Tasie (2017) for rice and Ricker-Gilbert & Jayne (2012) for maize.
[5] The Nigerian fertilizer policy since the 1940s has been explained in detail by Liverpool-Tasie and Takeshima (2013). Fertilizer subsidies have been provided by the government except for a few years given fiscal budget deficits.

at the individual level, more than one household member can apply to the GESS. The purpose of the GESS is to increase agricultural productivity by enhancing input use and to activate the fertilizer and seed industries by shifting the main tasks of the procurement and distribution of agricultural inputs to private companies.

The introduction of the e-voucher scheme is expected to decrease leakages to non-genuine farmers by sending vouchers directly to beneficiaries' mobile phones as text messages. However, during registration, the scheme faces many challenges, such as spelling errors from poor handwriting on application forms, lack of a verification mechanism to determine whether or not an applicant is a genuine farmer, and mistyping and omission of names during data entry (Olomola 2015). The information on registered farmers (name, location, occupation, and education) is compiled into a national farmer database that is used to select beneficiaries. However, how targeted households are selected is not clearly stated.

Once the targeted individuals have been determined, supply chain managers (selected private companies) are put in charge of sending text messages to the farmers to inform them about the location of the redemption center; the quantities, kinds, and prices of inputs to be received; and the redemption process period. Redemption centers are warehouses in which agro-dealers store their products for sale. To redeem their vouchers, farmers must show the text message and identification (the identity card issued by the GESS with an identification (ID) number, a voter card, or the national identity card). Unlike paper vouchers, which were studied by Liverpool-Tasie (2014) and were collectively redeemed by the leader of a farmer group, e-vouchers need to be redeemed individually. When the e-voucher is redeemed, the voucher number and the beneficiary's ID number are recorded and reported electronically to the GESS office. The assumption is that the GESS has improved transparency and accountability regarding agricultural input subsidies (Olomola 2015).

Subsidized fertilizer is obtained only at assigned redemption centers (and not at shops and markets). Redemption centers open for only a few months, just before cereal is planted (June/July in the sample area). Although GESS uses private sector agents to procure subsidized fertilizer, households consider them government's subsidy program, not commercial fertilizer. The price is normally set as a lump sum for two 50 kg bags of fertilizer (NPK and urea) per person. The subsidized price is approximately 40% of the market price (the median subsidized price per 50 kg is 3,000 naira, whereas the median unsubsidized price is 5,000 naira).[6] No credit is offered under the GESS. Unlike the pilot case examined by Liverpool-Tasie (2014a), farmer group membership is not a requirement to receive e-vouchers and subsidized fertilizer.

[6] Olomola (2015) indicates that the GESS offers two 50-kg bags of fertilizer for 5,000 naira (50% subsidy) and a 50-kg bag of improved seeds (90% subsidy, either rice or maize). In the survey data, however, variations in prices exist across localities. A smaller amount of improved seeds (for example, 20 kg) was normally given for free in the survey areas. These prices are at 2014 price level.

According to Agricultural extension workers interviewed by the author, the Nigerian government did not have any criteria for beneficiaries, except that they should be "genuine" farmers. At our study site, no differences exist in assets and landholdings between the participants and the non-participants; however, the participants have better access to farmer group memberships. In the GESS, a farmer group membership increases the likelihood of becoming a beneficiary of the program and of the quantity of fertilizer obtained. Although all farmers, including non-group members, are eligible for the program, group members tend to limit information and registration forms to members' families. Furthermore, the penetration rate of mobile phone is not 100%, which can exclude the ones who need the support most from the program. Thus, a program using e-vouchers can also suffer from elite capture, similar to a program targeting the use of paper vouchers (Liverpool-Tasie 2014a; Pan & Christiaensen 2012) and one without targeting (Banful & Olayide 2010).

3. Data and Empirical Framework

3.1 Data

To investigate the effect on rice growing households, we select two rice growing states, Nasarawa and Benue states, which are in the same agro-ecological zone that produces both cereal and roots crops, and in the same geopolitical zone (North-Central) with the lowest average subsidy rate among the northern states in the FMSP.[7] A household survey on rice growers was conducted in February–March 2013 and 2015 in the Nasarawa and Benue states in collaboration with Nasarawa State University, Keffi, and University of Agriculture, Makurdi., and so, sample rice-growing areas were purposely selected (54 villages in 12 LGAs, as indicated in Figure 1 and 2). In each village, a list of rice growers was created, and seven rice-growing households were selected randomly by generating random numbers (378 total households).[8] At the time of the data collection in 2015, survey teams could not visit five villages because of lack of security during or immediately after communal crises. Additionally, 16 households could not be traced because they relocated. Thus, the number of households in the panel data is 327 in 49 villages.

[Figure 1 and 2 about here]

In the sample area, rice is planted in June/July under rainfed lowland conditions. The other main crops—yam and maize—are planted in March/April and April/May, respectively. The main rice variety is an improved

[7] The subsidy rate in the FMSP was determined by agro-ecological zone and geo-political zones (Takeshima and Nkonya 2014).

[8] Although the World Bank's Living Standard Measurement Survey-Integrated Survey on Agriculture (LSMS-ISA) was conducted in 2015/16, there is no data whether household received subsidized fertilizer under GESS or not. Thus, LSMS-ISA cannot be used for examining the effect of GESS on household's consumption expenditure.

variety called Sipi (FARO). Land is prepared using a tractor service (33% of households) or manually (67%). Herbicides are commonly used for weeding. Fertilizer (NPK, urea) is also commonly used. Unsubsidized fertilizer is purchased from March to July and GESS redemption centers open in June/July. Redemption centers are located within the LGA. Two-thirds of the sample households did not pay transportation costs to buy fertilizer, and transportation costs to obtain fertilizer in the sample area are much lower than those in other areas of Nigeria (N460 in Liverpool-Tasie 2016). Selling paddy rice at the farm gate or the local market to local traders just after harvest is common. The price of rice received by farmers varies seasonally and geographically.

3.2 Empirical Framework

This article estimates the mean impact of the subsidy program on fertilizer use, farm productivity, and household welfare using a household fixed effects model with inverse probability weighing (IPW) approach (Imbens & Wooldridge 2009). We have household-level panel data that most of the households did not receive subsidy in 2012 but about 25% of them received the subsidy in 2014. By using this variation, we attempt to identify the effect of the subsidy. It is possible that beneficiaries are expected to be different from non-beneficiaries even in the absence of the subsidy program because households must apply to the program to be a beneficiary. If treatment status is correlated with the error term, the estimated impact of the program is biased. To mitigate this problem, IPW is applied to ensure that higher weights are assigned to households with similar observable characteristics as the treatment households in the pre-treatment period. Under a set of assumptions (conditional mean independence and common support), applying IPW results in unbiased impact estimates for ATT (Hirano *et al*. 2003).

Propensity scores ($\hat{p}$) are estimated using a probit model and observable characteristics in the 2012 survey as explanatory variables. [9] The estimated propensity scores are used to construct the weight $1/\hat{p}$ for treatment group and $1/(1-\hat{p})$ for control group, and an unbiased estimate of ATT is obtained through a weighted regression framework. Being a member of a farmer group increases the probability of receiving an application form for the GESS, and, thus, membership in a local group is expected to increase the probability of receiving subsidized fertilizer. The results of the probit model are shown in Appendix Table 1. To eliminate observations without common support, we used the commonly used kernel matching method (the Epanechnikov kernel) (Caliendo & Kopeinig 2008). Average baseline characteristics between the treatment and comparison groups were well balanced after applying the inverse probability weight.

Even after constructing a comparable control group based on observed characteristics, unobserved

[9] See Appendix Table 2 and Appendix Figure 1.

household characteristics may simultaneously affect program participation and outcome variables. HHFE are controlled to mitigate the bias from the effect of time-invariant unobservables (Smith and Todd 2005). Thus, our identification assumption is that there is no correlation between GESS beneficiary status and time-variant unobserved heterogeneity. Time variant factors that can affect GESS beneficiary status such as weather shocks are controlled for in regression model for assuring that this assumption holds. However, since there is no direct test to guarantee that this assumption holds, we acknowledge that it is one of the limitations of the study.

Although using panel data has advantages, they can cause attrition problems. As previously indicated, some of the original sample could not be re-surveyed. If the attrition is not random, then ATT can be biased. Consequently, we adopt the correction procedure suggested by Fitzgerald *et al*. (1998) and use attrition weights in all analyses. We first estimate a probit model to explain whether a household was interviewed in follow-up surveys and obtain the predicted probability that a household remains in the panel data.[10] The attrition weights are calculated as the inverse of the predicted probabilities to assign higher weights to households with lower probabilities of remaining in the sample but that were interviewed in the follow-up survey.

This regression-based methodology has advantages when the attrition problem also needs to be addressed. The attrition weight can be multiplied by the inverse probability weight to obtain a weight. We run the following weighted regression model:

$$y_{it} = \gamma R_{it} + \rho X_{it} + \varphi Z_{jt} + T_t + \alpha_i + e_{it}, \qquad (1)$$

where y is the outcome variable, such as the quantity of fertilizer applied, the value of outputs produced, rice yield, and per capita expenditures; R takes the value 1 if household i obtained subsidized fertilizer at time t and 0 otherwise; T takes the value of 1 when t is 2014 and 0 for baseline data (t=2012); X is a set of time-variant household characteristics; Z is a set of time-variant village characteristics; α represents unobserved HHFE; and e is an error term. We also control for ward-year fixed effects.[11] The coefficient of R (γ) is the effect of the subsidy program.

4. Results

4.1 Descriptive Statistics

Table 1 shows the distribution of households and the average quantity of subsidized fertilizer for households in the old program (FMSP) in 2012 and the GESS in 2012 and 2014 and this information are from the household survey.

[10] The estimation results are shown in Appendix Table 3. The pseudo R-squared shows relatively high explanatory power for the attrition probit model (Baulch & Quisumbing 2010).

[11] Ward is the lowest administrative unit in Nigeria which is below Local Government Area (LGA) and above village.

Although the GESS was implemented nationally in 2012, during that year, only 15 households (4% of the sample) obtained subsidized fertilizer from the program. In 2012, 46 households still obtained subsidized fertilizer from the FMSP. In 2014, no household obtained subsidized fertilizer from the old program, and 64 households and 77 individuals received subsidized fertilizer under the GESS. As explained in Section 2, each beneficiary of GESS is supposed to receive 100 kg of subsidized fertilizer. The table shows that some received fertilizer less or more than 100 kg. Under FMSP, the quantity obtained by beneficiaries is much greater than GESS and some of them received more than 1000 kg.

Table 2 shows the 2012 household characteristics according to whether or not a household obtained subsidized fertilizer and, if it did, whether under the GESS or the FMSP. No household received subsidized fertilizer in 2014 from the FMSP; thus, three groups in 2012 (FMSP, GESS, and no subsidy) and two categories in 2014 (GESS and no subsidy) existed. In 2012, no significant differences in total cultivated area and total fertilizer use existed among groups, whereas the proportion of households that purchased fertilizer from commercial sources was higher among non-beneficiaries. In particular, among the beneficiaries of the old subsidy program, 43% did not obtain fertilizer from commercial sources because the beneficiaries under the old subsidy program obtained larger quantities of subsidized fertilizer and did not need to buy more from commercial sources, as shown in Table 1. This finding also suggests that the GESS plays an important role in providing subsidized fertilizer to a larger population.

In 2012, relative to non-beneficiaries, beneficiary households were likely to be male-headed, older, and bank account holders. The observed characteristics of the beneficiaries under the GESS are quite similar to those under the FMSP except the experience in rice cultivation. However, a notable difference was found in their location, as measured by the distance to the state capital. The distance to the state capital may capture proximity to markets and information sources, other economic conditions, and access to agricultural programs because ADP staff are stationed in the state capital.

As shown in the last two columns of Table 2, in 2014, beneficiary households of the GESS were likely to be older and bank account holders living closer to the state capital than non-beneficiaries. Unlike the beneficiaries in 2012, social capital within a village as measured by farmer group membership seemed an important factor for becoming a beneficiary in 2014.

Table 3 shows the proportion of sample households who have access to the GESS, from gathering information to purchasing subsidized fertilizer. The percentage of households that know about the GESS increased from 45% in 2012 to 61% in 2014. Accordingly, the share of households that applied for the GESS increased from 29% to 46% (65% to 75% out of those who knew about the GESS). The main reason such households did not

apply for the GESS in 2014 is lack of information (73% of those who did not register did not know about the GESS, and 12% of them did not know how to apply). Lack of access to mobile phones and lack of money to purchase fertilizer are rather minor problems (4% and 1%, respectively, of those who did not register). No demand for fertilizer, as a reason, accounts for only 3% of the households who did not apply for the GESS, whereas inability to obtain the application form, or being rejected for registration with the GESS, account for 6%

Among those who received e-vouchers, about half did not obtain subsidized inputs under the GESS in 2012 (9.7%/19.2%). This share increased to 69% (19.2% out of 28%) in 2014, mainly from administrative problems related to the GESS. More than two-thirds of those who received vouchers but did not obtain inputs responded that no inputs were at the redemption centers. The other reasons for not obtaining inputs are as follows: inputs arrived late, input arrival date was not announced, and the name on the beneficiary's ID and that on the list at the redemption centers did not match[12] or beneficiaries were not allowed to redeem their e-vouchers without a reasonable explanation. These reasons suggest the importance of information for accessing the program.

4.2 Estimation Results

The first two columns of Table 4 show the estimation results for total fertilizer use. Although the coefficients of subsidy beneficiary status are positive, we do not find evidence that the fertilizer subsidy program (either FMSP in 2012 or GESS in 2012 or 2014) increased the quantity of fertilizer applied. The remaining columns of Table 4 provide the estimation results for rice production, including whether the subsidy program had an effect on rice cultivation area, quantity of fertilizer applied, rice production, yield, and income from rice production. There is no evidence that the subsidy program increased rice production and productivity by increasing fertilizer application and the area under rice cultivation.

Similar results are found for non-rice crops in columns 1–3 of Table 5, which indicates no evidence that the area under other crops and fertilizer application on other crops were increased by the subsidy program. As a result, we do not find evidence that the subsidy program increases crop income and per capita household expenditures (columns 4 and 5 of Table 5). We estimated same model after transforming income by taking log and inverse hyperbolic sign transformation. The coefficients of interest are still not statistically significant. This result contradicts that of Wossen *et al*. (2017), who find that participation in the GESS increased household total consumption expenditure by 31%.

Since Wossen et al. (2017) used instrumental variable estimation with cross-section data by controlling for state-fixed effects where an instrumental variable is the number of years the household head has resided in the

[12] According to ADP staff, application forms submitted on paper were entered into computers in India, and many data entry mistakes occurred given unfamiliar names and poor handwriting.

village, we apply similar estimation strategy to test if the difference comes from different methodologies.[13] For this, we use the data collected only in 2015 which is the same survey year as Wossen et al. (2017). Although same instrumental variable was applied, it suffers from a weak instrument problem. Therefore, we used different IVs: a dummy variable if household head was born in this village and its interaction term with age of household head. Similar reasonings as Wossen et al. (2017) that households who have lived in the village for long time are more likely to know the GESS since they have more connections and village leaders are likely to recognize them as eligible for the GESS, which increases the probability of their participation. These variables do not directly affect rice yield, rice income, and per capita expenditure as shown in the bottom of Appendix Table 4. Another difference comes from the main dependent variable. While this study uses an indicator variable if households received subsidized fertilizer as a measurement of access to the program, registering the program is a main measurement of the program participation in Wossen et al. (2017). Though they found similar results even for using alternative measurement (i.e., actual collection of subsidized fertilizer), we also test if different measurements of program status make the estimation results different or not. As shown in columns 4-6 of Appendix Table 4, we still do not find evidence that participation in the GESS increased the rice yield and household welfare. Since Wossen et al. (2017) does not state how many states and which states the data cover, we cannot tell if the difference of the results comes from that of the covered areas.[14] However, since they focus on maize production, this may imply that the GESS can enhance the household welfare in different geographical areas within Nigeria but not in rice growing communities of Central Nigeria. Thus, this will leave us a possibility that sample areas should be different, which may cause the different results.

One may argue that the difference is due to sample size or lack of power. Based on the 2012 data, before GESS started, non-beneficiary households applied 78 kg per hectare on rice plot on average (see column 5 of Table 2). The beneficiaries of GESS receive 100 kg of fertilizer. About 20% of sample households received subsidized fertilizer in 2014 (see Table 3). By using a 5% significance level and power of 0.8, the required sample size is calculated as 246. Although the sample size is small, it is enough to detect the increased fertilizer application. Thus, insignificant effect of the program on fertilizer use is likely to be explained by crowding out effect.

4.3 Mechanism: Crowding Out

[13] Wossen et al. (2017) use predicted value from the first stage probit model since their IV seems to suffer from weak instrument. We apply conventional instrumental variable estimation model by using Stata software's ivreg2 command.

[14] The paper mentions that the enumeration areas (EAs) were divided by the number of Local Government Areas (LGAs) in each of the selected states to obtain the number of EAs per LGA and 5 households per EA were sampled.

To test whether the subsidized fertilizer program crowds out commercial fertilizer demand, we apply a similar model as used in previous studies (Ricker-Gilbert & Jayne 2017; Mason *et al*. 2020; Jayne et al. 2013). The estimation model for commercial fertilizer demand is as follows:

$$F_{ijt} = \beta S_{ijt} + \rho X_{it} + \gamma Z_{jt} + T_t + \alpha_i + \varepsilon_{it}, \quad (2)$$

where F is the quantity of fertilizer obtained from a commercial source by household i living in village j at time t; S is the quantity of subsidized fertilizer obtained; X is a vector of a household's socio-demographic characteristics; α is the time-invariant household's heterogeneity; ε is an error term; and β, ρ, and γ are estimated coefficients. The crowding-out effect is estimated by β, which indicates the extent of the reduction in commercial fertilizer demand from receiving 1 kg of subsidized fertilizer.

Following previous studies, we adopt a correlated random effects model to control for time-invariant household heterogeneity, such as managerial ability and degree of risk aversion, which affects household i's demand for commercial fertilizer. Even after controlling for α, S is likely to be endogenous because it is correlated with time-varying unobserved factors. In our setting, local leaders allocated GESS application forms according to specific household characteristics that may not be observed by researchers. To address this correlation, the control function approach is used following Ricker-Gilbert & Jayne (2011) which adopt the number of years that the household head has lived in the village as IV for being beneficiary of the subsidy program in Zambia. In our setting, we use same IVs explained in Section 4.2: a dummy variable if household head was born in this village and its interaction term with age of household head. The quantity of fertilizer purchased from commercial source, however, should not be correlated with these variables after controlling for time-variant covariates. We apply a Tobit model to estimate the overall crowding-out effect, which provides the unconditional average partial effect across i and t.

Table 6 shows the results of equation (2) by measuring the degree of the crowding-out effects. Column 1 presents the result of the reduced form model that affects the quantity of subsidized fertilizer received by households. The coefficients of the identifying variable are significant. The age of the household head who were born in the village positively affects the quantity of subsidized fertilizer received because older household heads who were born in the village tend to have connections with local leaders, as other studies pointed out.

In column 2, the dependent variable is the quantity of commercial fertilizer purchased. The residual from the reduced form model is marginally significant, indicating that the quantity of the subsidized fertilizer received is endogenous in the demand for commercial fertilizer. The estimated coefficient (–0.84) indicates that receiving 100 kg of subsidized fertilizer decreases the quantity of purchased fertilizer from a commercial source by 84 kg. This effect is much larger than that in Kenya (–0.4, Mather & Jayne 2013), Zambia (–0.13, Mason *et al*. 2015), and Malawi (–0.15, Ricker-Gilbert & Jayne 2017). The net increase in fertilizer use by the GESS is limited

to 16 kg because of the crowding-out effect. Given that the average size of a rice plot is approximately 4 hectares and the average fertilizer application on a rice plot is 300 kg (75 kg x 4 hectare), the effect of the GESS on increased fertilizer use of a rice plot is accounted for by only 5% (16/300). Actually, we fail to reject that the estimated coefficient (-0.84) is different from -1, which means that commercial fertilizer demand is fully crowded out by subsidized fertilizer. This is consistent with the main result.

4.4 Mechanism: Fertilizer Responsiveness

In the previous subsection, we found that obtaining 100 kg of subsidized fertilizer from the GESS crowds out commercial fertilizer demand by 84 kg, and the net increase in the total fertilizer application is 16 kg. Why is the crowding-out effect so large? One possibility is that the quantity of fertilizer applied reaches the point at which additional fertilizer use does not increase revenue by more than its costs. To test this possibility, we estimate average and marginal physical products (APP and MPP) and marginal value cost ratios (MVCR) to fertilize. If the MPP is greater than the APP, rice is produced at a point at which additional fertilizer application increases production. If the MVCR (value of the MPP divided by the fertilizer price) is greater than 1, households can increase their income by increasing the fertilizer application rate. Fertilizer use is risky and rural farmers tend to be risk averse, so using a higher MVCR criteria than 1 is desirable (Sheahan *et al*. 2013). Following Liverpool-Tasie (2017), who examines rural households in Nigeria, we test whether the MVCR is greater than 2. The fertilizer price we use includes transportation costs.

We estimate the production function using the household fixed effect model where the rice yield per ha is regressed on a set of agricultural inputs applied such as the quantity of total fertilizer applied to a rice plot, the quantity of seeds used, herbicide used, machine use, and family labor. Although input use can be endogenous, the identification assumption that after controlling for HHFE, input use is not correlated with the error term should hold since the endogeneity is mainly due to farm managerial ability and local agricultural potential which are time-invariant (Mason et al. 2020). Furthermore, plot-level time-varying factors such as water accessibility (irrigated or not) is included in the estimation model, which partly addresses the problem caused by not controlling for time varying unobservables. Since this identification strategy was also used in previous studies, we follow this for making comparison of the results easy. Even so, we need to interpret the results with caution since we cannot test if the assumption holds. In addition to the quantity of fertilizer applied, we also estimate the MVCR of nitrogen and phosphorus because NPK and urea are two major fertilizers used in Nigeria, but the contents of each nutrient are different.[15]

[15] NPK contains 27% nitrogen and 13% phosphorus, whereas urea contains 46% nitrogen.

The estimation results are presented in Table 7. The coefficients of fertilizer and nitrogen indicate that their MPPs are 4.3 and 7.2, respectively, a result that is comparable with that of Liverpool-Tasie et al. (2017), in which the MPP of nitrogen is 8.9. The estimated MVCRs of subsidized and unsubsidized fertilizer are 5.4 and 3.2, respectively. The percentage of households with an MVCR greater than 2 is more than 90%, which suggests that even without the subsidy, households with conventional risk aversion can still increase their income by increasing the fertilizer application rate at commercial fertilizer price. Therefore, the reason why households that obtain subsidized fertilizer did not increase the fertilizer application rate as shown in Table 4 is not because they have applied the fertilizer more than that maximizes the profit. This is another evidence that GESS is not an effective program to enhance agricultural productivity at least in the study areas.

5. Conclusions

This paper used the household fixed effect model with propensity score weight to examine the effect of Nigeria's input subsidy program on fertilizer use, agricultural productivity, and income. We do not find any effect of the subsidy program on total fertilizer application, agricultural productivity, farm income, and total household income because a large crowding-out effect of subsidized fertilizer exists. This result contradicts that of Wossen *et al*. (2017), who estimate the effect of the GESS by using cross-section data, and find that the GESS increased household income without showing if households actually increased the fertilizer application rate. One possibility of the difference is that use of the commercial fertilizer among those who did not receive subsidy is higher in our sample area than in other parts of Nigeria,[16] and farmers apply fertilizer even without a subsidy. Other possibility is the difference in fertilizer response rate and market prices between rice and maize. Unfortunately, we cannot test if this causes the different conclusions.

Our results indicate that the subsidy program is not cost-effective for increasing fertilizer application and farm productivity in areas with a developed commercial fertilizer market where households have applied chemical fertilizer even without subsidy. The estimation results of the rice production function show that room exists to increase rice income by applying more fertilizer. Yet, access to subsidized fertilizer does not significantly increase total fertilizer application. This finding may suggest that farmers are more risk averse than the conventional level. Many sample households plant rice in the lowlands, which suffer from severe floods every five years or so. In such an environment, farmers may avoid large losses by increasing the fertilizer application rate in a specific plot.

[16] In Northern states studied by Liverpool-Tasie (2014), 72% of farmers who did not receive subsidy purchased chemical fertilizer from private market while in our study areas, 84% of those who did not receive subsidy did so.

Farmer group membership is positively associated with the likelihood of becoming a beneficiary of the program. Even though all farmers, including non-group members, are eligible for the program, group members tend to limit the information and registration forms to member households. Thus, policymakers should carefully plan a program using e-vouchers that avoids elite capture—similar to programs that target by using paper vouchers and those that do not target.

The experience in the first couple of years of the implementation of the GESS highlights many challenges. The most serious one is the lack of clarity on how the beneficiaries are selected. According to Olomola (2015), the beneficiaries are selected based on a national farmer database compiled by the government. This database, however, contains only information on those who register in the program and, as described in this study, only a few farmers could manage to obtain application forms. In addition, as shown in the estimation results, households living closer to the state capital are likely to receive a voucher. It was shown that the program implementation was incomplete due to administrative challenges. All these factors have contributed to the insignificant impact of the program on farmers' welfare improvement. For the GESS to become an effective subsidized fertilizer program, the government has to ensure that the registration process at the village level includes in the database all households that are potentially eligible for the program. After the general election in 2015 which was coincided with economic downturn and fiscal indebtedness in Nigeria, GESS has been dormant. It is not possible to examine the effectiveness of GESS in the long run. Since electronic transfers using mobile phone has been adopted widely in many SSA countries, it is expected that the other countries introduce similar program to GESS. The experience in Nigeria should be used for designing a program to ensure better implementation.

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Table 1: Quantity of subsidized fertilizer obtained

	Households who received			Individuals who received
	GESS in 2012	FMSP in 2012	GESS in 2014	GESS in 2014
	(1)	(2)	(3)	(4)
Number of households with subsidized fertilizer	15	46	64	77
Mean quantity of subsidized fertilizer (kg)	160.0	255.4	128.4	97.7
(s.d.)	(122.8)	(268.1)	(71.2)	(20.2)
Median quantity of subsidized fertilizer (kg)	100	175	100	100
Maximum quantity of subsidized fertilizer (kg)	500	1250	500	200

Note: Number of HH with more than 1 member received subsidized fertilizer is 16 where 14 of them had 2 members while one with 3 members and one with 5 members.

Table 2: Household characteristics in 2012 by access to subsidized fertilizer

	Status in 2012					Status in 2014		
	GESS	FMSP		no subsidy		GESS 2014	no GESS	
	(1)	(2)	(a)	(3)	(b)	(4)	(5)	(c)
Number of HH	15	46		266		64	263	
Total cultivated area (ha)	7.93	8.92		9.38		9.46	8.29	
	(6.29)	(6.89)		(6.45)		(6.73)	(5.32)	
% of households who did not apply fertilizer	0.067	0.065		0.158	*	0.016	0.205	*
	(0.258)	(0.250)		(0.365)		(0.125)	(0.405)	
total fertilizer applied (kg)	668.33	665.98		533.54		580.08	545.73	
	(454.78)	(718.07)		(622.35)		(637.85)	(613.48)	
% of HH who bought commercial fertilizer	73.33	56.52		84.09	*	86.89	77.86	
	(45.77)	(50.12)		(36.65)		(34.04)	(41.60)	
Farmers association member in 2011	0.283	0.200		0.180		0.321	0.167	*
	(0.455)	(0.414)		(0.385)		(0.468)	(0.374)	
Years of rice cultivation experience in 2011	24.73	18.33		17.15	*	18.19	17.58	
	(12.22)	(12.09)		(9.18)		(9.45)	(9.98)	
1 if born in the village	0.600	0.826	*	0.774		0.854	0.760	
	(0.507)	(0.383)		(0.418)		(0.357)	(0.428)	
Number of household members	10.67	10.35		9.73		10.08	9.81	
	(3.85)	(4.33)		(4.62)		(4.74)	(4.51)	
Female headed household =1	0.000	0.022		0.086	*	0.063	0.076	
	(0.00)	(0.147)		(0.282)		(0.244)	(0.266)	
Head's years of education	6.73	8.74		7.42		8.28	7.40	
	(5.75)	(5.54)		(5.42)		(5.34)	(5.48)	
Head's age	50.87	46.87		44.51	*	48.05	44.42	*
	(13.23)	(13.38)		(10.64)		(9.61)	(11.51)	
Size of land owned (hectare)	7.40	5.17		6.74		7.02	6.43	
	(11.47)	(7.39)		(7.36)		(8.74)	(7.30)	
log(initial assets, naira)	12.09	11.42		11.35		11.71	11.32	
(household, agricultural assets)	(0.78)	(1.33)		(1.94)		(0.99)	(1.98)	
Own phone (=1 if at least one member	0.867	0.870		0.800		0.875	0.795	
Own phone)	(0.352)	(0.341)		(0.403)		(0.333)	(0.405)	
Have bank account	0.533	0.478		0.342	*	0.531	0.331	*
(=1 if at least one member has account)	(0.516)	(0.505)		(0.475)		(0.503)	(0.471)	
Receive remittance (=1 if HH received	0.133	0.087		0.102		0.063	0.110	
remittance in the last 12 months)	(0.352)	(0.285)		(0.303)		(0.244)	(0.314)	
Muslim HH =1 (=0 otherwise)	0.267	0.304		0.259		0.219	0.277	
	(0.458)	(0.465)		(0.439)		(0.417)	(0.449)	
Village level variable								
1 if village affected by flood in the last 12 months	0.733	0.457		0.466		0.375	0.502	*
	(0.458)	(0.504)		(0.500)		(0.488)	(0.501)	
Distance to state capital (km)	25.67	49.43	*	61.67		45.23	61.5	*
	(21.14)	(43.27)		(46.13)		(40.81)	(46.17)	

Note: Figures in parentheses are standard deviations. * indicates means are different at the 5% level. Column (a) tests differences in means of (1) and (2), column (c) tests those of (4) and (5), while column (b) tests between (3) and recipients of subsidy in 2012 (column (1) and (2)). The current value of assets owned in the beginning of the survey period (February 2011). Items are hand hoe, sickle, spray pumps, water pump, water tank/ drum, plough sets, carts, wheelbarrows, tractor, grinders, tarpaulin, lamps, watch/clock, bicycle, radio, generator, TV, chair, tables, beds, motor bike, vehicles, sofa, mattress, sewing machine, knitting machine, fridge, fan, satellite dish, solar panel, and computer.

Table 3: Access to GESS

	2012	2014
% Households knowing GESS	44.8	61.1
	(49.8)	(48.8)
% Households registering/applying GESS	29.2	46.0
	(45.5)	(49.9)
% Households receiving voucher (text-message)	19.2	28.0
	(39.4)	(45.0)
% Households obtaining fertilizer from GESS	9.7	19.2
	(29.7)	(39.4)

Note: 327 panel households. Figures in parentheses are standard deviations.

Table 4: Effects of Obtaining Subsidized Fertilizer from GESS or FMSP on Fertilizer Use and Rice Production (HHFE-IPW)

	Total fertilizer applied (kg) (1)	Total fertilizer applied per ha (2)	Area under rice (ha) (3)	Fertilizer applied per ha (4)	Paddy rice produced (ton) (5)	Yield (ton/ha) (6)	Rice income per ha (million naira) (7)
Received subsidy at time t	52.917	12.536	0.453	9.061	-0.965	0.141	-0.005
	(89.105)	(11.083)	(1.093)	(13.484)	(1.707)	(0.178)	(0.015)
No. HH members	-30.667	-2.685	0.090	0.927	-0.099	0.063	0.002
	(18.828)	(2.377)	(0.201)	(2.782)	(0.257)	(0.058)	(0.005)
Share of male adults age 15-54	46.657	-17.926	-5.537	66.484	0.767	-0.653	-0.044
	(445.972)	(53.318)	(3.826)	(56.468)	(4.874)	(0.692)	(0.050)
Share of female adults age 15-54	128.280	-7.897	3.202	-19.030	-1.339	-0.442	-0.098
	(519.299)	(60.590)	(3.875)	(55.517)	(5.854)	(0.803)	(0.068)
Head's years of education	63.363**	5.768*	-0.069	3.294	-0.092	0.002	-0.004*
	(26.207)	(3.009)	(0.087)	(2.172)	(0.151)	(0.023)	(0.002)
Age of HH head	0.172	-0.013	-0.035	-0.222	-0.042	0.005	-0.000
	(4.206)	(0.456)	(0.043)	(0.539)	(0.066)	(0.009)	(0.001)
Land owned (ha)	0.551	-3.000	0.170	-0.001	0.113	-0.032	0.002
	(15.762)	(1.844)	(0.105)	(1.444)	(0.143)	(0.020)	(0.002)
Log(value assets)	-12.412	-0.051	-0.006	-0.316	-0.116	-0.009	-0.002
	(21.564)	(2.937)	(0.112)	(1.831)	(0.174)	(0.038)	(0.002)
1 if own phone	-39.820	3.515	-0.040	4.923	-2.034	0.025	-0.011
	(108.151)	(12.981)	(1.144)	(12.517)	(1.786)	(0.139)	(0.012)
1 if own bank account	-102.194	-16.705*	-0.888	-7.815	-0.418	-0.074	-0.000
	(77.255)	(10.000)	(0.763)	(8.224)	(0.926)	(0.114)	(0.011)
1 if receive remittance	-132.158	-6.262	-0.923	-28.716**	-4.832*	-0.627***	-0.017
	(101.347)	(9.401)	(1.065)	(11.227)	(2.519)	(0.171)	(0.016)
1 if village affected by flood	-176.505	3.002	-4.742**	23.835	-7.058	-0.056	-0.027
	(220.355)	(20.420)	(2.270)	(20.606)	(4.487)	(0.324)	(0.023)
1 if village had communal violence	-315.528**	-25.934	-1.150	-26.530	-2.098	-0.163	0.084
	(159.466)	(25.454)	(1.490)	(27.456)	(2.464)	(0.473)	(0.061)
1 if Year is 2014	102.917	12.536	0.453	9.061	-0.965	0.141	-0.005
	(139.105)	(11.083)	(1.093)	(13.484)	(1.707)	(0.178)	(0.015)
Ward FE x Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. of Observations	648	648	648	648	648	648	648
R-squared	0.203	0.191	0.324	0.177	0.364	0.374	0.339
Number of HHID	324	324	324	324	324	324	324

Note: Robust standard errors are in parentheses. Standard errors are clustered at household level.

Table 5: Effects of Obtaining Subsidized Fertilizer from GESS or FMSP on Other Crops and Welfare (HHFE-IPW)

	Are under other crops (ha)	Fertilizer applied to other crops (kg)	Fertilizer applied to other crops per ha (kg)	Crop income (million naira)	Log(per capita expenditure)
	(1)	(2)	(3)	(4)	(5)
Received subsidy at time t	-0.974	34.067	1.806	-0.003	-0.044
	(0.908)	(55.957)	(13.437)	(0.012)	(0.195)
No. HH members	-0.069	-21.801*	-4.057	0.001	-0.017
	(0.197)	(11.499)	(3.493)	(0.003)	(0.035)
Share of male adults age 15-54	8.510**	62.585	-16.921	-0.033	-0.523
	(3.513)	(230.585)	(63.073)	(0.038)	(0.715)
Share of female adults age 15-54	-2.969	89.514	13.796	0.033	0.662
	(3.161)	(304.688)	(72.623)	(0.047)	(0.621)
Head's years of education	0.058	50.012***	12.810***	-0.001	-0.011
	(0.073)	(16.656)	(3.653)	(0.002)	(0.022)
Age of HH head	0.098***	0.651	-0.420	-0.000	-0.005
	(0.037)	(2.430)	(0.646)	(0.001)	(0.011)
Land owned (ha)	0.465***	-0.061	-4.061*	0.002	0.013
	(0.123)	(8.025)	(2.099)	(0.001)	(0.020)
Log(value assets)	-0.184**	1.306	0.551	-0.001	-0.015
	(0.087)	(9.043)	(4.107)	(0.002)	(0.025)
1 if own phone	-1.022	32.299	8.642	-0.017*	0.132
	(0.993)	(45.454)	(14.236)	(0.010)	(0.159)
1 if own bank account	0.968	-78.269*	-22.010*	-0.009	0.062
	(0.677)	(43.646)	(13.169)	(0.008)	(0.176)
1 if receive remittance	0.439	-0.115	12.144	-0.007	-0.056
	(0.509)	(41.566)	(13.205)	(0.011)	(0.152)
1 if village affected by flood	0.462	-85.968	-13.792	-0.015	0.106
	(1.053)	(111.244)	(35.752)	(0.017)	(0.225)
1 if village had communal violence	-0.566	-115.293	0.699	0.061	-0.426
	(1.195)	(78.544)	(20.567)	(0.058)	(0.417)
1 if Year is 2014	-0.974	34.067	1.806	-0.003	-0.044
	(0.908)	(55.957)	(13.437)	(0.012)	(0.195)
Ward FE x Year FE	Yes	Yes	Yes	Yes	Yes
No. of Observations	648	648	648	648	648
R-squared	0.355	0.256	0.216	0.183	0.247
Number of HHID	324	324	324	324	324

Note: Robust standard errors are in parentheses. Standard errors are clustered at household level. *** p<0.01, ** p<0.05, * p<0.1

Table 6: Effect of Subsidized Fertilizer on Commercial Fertilizer Demand

	Quantity of subsidized fertilizer received (kg)Tobit	Commercial Fertilizer Demand (kg) Correlated RE Tobit
Quantity of subsidized fertilizer received (kg)		-0.841**
		(-3.49)
No. HH members	-14.968	-64.021*
	(-0.84)	(-2.29)
Share of male adults age 15-54	0.040	-242.454
	(0.00)	(-0.58)
Share of female adults age 15-54	214.655	-383.662
	(0.71)	(-0.85)
Head's years of education	15.203	49.783**
	(1.35)	(2.79)
Age of HH head	2.630	13.597*
	(0.55)	(2.14)
Land owned (ha)	-12.565	-17.385
	(-1.37)	(-1.29)
Log(value assets)	26.605	23.207
	(1.59)	(1.19)
1 if own phone	50.887	-22.525
	(0.63)	(-0.21)
1 if own bank account	-38.812	67.762
	(-0.70)	(0.81)
1 if village affected by flood	63.118	178.037**
	(1.49)	(2.76)
1 if village had communal violence	-107.182	-195.412
	(-1.11)	(-1.24)
Distance to state capital (km)	-0.922+	-0.624
	(-1.81)	(-0.80)
1 if Year is 2014	-37.980	-83.670
	(-0.84)	(-0.41)
1 if head was born in the village	-336.957*	
	(-2.01)	
Born in village x head's age	7.339*	
	(2.12)	
Residual from reduced form equation		0.793*
		(2.26)
Observations	651	651
Number of HHID	327	327
Mean	34.31	465.15
(s.d.)	(106.90)	(599.70)

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. LGA FE included in columns 3. Over-time means of time varying explanatory variables are controlled in column 2. Marginal effects, not coefficients, are shown.

Table 7. Yield Response Function (HHFE)

	(1)	(2)
Nitrogen (kg/ha)	7.214**	
	(3.177)	
Phosphorus (kg/ha)	20.317	
	(12.650)	
Fertilizer (kg/ha)		4.346***
		(0.872)
1 if Modern variety	-40.546	-32.358
	(196.020)	(195.373)
Seed (kg)	-0.077	-0.073
	(0.176)	(0.173)
1 if seeds were purchased	-123.108	-127.972
	(154.552)	(150.020)
1 if Ploughed by tractor	-208.393	-222.999
	(161.193)	(157.997)
1 if plot is irrigated	490.992	497.721
	(417.275)	(390.661)
1 if rice was intercropped	-249.153	-272.757
	(395.184)	(388.634)
1 if herbicide was used	523.929*	580.546**
	(287.051)	(286.685)
Relative price (urea/output)	-655.471***	-602.578***
	(190.487)	(184.309)
No. HH members	126.039***	128.125***
	(46.393)	(45.433)
Share of male adults age 15-54	-225.280	-235.088
	(660.349)	(638.195)
Share of female adults age 15-54	621.064	690.975
	(715.376)	(705.565)
Head's years of education	11.837	9.870
	(26.306)	(25.875)
Age of HH head	-3.802	-4.325
	(8.291)	(8.175)
Land owned (ha)	-29.030	-29.540
	(18.618)	(18.002)
Log(value assets)	17.763	15.263
	(33.470)	(33.553)
1 if own phone	85.969	115.947
	(179.740)	(176.615)
1 if Year is 2014	215.303**	203.145**
	(95.370)	(93.443)
Observations	639	639
R-squared	0.156	0.164
Number of HHID	325	325

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Figure 1: Sample states

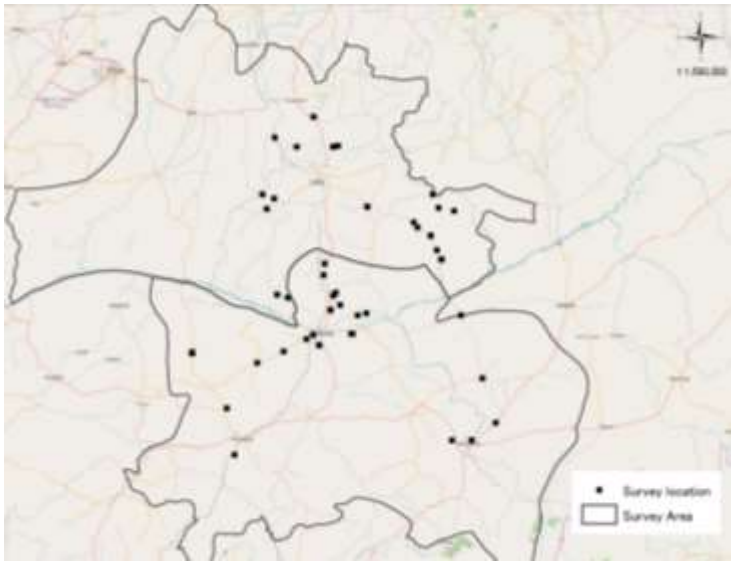
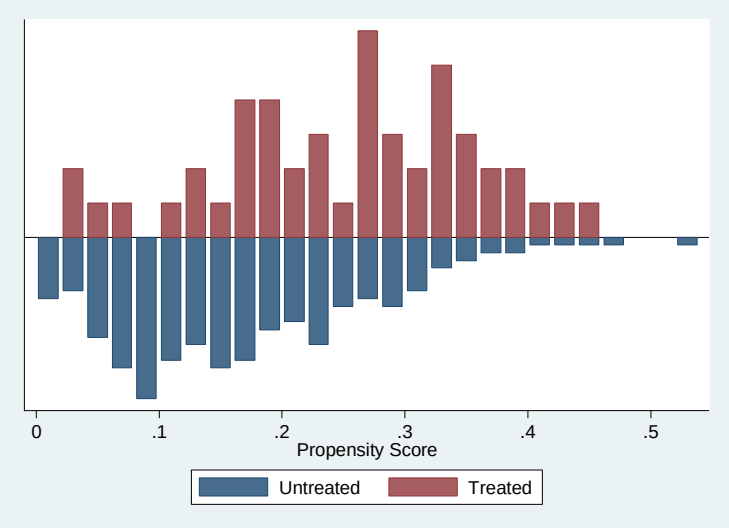


Figure 2: Survey communities



Appendix Figure 1. Distribution of Propensity Score
(Treated = those who obtained subsidized fertilizer either in 2012 or 2014)

Appendix Table 1: Correlates of Being Beneficiary of GES in 2014 (Propensity Score), Probit model

VARIABLES	1 if HH received subsidized fertilizer either in 2012 or 2014
1 if born in the village	-0.498
	(0.362)
Born in the village x head's age	0.010**
	(0.005)
Years of rice cultivation experience in 2011	0.001
	(0.002)
No. HH members	0.000
	(0.005)
Share of male adults age 15-54	0.020
	(0.113)
Share of female adults age 15-54	0.041
	(0.149)
1 if head is female	0.057
	(0.102)
Head's years of education	0.002
	(0.004)
Age of HH head	-0.008
	(0.005)
Land owned (ha)	-0.001
	(0.003)
Log(value assets)	0.004
	(0.014)
1 if own phone	0.043
	(0.046)
1 if own bank account	0.010
	(0.043)
Distance to state capital (km)	-0.001
	(0.000)
1 if state is benue	0.071
	(0.045)
Pseudo R squared	0.060
Observations	324

Note: Explanatory variables are measured in 2012, except the first two variables. Estimated by Probit regression. Marginal effects were reported. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Appendix Table 2. Balancing Test Results

	Treated	Control	t-stats
1 if born in the village	0.854	0.861	0.10
Born in the village x head's age	40.46	40.38	0.02
Years of rice cultivation experience in 2011	18.18	17.71	0.24
No. HH members	9.79	9.70	0.10
Share of male adults age 15-54	0.341	0.340	0.03
Share of female adults age 15-54	0.292	0.290	0.06
1 if head is female	0.083	0.084	0.02
Head's years of education	8.417	8.34	0.07
Age of HH head	46.02	45.90	0.06
Land owned (ha)	6.190	6.115	0.06
Log(value assets)	11.62	11.64	0.10
1 if own phone	0.875	0.850	0.35
1 if own bank account	0.438	0.426	0.11
Distance to state capital (km)	48.81	50.82	0.24
1 if state is Benue	0.583	0.589	0.06

Notes: t-stats for the mean are different between two groups before matching. Treated = those who received subsided fertilizer either in 2012 or 2014.

Appendix Table 3: Correlates of Remaining in Sample in 2014 (Attrition)

VARIABLES	1 if HH was interviewed in 2014 Probit, dy/dx
1 if born in the village	0.175**
	(0.077)
Born in the village x head's age	-0.005
	(0.003)
Years of rice cultivation experience in 2011	0.003
	(0.002)
No. HH members	-0.011**
	(0.005)
Share of male adults age 15-54	-0.109
	(0.096)
Share of female adults age 15-54	-0.186
	(0.120)
1 if head is female	0.153
	(0.101)
Head's years of education	0.006
	(0.004)
Age of HH head	0.007**
	(0.003)
Land owned (ha)	-0.003
	(0.003)
Log(value assets)	-0.010
	(0.007)
1 if own phone	-0.048
	(0.049)
1 if own bank account	0.007
	(0.041)
Distance to state capital (km)	0.003***
	(0.001)
1 if state is Benue	-0.257***
	(0.077)
LGA FE	Yes
Pseudo R2	0.223
Observations	422

Note: Explanatory variables are measured in 2012, except the first two variables. *** p<0.01, ** p<0.05, * p<0.1

Appendix Table 4: Effects of Obtaining Subsidized Fertilizer from GESS or FMSP on Rice Yield, Crop Income and Welfare (2015 cross-section data with state fixed effects)

	1 if received subsidized fertilizer			1 if registered GESS		
	Rice yield (ton/ha)	Rice income (million naira)	Log(per capita expenditure)	Rice yield (ton/ha)	Rice income (million naira)	Log(per capita expenditure)
	(1)	(2)	(3)	(4)	(5)	(6)
1 if GESS+	0.253	0.009	-0.831	-0.194	0.026	-0.456
	(1.336)	(0.065)	(1.132)	(1.007)	(0.050)	(0.836)
R-squared	0.282	0.257	0.217	0.068	0.001	0.235
Number of observations	324	324	324	324	324	324
	0.060	0.029	0.193	0.068	0.001	0.235
	Coefficients of IVs in 1st-stage model					
1 if born in the village	-0.379*			-0.668**		
	(0.218)			(0.272)		
Born in the village x age of household head	0.010**			0.014**		
	(0.005)			(0.006)		
	Validity tests of IVs++					
1 if born in the village	0.161	-0.019	0.271	0.161	-0.019	0.271
	(0.671)	(0.034)	(0.583)	(0.671)	(0.034)	(0.583)
Born in the village x age of household head	-0.001	0.000	-0.007	-0.001	0.000	-0.007
	(0.014)	(0.001)	(0.012)	(0.014)	(0.001)	(0.012)

Note: Robust standard errors are in parentheses. Other controls are same as Table 4 excluding year dummy and ward-year time trend. For columns 1-3, the main dependent variable is defined based on if households received subsidized fertilizer while for columns 4-6, it is if households registered GESS. The bottom rows under validity tests of IVs show the coefficients of two variables on which y regressed to test if these IVs do not directly affect the outcome variables. The estimation model is OLS with state fixed effects as well as other controls used in Table 4 (except GESS).

*** p<0.01, ** p<0.05, * p<0.1