Evaluating the Impact of Agricultural Input Subsidy Scheme on Farmers' Productivity, Food Security and Nutrition Outcomes in the Northcentral and Southwest Regions of Nigeria

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By

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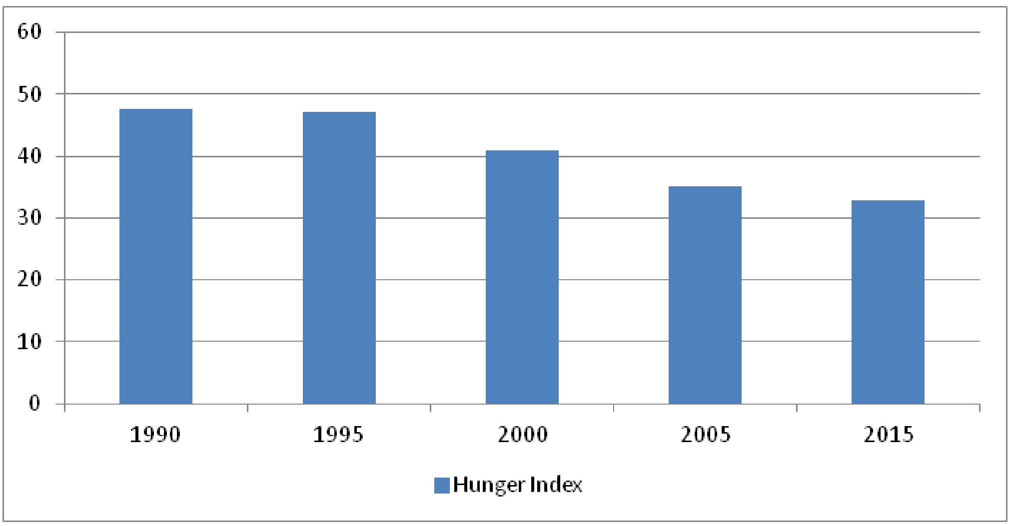
1. Introduction

Despite its rich endowment of natural resources and high agricultural potentials, Nigeria is currently facing increasing food and nutrition security challenges. Decades of policy attention to boost agricultural production have helped to moderate the pangs of food insecurity. There is a National Food and Nutrition Policy (NFNP) which seeks inter alia to improve food security at the household and aggregate levels to guarantee that families have access to adequate and safe food to meet nutritional requirements for a healthy and active life. There has been strong emphasis in the country on policy formulation and articulation of strategies. There is always a good grasp of the food security and nutrition challenges and appropriate targets have always been set to achieve desired results. Thus, the country has made giant strides regarding hunger which is a key component of access to food. It is synonymous with chronic undernourishment. Evidence suggests that efforts aimed at increasing access to food in the country have resulted in considerable reduction in hunger over the years (see Fig. 1).

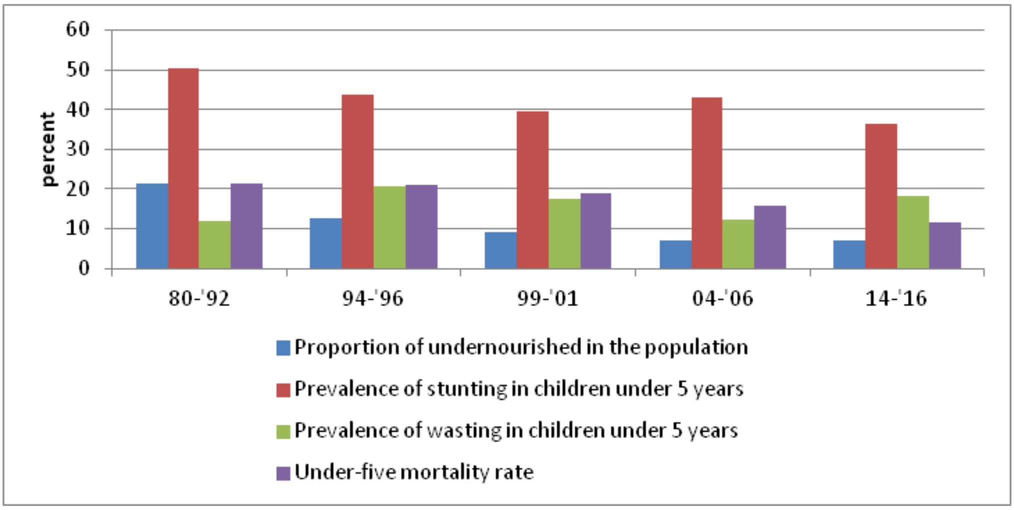
Fig. 1: Trends in Hunger Index Score in Nigeria



Source: Author's graph using data from IFPRI GHI Report, 2015

Indeed, the proportion of undernourished in the population has been fallen persistently; from 21.3 percent in the 1980s to single digit (9.2 percent) at the turn of the century and to only 7 percent by 2014/2016 (Fig. 2). It is important to stress however, that the problem of malnutrition has been far more intractable than that of access to food; and it varies from time to time and by type of indicators. Prevalence of stunting has remained the most severe manifestation of the problem; followed by under-five mortality rate and prevalence of wasting in children less than five years of age. These indicators have been trending downwards right from 1980 to 2016 except for wasting which is more serious in 2016 than it was in the 1980s and late 1990s (Fig. 2).

Figure 2: Trends in malnutrition in Nigeria, 1980-2016



Source: Author's graph using data from IFPRI GHI Report, 2015

Nonetheless, the downward trend does not mean that remedial measures are yielding the same effects in different parts of the country or among different socio-demographic groups neither is it a reflection of the different magnitudes of the various indicators of malnutrition across the country. In any case, problems remain on the resources required for policy implementation and institutional structure to deliver the output and services in order to achieve the specified targets. The fundamental issues are inadequacy of resources, imbalances in resource allocation, limited executive capacity as well as poor intergovernmental relationships and weak coordination of the multiple agencies involved in the implementation of nutrition policies. Although there is sincerity of purpose in the context of policy to address the problem, functional clarity is lacking among implementing agencies. Conflicting and overlapping interests among the multiple stakeholders exacerbate implementation weaknesses and stifle resource allocation for addressing food insecurity and dietary inadequacies. Other dimensions of the food security challenges include widening food supply and demand gap on account of rapid urbanization, fast-growing population, low productivity, poor infrastructure and institutional rigidities relating to financial and land market transactions. These have resulted in huge food deficit necessitating the nation's reliance on food imports with devastating implications on external reserve.

Furthermore, the high rate of urbanization and population growth indicates that the population of Nigeria (182 million people in 2015 with 48 % living in urban areas) is expected to double by 2040 (IITA, 2017) putting pressure on agriculture and the aging smallholder farmers. The farmers that are expected to meet the rising food demand must themselves be assured of their own food security and improved nutritional status to guarantee healthy living and to cope with the rigour of farming. The critical role of agriculture in ensuring food and nutrition security is recognized globally and reinforced in the Sustainable Development Goal (SDG) 2 which places emphasis on the need to end hunger, achieve food security and improved nutrition, and promote sustainable agriculture by 2030. In this connection, doubling the productivity and incomes of small-scale food producers; ensuring sustainable food production systems and implementing resilient agricultural practices; and maintaining the genetic diversity of seeds, plants, and animals are key targets to be achieved. Besides, the agricultural burden of food security in recent times is intensifying on account of insurgency activities in the Northeast of the country. Since 2014, the insurgency in the Northeast of the country (i.e. Borno, Yobe, and Adamawa states) has displaced 2.6 million people, including 700,000 who have taken refuge in neighbouring countries (IITA, 2017). The conflict has added pressure to a fragile resource environment and increased the food and nutrition insecurity of vulnerable women and children who rely on agriculture as means of livelihood. Many farmers in this region are no longer able to practice agriculture with adverse consequences on aggregate food production in the country. In the midst of the seeming confusion in the food and nutrition policy implementation process, the agricultural sector has concentrated efforts on the supply side; ensuring food availability and providing support to farmers to modernize their production system through increased access to modern inputs driven by the input subsidy policy.

Nigeria's input subsidy policy has a checkered history which dates back to the 1980s when the federal government introduced it to promote farmers' access to fertilizer following critical supply shortages, rising cost and inefficient distribution system. Since then there has been periodic review of the policy to enhance the efficiency of fertilizer distribution and reduce its fiscal burden. Various reform measures were taken including the temporary withdrawal of fertilizer subsidy in 1997. To address the effect on demand by farmers at that time, government reduced the import tariff on fertilizers from 10 percent in 1996 to five percent in 1997. Following the return to civilian administration in 1999, the subsidy was re-introduced but at a reduced rate of 25 percent and the import tariff was further reduced from five percent to zero percent in 2000. The value-added tax (VAT) and excise duty were also abolished. According to analysts the reform process failed to accord any priority to the development of institutional capacity and building the necessary human capacity for efficient and transparent delivery of services in the sector. Consequently, fertilizer use decreased from over 500,000 nutrient tons in 1994 to approximately 100,000 nutrient tons in 1999 (IFDC/IITA/WARDA, 2000).

The reform measure which started in 1994 culminated in the launch of a national fertilizer policy for the country in 2006 to facilitate farmers' timely access to adequate quantity of both organic and inorganic fertilizers of appropriate quality and affordable prices. The policy also placed emphasis on the liberalization of the procurement and distribution of fertilizer, entrenchment of transparency and marketing efficiency in a competitive environment and the reliance on the private sector to play a leading role in the sector. By 2008, the Federal Government announced its intention to disengage from direct involvement in fertilizer procurement and distribution as soon as a suitable alternative is identified. That same year, the IFDC in collaboration with the Federal Ministry of Agriculture and Rural Development (FMARD), piloted a Fertilizer Voucher Scheme (FVP) in Kano and Bauchi States with gradual expansion in 2009 and 2010. The scheme demonstrated that a voucher system of fertilizer subsidy administration was feasible and that small-scale farmers could benefit directly from such a system that was managed by the private sector. Indeed, the private sector and some states have since assumed greater responsibilities for production, procurement and marketing activities. Most of the states have established blending plants to increase the local supply of blended products while others procure fertilizers from the main private sector producers and importers at market prices and distribute them to farmers at subsidized prices.

In 2011, the fertilizer voucher system was adopted as a policy instrument nationwide and it formed the basis for the design of the Growth Enhancement Support Scheme (GESS) which was a Federal Government initiative, implemented under the Agricultural Transformation Agenda from 2011 to 2015. Under the GESS, agricultural fertilizer subsidy was provided at 50% subsidy rate with other incentives (such as provision of improved seeds) to encourage improvement in productivity, household food security and income of farmers. Specifically, the scheme sought to: (1) target five million farmers annually for four years for the delivery of subsidized agricultural inputs via their mobile phones using an electronic-wallet app; (2) deliver input subsidy directly to farmers to ensure that modern inputs are procured at affordable prices and used at the right time and place; (3) increase the use of fertilizer from 13 kg/ha to 50 kg/ha in order to enhance the productivity of farmers; and (4) liberalize the procurement and distribution of fertilizer, and strengthen government policy and regulation to bring about better quality and improved private sector participation. Although evidence suggests that the scheme has been successful in terms of the delivery of the subsidy judging by the increase in the quantity of subsidized fertilizer distributed to farmers which rose from 120,903 metric tonnes in 2012 to 748,834 metric tonnes in 2014 (Olomola, 2015), there has been no evaluation of the impact of the scheme on household food security and nutrition. This is a major lacuna to be bridged by the proposed study. And this raises the question as to whether the full range of benefits of the scheme has been uncovered and brought to bear on policy decisions in support of SDG 2 and in strengthening food and nutrition security in

Nigeria. Specifically, has the government's subsidy intervention resulted in any significant increase in the productivity and incomes of farmers in Nigeria? How has the intervention influenced the food security status of the farmers? What is the impact of the intervention on nutrition outcome of the smallholder farmers? These research questions are investigated in this study.

By seeking to measure the food and nutrition security benefits of government's agricultural input subsidy schemes the study attempts to substantiate the benefits of such intervention to the public at large beyond the customary expectation of increase in agricultural output. Measuring the food and nutrition impact of such intervention is crucial because the rural areas inhabited by the farmers who participate in such schemes are the domain of the poorest and easily the most food-insecure and nutritionally disadvantaged groups of Nigerians. Determining whether such an intervention has a positive or negative effect on food and nutrition security should provide the evidence base to guide policy decision to design a more effective intervention that recognizes agricultural input subsidy as a form of social protection rather than a distortion of the agricultural input market. In this connection the study provides evidence to inform agricultural input policy development and assist the reform of the subsidy delivery system.

Objectives

The broad goal of this study is to examine the impact of agricultural input subsidy on agricultural productivity, food security and nutrition outcomes of smallholder farmers in Nigeria. The specific objectives are to:

(i) Estimate the factors influencing smallholder farmers' participation in the fertilizer subsidy scheme in Southwest and Northcentral Nigeria.

(ii) Analyse the determinants of food security among the smallholder farmers in southwest and north-central Nigeria, and

(iii) Estimate the impact of the fertilizer subsidy scheme on smallholder farmers' productivity, food security and nutritional status in Southwest and Northcentral Nigeria.

Working hypotheses

The study was guided by the following working hypotheses: (i) participation of smallholder farmers in the subsidy scheme does not significantly depend on their non-farm characteristics, (ii) farmers' participation in the subsidy scheme has no significant impact on their productivity, (iii) there is no significant improvement in farmers' food security and nutrition status on account of their participation in the subsidy scheme.

Review of literature

Agricultural interventions that seek to improve the performance of farmers in terms of increases in productivity, profitability and income have been found to affect the food and nutrition security of such farmers. In this regard several stylized facts have been established in the literature. Evidence in respect of the impact of agricultural interventions on household food security suggests that (i) The effects on food security of agricultural policies or interventions that affect food prices are likely to depend on whether rural households are net sellers or net purchasers of those food commodities, (ii) the effect on food security of cash crop production is likely to depend on whether the land and labor utilized are in surplus and on the extent of variability in the supply prices of basic food crops (iii) the effect of agricultural interventions on food security is likely to be more positive if the interventions focus on those agricultural tasks normally undertaken by women, if they increase intercropping, increase small-scale agricultural processing, and increase the production of food disproportionately consumed by food-insecure households, (iv) agricultural interventions that displace labor through large-scale mechanization are more likely to have negative food security effects and (v) increasing employment of unemployed and under-employed population groups is likely to translate into reduced food insecurity. With regard to nutrition the review suggests that positive and significant nutrition impacts are most likely to occur from agricultural interventions when (i) household members regularly consume the food commodity being produced, (ii) the intervention includes explicit nutrition counseling, (iii) the intervention includes home gardens, and (iv) the project introduces micronutrient-rich plant varieties (Levinson, 2011).

In a recent study, Mazunda et al. (2015) analyze the impacts of crop diversification on farm household's food and nutrition security in Malawi using household dietary diversity and nutritional adequacy indicators computed from household survey data. Their results provide evidence that crop diversification improves household food and nutrition security among farming households. They used household dietary diversity scores (HDDS) and micronutrient-sensitive household dietary diversity scores (MsHDDS) as indicators of food security and nutritional status respectively. The results show that household food and nutrition increased by 21 percent, but the greatest impact of crop diversification was on micronutrient adequacy indicators.

Empirical studies involving the use of dietary diversity and nutritional adequacy as indicators of nutritional outcomes also have recent applications in other African countries. However, available studies are not intervention-based nor are they targeted at evaluating agricultural policies. They relate more to the agricultural production systems and how diversity of crop produced is related with nutritional outcomes. The growing consensus as far as this course of investigation is concerned is that crop diversification and dietary diversity are positively related. The findings from Kenya and Tanzania show that the number of crops grown by a farmer is positively associated with household dietary diversity (Mazunda et al., 2015). And in Mali, it was found that the number of crops cultivated by a household was positively associated with adult nutrient adequacy (Torheim et al. 2004). Moreover, Jones et al. (2014) found that farm production diversity was positively associated with farm household dietary diversity in Malawi.

This study follows in the recent approach of assessing the various ways agriculture can contribute to improvement in nutrition. People rely on agriculture as the primary source of food; but the food producers themselves are not always considered in any intervention to improve nutritional wellbeing. Thus, this study differs from previous studies by focusing on the nutritional outcomes of an intervention (subsidy) scheme aimed at improving the productivity and food security of farmers themselves. Methodologically, a different econometric approach involving the application of Endogenous Switching Regression (ESR) is applied in this study to validate the impact of the intervention. This is a more robust technique of handling the issues of counterfactual and heterogeneity given the production behaviour of smallholder farmers in Nigeria and the socioeconomic environment in which they operate.

Nonetheless, the analysis is cognizant of the conceptual and empirical challenges that should be addressed even in the application of suitable econometric techniques. For instance, the literature is replete with conceptual challenges to define treatment group in subsidy schemes and clearly isolate the impact of the subsidy. Such challenges include the tendency of participating farmers to (1) sell, barter or give away the voucher, (2) use the voucher to purchase fertilizer and seed and then sell, barter or give some or all of the inputs away, or (3) acquire the inputs and apply the subsidized fertilizer to unintended crops (Ricker-Gilbert et al., 2013). An attempt is made in this study to surmount such challenges by focusing on farmers that participated in the fertilizer subsidy scheme and who purchased fertilizer at the subsidized price and used it for production purposes and for the intended crops. Besides, no farmer participating in any other subsidy scheme apart from the GESS is included in the sample. Under the GESS scheme, farmers who received fertilizer subsidy also received subsidized seeds as part of the package. This approach is more likely to substantiate the impact of the scheme rather than focusing on different points of evaluation such as relying on the number and combination of vouchers received by farmers (Chibwana et al., 2011), or a particular type of fertilizer voucher received (Holden and Lunduka, 2012), or the total monetary value of all vouchers received (Fisher and Shively, 2005; Shively et al., 2012) as an indicator or scheme participation. The farmers included in the "treatment" group for the purpose of impact evaluation in this study are among the registered farmers who received their subsidy through an electronic wallet (payment system) and went ahead to redeem their fertilizer (NPK and Urea) as well as maize and rice seeds as a package and used them for the production of those crops.

Apart from the conceptual challenge, there is also the empirical challenge in the estimation of impacts arising from the design of subsidy schemes. A critical challenge usually encountered in the literature (and which applies to the situation in Nigeria) arises from the non-random process by which program beneficiaries are selected or targeted. Thus, any empirical modeling of subsidy impact must take cognizance of the inherent selection bias in beneficiary targeting since governments do not randomly distribute subsidized inputs to farmers. According to Ricker-Gilbert et al. (2013), there is the likelihood of the amount of subsidized fertilizer that a household receives being correlated with poverty status, household income, or underlying features that influence these outcome variables. This is because government officials in some areas may distribute fertilizer to households who are more productive, while in other areas fertilizer may be targeted to less productive households because targeting guidelines in many countries are unavailable or unclear. The endogeneity of subsidies and their impacts have been dealt with in the literature by various studies which adopted an instrumental variable (IV) approach using a variety of instruments including number of years the household head has lived in a village (Chibwana et al. 2011, Ricker-Gilbert et al. 2011; Shively et al. 2012), fixed costs of acquiring fertilizer (Holden and Lunduka 2012), whether a member of parliament resides in the community (Ricker-Gilbert and Jayne 2011) and the official quantity of subsidized inputs distributed to a household's district (Mason and Ricker-Gilbert 2012). This approach creates the common challenge in moving from correlation to causation of trying to locate an instrument that is correlated with acquiring subsidized inputs, but uncorrelated with unobservable factors that affect outcome variables of interest. A major criticism of the approach is that exogeneity of an IV is a hypothesis that cannot be tested directly and the possibility that some of the instruments are themselves endogenous cannot be completely ruled out (Ricker-Gilbert et al., 2013).

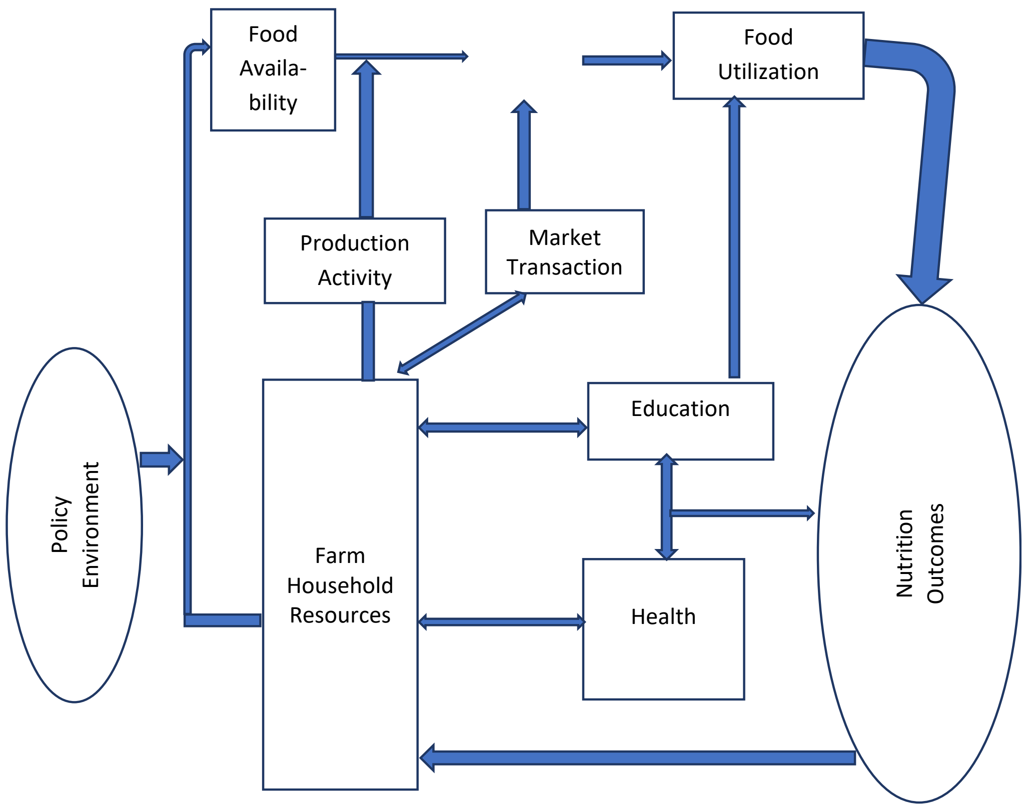
In this study therefore, an endogenous switching regression approach is adopted in modeling the impact of the subsidy scheme. This method is apt to provide a more robust result and at the same time take care of the selection bias and endogeneity. Moreover, the study itself is novel in the Nigerian context; since no attempt has been made in the country to evaluate the impact of the fertilizer subsidy scheme on farmers' food and nutrition security. The study attempts to fill this lacuna and provide the evidence base to inform policy aimed at fostering food and nutrition security in the country.

2. Conceptual framework and methodology

People's need for food is derived basically from agriculture. There is, therefore, an intrinsic link between agriculture, food security and nutrition (Figure 3). The different pathways through which agriculture and nutrition are linked have been well developed in the literature. According to the World Bank (2007) the five archetypal pathways linking agriculture with food consumption and human nutrition are as follows. (1) Production-for-own-consumption - This refers to increase in consumption arising from increased food production. (2) Production-for-income – This refers to increased income from the sale of (surplus) agricultural commodities. (3) Empowerment of women farmers - this model regards women as agents instrumental to improved household food security, health and nutrition outcomes. (4) Lower real food prices resulting from increased food production and availability. Increased food production can lead to a reduction in food prices thus raising the real income of consumers. In turn, lower food prices can increase household food security and raise energy and micronutrient consumption. (5) Macroeconomic growth arising from agricultural growth. Agricultural growth leads to increased national income and macroeconomic growth and to poverty reduction and improved nutrition outcomes. Theoretically, growth in agriculture can lead to broad improvements in nutrition through its contributions to macroeconomic growth and national income.

When changes are introduced into the production system in the form of subsidy intervention for instance, the expected nutrition outcomes are generated through these pathways. The pathway through which outcomes are produced depends on the nature of intervention. In the case of the GESS, the subsidy is being delivered to promote the use of modern inputs such as improved seeds and fertilizer. Thus, the nutritional outcomes are to be generated through the pathways (1), (2) and (4) above. The nutritional outcomes can therefore, be considered in terms of (i) Household-level food consumption, which includes household level consumption of foods and household expenditure on foods and food groups, (ii) individual food and nutrient intake, which includes intakes of macro- and micronutrients and (iii) nutrition status, which includes anthropometric indicators, such as height, weight, and body mass index, and micronutrient-specific indicators (World Bank, 2007). In theory, as stipulated in the food price pathway described above, reduced food prices allow greater access to food which in turn can lead to improved nutrition. The pathways (1), (2) and (4) described above basically reflects not only the agriculture-nutrition linkage but also the key elements of food security. Food security exists when all people, always, have physical and economic access to enough, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life (FAO, 2002). With increased food production, availability and access, as the three pathways indicate, food security is also an expected outcome of the subsidy intervention.

Figure 3: Conceptual Framework for Agriculture-Food Security-Nutrition Linkage



The fertilizer subsidy scheme can be linked with the productivity, food security and nutritional status of farmers by considering changes in food production and consumption of smallholder farmers participating in the scheme compared with the non-participating farmers. Specifically, improved productivity, food security and nutritional status may arise in the case of smallholders in the study areas (Niger and Ogun States) who used subsidized fertilizer and improved seeds in their farming enterprises under the subsidy scheme. For such farmers, increased production at the household level should increase food availability leading to increase in own consumption and food security. Smallholder farmers who participated in the input (fertilizer and seed) subsidy scheme and who used the inputs are more likely to have higher yield than their non-participating counterparts. Such smallholder farmers with higher output have a possibility of stocking some for home consumption and selling some produce to the market and subsequently use the farm income to purchase other crops and animal foods e.g., fruits, vegetables, oils, meat, fish, eggs, dairy products and so forth. With increased own food consumption and higher revenue, such households would consequently be more food secured for certain periods of the year and have higher nutritional status compared to those with lower outputs.

Methodology

This study adopts a mixed method approach involving the use of existing survey data supplemented by other secondary data obtained from key agencies associated with the GESS scheme and input subsidy policy in Nigeria. The impact of the subsidy policy is assessed quantitatively using econometric techniques. The input subsidy scheme is intended to improve farmers' productivity, boost food production and ensure increased food availability and income and thus create opportunities for better food consumption and nutrition outcome. For analytical purposes therefore, the outcomes of interest are productivity, food security and nutritional adequacy. Productivity is measured by total value of output per hectare of cultivated land area (i.e. land productivity). Household Dietary Diversity Score (HDDS) is used as a proxy for household food security. It reflects, at a glance, the economic ability of a household to consume a variety of foods. HDDS is a promising measurement tool that is widely used in the literature (Arimond and Ruel, 2006; Kennedy et al., 2007) to capture food security. The HDDS is based on a set of 12 food groups proposed by FANTA (2014) which consists of cereals; root and tubers; vegetables; fruits; meat, poultry and offal; eggs; fish and seafood; pulses/legumes/nuts; milk and milk products; oil/fats; sugar/honey and miscellaneous (Swindale and Bilinsky, 2006a, 2006b). The quantity of specific food items consumed in each group was converted to micronutrient values using FAO standard food composition tables for use in Africa, FAO dietary assessment guides (FAO; 2018) and online version of nutrient composition values based on USDA national nutrient data base for standard reference. Regarding nutrition outcome we use nutrient intake adequacy as the indicator.

Nutrient adequacy is the level of intake of an essential nutrient in relation to the nutrient requirement for adequate health which is expressed as the percentage of recommended dietary allowance (Drewnowski and Fulgoni, 2008). To estimate the nutrient adequacy of the diet, a nutrient adequacy ratio (NAR) was calculated for 11 micronutrients (vitamin A, thiamine, riboflavin, niacin, ascorbic acid, calcium, iron, magnesium, phosphorus, potassium and zinc). NAR was calculated for each nutrient as the ratio of daily individual intake to standard recommended adult equivalent amounts. Mean adequacy ratio (MAR) which is an overall measure of nutrient adequacy was also calculated as follows in line with standard procedures (Krebs-Smith et al. 1987; Parvin et al. 2004; Rathnayake et al., 2012, Hatloy et al. 1998).

$$\text{NAR} = (\text{Nutrient intake} \div \text{Recommended intake}) \times 100$$

$$\text{MAR} = \Sigma\text{NAR (each truncated at 1)} \div \text{Number of nutrients}$$

NAR was truncated at 1 so that a nutrient with a high NAR could not compensate for a nutrient with a low NAR (Hatloy et al. 1998). The nutrient adequacy ratios are also categorized as low intake (intake <60%), adequate intake (60% - 80%) and high intake (80% - 100%) following Oladoyinbo et al. (2017).

Econometric model for evaluating the impact of the subsidy scheme

Farmers are desirous of participating in the GESS (subsidy scheme) to facilitate access to modern inputs (fertilizer and improved seeds) and enhance their production activities for improved productivity and profitability. Invariably, the production behaviour of farmers is contingent on the decision to participate. Their participation may have significant economic benefits and, it may lead to improvement in food and nutrition security. Households will decide to participate based on the expectation that it is be profitable or otherwise advantageous to their production activities. The decision of the farmers as rational agents can be modeled in random utility framework (de Janvery et al., 2010; Becerril and Abdulai, 2010; Ali and Abdulai, 2010). The difference between the utility from participation in GESS (that is utility of being beneficiary of subsidy (UBSi) and nonparticipation that is non-beneficiary of subsidy (UNBSi) may be denoted as S* such that a utility-maximizing farm household, i, will choose to participate in the GESS if the utility gained from participation is greater than the utility of not participating (S* = UBSi - UNBSi > 0). Since these utilities are unobservable, they can be expressed as a function of observable elements in the following latent variable model.

$$\boldsymbol{S}_i^* = \alpha Z_i + \boldsymbol{\eta}_i \qquad \text{with } S_i = \begin{cases} 1, & if\ \boldsymbol{S}_i^* > 0 \\ o, & \text{otherwise} \end{cases} \tag{1}$$

Where S is a binary indicator variable that equals 1 if a farmer is a participant in the GESS (i.e. subsidy beneficiary) and zero otherwise; α is a vector of parameters to be estimated; Z is a vector of factors influencing decision to participate and η is an error term with mean zero and variance, σ_η^2 . To examine the impact of the input subsidy scheme, the focus of analysis is to assess whether or not changes in farmers' productivity, food security and household nutrition outcomes can be attributed to their participation in the scheme while controlling for changes in household characteristics and other extraneous factors. For these outcomes the relationship can be specified in the following equation.

$$Y_i = \beta X_i + \gamma \boldsymbol{S}_i + \mu_i \tag{2}$$

where Yi represents outcome variable (productivity, food security or nutrition outcome), S is an indicator variable for GESS participation as defined above, X_i are observable variables, β and γ are vectors of parameters to be estimated and μ_i is an error term. In this formulation, the impact of the subsidy scheme is measured by the estimates of the parameter, γ.

The relationship between the outcome variable and treatment variable in Eq. 2 seems to be bi-causal in the sense that subsidy scheme participation affects an outcome, say productivity but at the same time productivity also affects participation since farmers who decide to participate in the subsidy scheme may be the ones who actually find it most profitable or are indeed more productive. In this case the outcome and treatment indicator (subsidy) are simultaneously related. This simultaneity (reverse causality) bias creates the problem of endogeneity.

Moreover, in the case of farmers included in this study, the decision to participate is voluntary thus giving rise to the familiar problem of self-selection bias in the sense that the assignment of farmers to groups is non-random (even for controlling for observed independent variables), but instead is a function of the outcome variable. Therefore, OLS estimation yields inconsistent estimates of participation and of other independent variables in the model. The sources of inconsistencies are reverse causality as well as correlation in unobserved factors (unobserved heterogeneity) that may affect participation decision and the independent variables in the model. The decision to participate may also be endogenous with respect to the outcome variable; and this is another dimension of the endogeneity problem. In any case, econometric problems arise because standard regression techniques result in biased and inconsistent estimators if unobserved factors affecting the response (outcome) are correlated with unobserved factors affecting the switch/selection process (Hausman, 1978; Heckman, 1979; Wooldridge, 2002). The application of propensity scores matching approach (PSM) in this circumstance is inadvisable in the sense that it may reduce the selection bias due to observables, while the bias due to unobservables remains unresolved. Moreover, the two types of selection bias (due to observables and unobservables) need not have same sign. So, reducing one of the bias need not reduce the other (Ravallion, 2001). In the light of the foregoing, the endogenous switching regression (ESR) model is used to overcome these sources of inconsistencies.

The endogenous switching regression (ESR) Mmodel

The endogenous switching regression model accounts for both endogeneity and selectivity bias (Alene and Manyong, 2007; Di Falco et al., 2011). ESR allows for a joint determination (estimation) of the selection equation and the outcome equation which may be affected by participation. The endogenous switching model allows one to: (i) model both the allocation of farmers to schemes and the effects of scheme participation on other outcomes, (ii) estimate the degree to which common unmeasured variables affect both the outcome and treatment variables, (iii) obtain estimates of the effects of other variables within the level of treatment variables that take account of potential selection biases; and (iv) estimate the impact of the treatment regime (subsidy) by simulating how individuals would fare had they entered groups different from those they in fact occupy (Maddala, 1992; Amemiya, 1985). Consistent estimators can be obtained by maximum likelihood estimation of a joint model of the outcome and switching or selection variable (Miranda and Rabe-Hesketh, 2006). Given these circumstances the endogenous switching regression model is adopted in this study. The model considers that observations are ordered into two regimes conditional on a criterion function, S_i, that determines which regime a farmer faced.

$$\boldsymbol{S}_i^* = \alpha Z_i + \boldsymbol{\eta}_i \tag{3}$$

Regime 1(participants): $$Y_{1i} = \beta_1 X_{1i} + \mu_{1i} \quad \text{if } S_i = 1 \tag{4a}$$

Regime 2(non-participants): $$Y_{2i} = \beta_2 X_{2i} + \mu_{2i} \quad \text{if } S_i = 0 \tag{4b}$$

Where S_i^* is the unobservable or latent variable for GESS participation, S_i is its observable counterpart, Z_i are non-stochastic vectors of observed farm and non-farm characteristics determining participation, Y_i is outcome variable (e.g. productivity, food security or nutrition outcome) in regimes 1(participants) and 2 (non-participants), X_i represents a vector of exogenous variables influencing farmers outcome behaviour while η_i and μ_i are random disturbances associated with the participation and outcome variable respectively. The error term η_i is assumed to be correlated with errors μ_{1i} and μ_{2i} and all three terms are assumed to have a trivariate normal distribution. Since the error term of the selection equation (3) is correlated with the error terms of the outcome functions (4a) and (4b), the expected values of μ_{1i} and μ_{2i} conditional on the sample selection are nonzero and are defined as:

$$E[\mu_{1i} \mid \boldsymbol{S}_i = 1] = \sigma\mu_1\eta \frac{\emptyset\ (\alpha Z_i)}{\Phi\ (\alpha Z_i)} = \sigma\mu_1\eta\lambda_{1i}$$

$$E[\mu_{2i} \mid \boldsymbol{S}_i = 0] = -\sigma\mu_2\eta \frac{\emptyset(\alpha Z_i)}{1-\Phi(\alpha Z_i)} = \sigma\mu_2\eta\lambda_{2i}$$

Where Ø(.) and Φ(.) are the standard normal probability density function and normal cumulative density function respectively, $\lambda_{1i} = \frac{\emptyset\ (\alpha Z_i)}{\Phi\ (\alpha Z_i)}$ and $-\frac{\emptyset(\alpha Z_i)}{1-\Phi(\alpha Z_i)}$. If the estimated covariance $\sigma\mu_{1\eta}$ and $\sigma\mu_{2\eta}$ are statistically significant then the decision to participate and the output of the farmer are correlated. The implication is that there is evidence of endogenous switching and the null hypothesis that there is absence of sample selectivity bias is rejected.

Impact of fertilizer subsidy – Treatment and heterogeneity eEffects

The above ESR model is employed to determine the impact of input subsidy by comparing observed and counterfactual production, food security and nutritional outcomes. The endogenous switching regression model has the advantage of being used to (i) compare the expected outcomes of the farm households that participated with those that did not participate (ii) investigate the expected outcome in the counterfactual hypothetical cases (a) that the participating farmers did not participate and (b) that the non-participants indeed participated. This is with a view to determining the treatment effects (treatment effect on the treated and the treatment effect on the untreated) and heterogeneity effects (base heterogeneity and transitional heterogeneity). The conditional expectations in the four scenarios is defined as:

$$\mathrm{E}[Y_{1i} \mid \boldsymbol{S}_i = 1] = \beta_1 X_{1i} + \sigma\mu_1\eta\lambda_{1i} \quad \text{5a)}$$

$$\mathrm{E}[Y_{2i} \mid \boldsymbol{S}_i = 0] = \beta_2 X_{2i} + \sigma\mu_2\eta\lambda_{2i} \quad \text{(5b)}$$

$$\mathrm{E}[Y_{2i} \mid \boldsymbol{S}_i = 1] = \beta_2 X_{2i} + \sigma\mu_2\eta\lambda_{1i} \quad \text{(5c)}$$

$$\mathrm{E}[Y_{1i} \mid \boldsymbol{S}_i = 0] = \beta_1 X_{1i} + \sigma\mu_1\eta\lambda_{2i} \quad \text{(5d)}$$

Following Heckman et al., (2001), Carter and Milon (2005) and Di Falco et al., (2011) the treatment and heterogeneity effects is obtained as follows.

$$\mathrm{TT} = \mathrm{E}[Y_{1i} \mid S_i = 1] - \mathrm{E}[Y_{2i} \mid S_i = 1] = X_{1i}\,(\beta_1 - \beta_2) + \lambda_{1i}(\sigma\mu_1\eta - \sigma\mu_2\eta) \quad (6)$$

$$\mathrm{TU} = \mathrm{E}[Y_{1i} \mid S_i = 0] - \mathrm{E}[Y_{2i} \mid S_i = 0] = X_{2i}\,(\beta_1 - \beta_2) + \lambda_{2i}(\sigma\mu_1\eta - \sigma\mu_2\eta) \quad (7)$$

$$\mathrm{BH}_1 = \mathrm{E}[Y_{1i} \mid S_i = 1] - \mathrm{E}[Y_{1i} \mid S_i = 0] = \beta_1(X_{1i} - X_{2i}) + \sigma\mu_1\eta\,(\lambda_{1i} - \lambda_{2i}) \quad (8)$$

$$\mathrm{BH}_2 = \mathrm{E}[Y_{2i} \mid S_i = 1] - \mathrm{E}[Y_{2i} \mid S_i = 0] = \beta_2(X_{1i} - X_{2i}) + \sigma\mu_2\eta\,(\lambda_{1i} - \lambda_{2i}) \quad (9)$$

$$\mathrm{TH} = \mathrm{TT} - \mathrm{TU} \quad (10)$$

Where,

TT = effect of the treatment on the treated
TU = effect of the treatment on the untreated
BH1 = effect of base heterogeneity for subsidized farmers (S_i= 1)
BH2 = effect of base heterogeneity for non-subsidized farmers (S_i=0)
TH = transitional heterogeneity (TT-TU)

By obtaining the transitional heterogeneity we seek to determine whether the effect of subsidy intervention is smaller or larger for participating and non-participating farmers relative to their counterfactual scenario.

Empirical specification of the endogenous switching regression model

The ESR model shown in equation 3 is a probit model of participation in the subsidy scheme which can be specified as:

$$S_i = \gamma_o + \gamma_1 AGE + \gamma_2 HHSIZE + \gamma_3 GENDER + \gamma_4 FARMEXP + \gamma_5 NFINCOM + \gamma_6 QTYFERT + \gamma_7 QTYSEED + \gamma_8 LABOUR + \gamma_9 MSTAT + \gamma_{10} REGION + \gamma_{11} SETPATTERN + \gamma_{12} EDUC + \gamma_{13} CREDIT + \gamma_{14} MKTDIST + \varepsilon_{1i} \quad (11)$$

Where,

Si = dummy variable for subsidy beneficiaries = 1 for participants and 0 for non-participants
AGE = Age of household head (years)
HHSIZE = Household size (nos)
GENDER = Dummy variable for gender of household head (male=1; female=0)
FARMEXP = Farming experience (years of farming)
NFINCOM = Nonfarm income (₦)
QTYFERT = Quantity of fertilizer per hectare (Kg)
QTYSEED = Quantity of seed per hectare (Kg)
LABOUR = Labour use per hectare (man-days)
EDUC = Educational attainment (Years of schooling)
MSTAT = Marital status (Dummy: married = 1; otherwise = 0)
REGION = Dummy (north = 1; south =0)
SPATTERN = Settlement pattern (Dummy: rural = 1; otherwise = 0)
CREDIT = Credit Use (Dummy: Used formal credit = 1; otherwise = 0)
MKTDIST = Distance to market (Km)

Regimes 1 and 2 for farmers' productivity

First, the analysis considers the impact of the subsidy scheme on farmers' productivity. Thus, the productivity equation representing the two regimes indicated in equations 4a and 4b is specified as:

$$LnY_i = \beta_o + \beta_1 Ln\text{AGE} + \beta_2 Ln\text{HHSIZE} + \beta_3\text{GENDER} + \beta_4 Ln\text{FARMEXP} + \beta_5 Ln\text{NFINCOM} + \beta_6 Ln\text{LABOUR} + \beta_7\text{MSTAT} + \beta_8 Ln\text{EDUC} + \beta_9 Ln\text{QTYFERT} + \beta_{10} Ln\text{QTYSEED} + \beta_{11}\text{REGION} + \beta_{12}\text{SPATTERN} + \varepsilon_{1i} \quad (12)$$

Where, Y_i is the value of output per hectare and all other variables are as earlier defined.

Regimes 1 and 2 for food security

Food security status is measured by the household dietary diversity score (HDDS) which is a proxy measure of food security. The estimating food security status equation that follows the two regimes indicated in equations 4a and 4b is expressed as:

$$LnHDDS_i = \alpha_o + \alpha_1 Ln\text{HHSIZE} + \alpha_2 Ln\text{FARMEXP} + \alpha_3 Ln\text{NFINCOM} + \alpha_4 Ln\text{EDUC} + \alpha_5 Ln\text{QTYFERT} + \alpha_6 Ln\text{QTYSEED} + \alpha_7 Ln\ \text{FARMSIZE} + \alpha_8\text{REGION} + \alpha_9 Ln\ \text{REMIT} + \alpha_{10}\text{HHFEXP} + \varepsilon_{1i} \quad (13)$$

Where HDDS is household dietary diversity score as earlier defined, REMIT is remittance, HHFEXP is household expenditure on food, FARMSIZE is land area cultivated and all other variables are as earlier defined.

Regimes 1 and 2 for nutritional outcome

In the case of nutritional outcome, nutrient intake adequacy is used as an indicator. The estimating nutritional outcome equation like the aforementioned outcome indicators shown in equations 4a and 4b is specified as:

$$LnNAR_i = \gamma_o + \gamma_1 Ln\text{HHSIZE} + \gamma_2 Ln\text{FARMEXP} + \gamma_3 Ln\text{NFINCOM} + \gamma_4 Ln\text{EDUC} + \gamma_5 Ln\text{QTYFERT} + \gamma_6 Ln\text{QTYSEED} + \gamma_7 Ln\text{FARMSIZE} + \gamma_8\text{REGION} + \varepsilon_{1i} \quad (14)$$

Where NAR is nutrient adequacy ratio as defined earlier. The empirical assessment of determinants of farmers' participation and impact of the subsidy scheme is achieved through the joint estimation of equations 11 and 12 regarding farmers' productivity; equations 11 and 13 in the case of farmers' food security and equations 11 and 14 for nutrient intake adequacy. According to the theoretical specifications in equations 3, 4a and 4b, the productivity function in equation 12, food security function in equation 13 and nutrient adequacy function in equation 14 is based in each case on the two regimes of participants and non-participants in the subsidy scheme that is involved in the joint estimation. For identification purposes, the usual condition that the selection equation contains at least one variable not in the outcome equation is followed. Essentially, this involves inclusion of variables that uniquely determine the discrete decision to participate in the subsidy scheme but not the continuous decision regarding production, food security and nutrition. Thus, for identification purposes, two variables – use of credit and distance to the market are included in the selection equation in the ESR model (equation 11) but not in equations 12, 13 and 14. The full information maximum likelihood (FIML) method is employed in estimating the endogenous switching regression model using the STATA package.

After estimating the model parameters, the impact of the subsidy scheme and heterogeneity effects conditional on specific criterion function as earlier specified in equations 5 (a) – (d) can be obtained as illustrated in Table 1. From the matrix shown in the table, the treatment (subsidy) effect on the subsidized farmers i. e. treatment effect on the treated (TT) is the difference between (a) and (c). The effect of the treatment (subsidy) on the non-subsidized farmers i.e. treatment effect on the untreated (TU), is the difference between (d) and (b). The effect of base heterogeneity of the subsidized farmers is the difference between (a) and (d). The effect of base heterogeneity of farmers who decided not to participate in the subsidy scheme is the difference between (c) and (b); while the transitional heterogeneity (TH) is computed as the difference between (TT) and (TU). The essence is to determine whether the effect of subsidy is smaller or larger for farmers who participated in the subsidy scheme and those who did not participate relative to their counterfactual case.

Table 1: Conditional expectations, treatment effects and heterogeneity

Sub-sample	Decision Stage		Treatment Effects
	To Participate	Not Participate	
Subsidized Farmers	(a) $E[Y_{1i} \mid S_i = 1]$	(c) $E[Y_{2i} \mid S_i = 1]$	TT
Non-subsidized Farmers	(d) $E[Y_{1i} \mid S_i = 0]$	(b) $E[Y_{2i} \mid S_i = 0]$	TU
Heterogeneity Effects	BH1	BH2	TH

Note: In the case of food security for instance, (a) and (b) represent observed expected food security outcome (HDDS), and (c) and (d) represent counterfactual food security outcome among the farmers.
Si = 1 if farmer is subsidized and Si = 0 if farmer is non-subsidized
Y1i = household dietary diversity score for subsidized farmers
Y2I = household dietary diversity score for non-subsidized farmers
TT: the effect of the treatment (i.e. subsidy) on the treated group (i.e. subsidized farmers);
TU: the effect of the treatment (i.e. subsidy) on the untreated group (i.e. non-subsidized farmers);
BHi: the effect of base heterogeneity for subsidized farmers (i=1), and non-subsidized farmers (i=0)
TH= (TT-TU), i.e., transitional heterogeneity

Data source

This study used IFPRI data set collected in 2014 in the assessment of the implementation performance of the GESS under IFPRI's National Strategy Support Scheme (NSSP). In collecting the data, a multi-stage stratified random sampling approach was adopted. In the first stage, the country was stratified into six agro-ecological zones which coincide with the six geo-political zones three of which are in the north and three in the south. One zone was purposively selected from the north (North-central) and one from the south (Southwest) on account of the various GESS and Agricultural Transformation Agenda components being intensively implemented in the zones. Thereafter, one state (Ogun) was selected from the southwest zone and one state (Niger) from the north-central zone. The states were stratified into LGAs and five LGAs were randomly selected in each state. In the second stage, the 2013 register of farmers was obtained from Cellulant – a company working with the FMARD in Abuja to register farmers. This was used to stratify the farmers into GESS and non-GESS participants (i.e. those who benefited from the input subsidy through e-wallet and redeemed their inputs and those who did not). A random sample of 1000 farmers was drawn from each group to give a total of 2000 farmers included in the survey. The survey instrument contained modules on food security which were used to collect data on quantity of food consumed, expenditure on education of children, expenditure on clothing, expenditure on healthcare of household members and expenditure on the various food items – cereals, pulses, vegetables, fruits, meat, fish, eggs, milk, oil and other food items.

3. Description of key characteristics of the smallholder farmers

The results focus on the description of key characteristics of the farmers who participated in the subsidy scheme (subsidy farmers) and their counterparts who did not participate (non-subsidy farmers) and the results of the econometric analysis. The farm households are described in terms of the socioeconomic characteristics of the household head (age, education, gender, marital status, farming experience), household characteristics (household size, food expenditure, per capita income, location), farming characteristics (farm size, use of inputs such as fertilizer, seed and labour) and non-farm characteristics that can affect their farming operations (non-farm income, remittance, access to credit, distance to market) as well as performance variables (such as value of farm output and productivity). We examine the differences in these variables for the subsidy and non-subsidy farmers and present the results in Table 2.

The age, marital status and educational attainment of subsidized farmers do not differ significantly from that of their non-subsidized counterparts. However, there seems to be more male farmers in the former group than it is the case with the latter. The non-subsidized farmers also have better experience than the subsidized farmers. The per capita income and expenditure on food do not differ significantly between the two categories of farm households even though the household size of the non-subsidized group is significantly larger than that of the subsidized group. Also, the household dietary diversity score of the former is lower than that of the latter. Although, the non-subsidized households have larger farm size and higher non-farm income, and use more inputs such as seed and labour, with better access to remittances, their productivity (in terms of value of output per hectare) is lower than that of the subsidized households.

The results of this descriptive analysis show clearly that the non-subsidized group has lower levels of the outcome variables – productivity and household dietary diversity which are the focus of the subsidy impact analysis in this study.

Comparison of micronutrient intake among the farmers

The micronutrient intake for the two groups of farmers are presented in Table 3. The analysis is focused on essential minerals and vitamins. We found that micronutrient intake of the subsidized group is above average for both minerals and vitamins while that of the non-subsidy farmers is below average for each of the selected micronutrients.

Table 2: Comparison of characteristics of subsidized and non-subsidized farmers

Variables	Subsidized Farmers S= 1	Non-Subsidized Farmers S= 0	All Farmers	t-test of difference	
				t-statistic	Prob>|t|
Characteristics of Household Head					
Age (years)	44.36	43.69	44.03	-1.34	0.18
Gender (Dummy variable) Male = 1; Female = 0)	.69	.78	.74	4.48	0.00***
Maristat (Dummy variable) Married =1; otherwise = 0)	.98	.98	.98	-0.91	0.36
EDUC (years of schooling)	7.13	7.45	7.29	1.34	0.18
Farming experience (years)	17.19	18.54	17.87	2.62	0.01***
Household characteristics					
Household size (number of persons)	7.02	8.85	7.93	6.79	0.00***
Food expenditure (₦)	30985.47	31356.03	31170.75	0.27	0.79
HDDS (score)	8.422	8.03	8.23	-6.04	0.00***
Income per capita (₦)	50952.14	53296.05	52124.09	0.87	0.39
Settlement pattern (Dummy: rural = 1; otherwise = 0)	.50	.50	.50	0.00	1.00
Farming characteristics					
Farm size (Ha)	2.52	2.89	2.70	4.28	0.00***
Quantity of fertilizer (Kg)	172.81	162.60	167.71	-1.06	0.29
Quantity of seed (Kg)	63.811	178.56	121.19	6.57	0.00***
Labour (man-days)	15.09	18.439	16.76	4.53	0.00***
Non-Farm characteristics					
Non-farm income (₦)	274961.3	311508.1	293234.70	3.58	0.00***
Remittance (₦)	.17	.239	.21	3.60	0.01***
Credit use (Dummy: Used formal credit = 1; otherwise = 0)	.49	.443	.47	-2.46	0.01***
Distance to market (Km)	8.95	10.34	9.64	1.61	0.11
Household Agricultural Performance Characteristics					
Value of output (₦)	155439.90	158521.30	156980.60	0.36	0.72
Land productivity (₦)	76432.50	65116.40	70774.45	-3.01	0.01***
Labour productivity (₦)	6.67	7.18	6.93	1.01	0.31

Source: Author's computation
Note: ***significant @ one percent level
**significant @ five percent level

On the average, the level of intake of each of the micronutrients is higher for the subsidized farmers than that of their non-subsidy counterparts. As shown in Table 3 the difference in micronutrient intake between the two groups of farmers is highly significant in statistical sense. Moreover, all the sampled farmers have low NAR for all the micronutrients except for iron, Riboflavin (vitamin B2) and niacin (vitamin B3). Intake of minerals is generally low for the non-subsidy farmers and the same situation prevails for the subsidized farmers except for iron which level of intake is considered adequate. Overall, the intake of vitamins for both group of farmers is found to be adequate (Table 4).

Table 3: Comparison of nutrient intakes of subsidized and non-subsidized farmers

Variables	Subsidized Farmers S= 1	Non-Subsidized Farmers S= 0	All Farmers	t-test of difference	
				t-statistic	Prob>|t|
Minerals (Daily intake per adult equivalent)					
Calcium (mg)	95.03	64.26	79.65	-9.62	0.00***
Iron (mg)	7.53	4.3	5.97	-11.98	0.00***
Magnesium (mg)	168.47	98.428	133.45	-13.34	0.00**
Phosphorus (mg)	310.65	198.98	254.82	-10.67	0.00***
Potassium (mg)	1469.22	874.94	1172.08	-12.68	0.00***
Zinc (mg)	6.43	3.95	5.19	-9.30	0.00***
Vitamins (Daily intake per adult equivalent)					
Vitamin A (mcg)	535.06	266.44	400.75	-10.86	0.00***
Thiamine (mg)	4.72	2.87	3.74	-7.48	0.00***
Riboflavin (mg)	2.00	1.25	1.63	-8.08	0.00***
Niacin (mg)	498.15	289.53	393.84	-7.41	0.00***
Vitamin C (mg)	37.59	30.55	34.08	-4.51	0.00***

Source: Author's computation
Note: ***significant @ one percent level

Table 4: Comparison of nutrient intake adequacy of subsidized and non-subsidized farmers

Variables	Subsidized Farmers S= 1		Non-Subsidized Farmers S= 0		All Farmers	t-test of difference	
						t-statistic	Prob>|t|
Minerals NAR	%	Category	%	Category	%		
Calcium	9.50	Low	6.42	Low	7.96	-9.62	0.00***
Iron	68.25	Adequate	46.93	Low	57.58	-15.81	0.0***
Magnesium	39.94	Low	23.51	Low	31.72	-17.02	0.00***
Phosphorus	41.09	Low	26.86	Low	33.97	-13.75	0.00***
Potassium	30.75	Low	17.89	Low	24.32	-15.76	0.00***
Zinc	48.41	Low	30.99	Low	39.70	-13.81	0.00***
Vitamins NAR							
Vitamin A	56.45	Low	38.11	Low	47.27	-12.22	0.00***
Thiamine	93.97	High	85.86	High	89.93	-8.72	0.00***
Riboflavin	78.43	Adequate	61.34	Adequate	69.89	-13.29	0.00***
Niacin	99.18	High	97.09	High	98.13	-4.19	0.00***
Vitamin C	39.73	Low	30.44	Low	35.08	-8.61	0.00***
Micronutrients MAR (%)							
Minerals	39.65	Low	25.42	Low	32.53	-16.27	0.00***
Vitamins	73.59	Adequate	62.61	Adequate	68.10	-14.38	0.00***
All nutrients	55.14	Low	42.34	Low	48.74	-16.40	0.00***

Source: Author's computation
Note: ***significant @ one percent level
NAR = Nutrient Adequacy Ratio
MAR = Mean Adequacy Ratio

Despite the generally low level of adequacy of intake of all the micronutrients, the level attained by the subsidized farmers is significantly higher than that of their non-subsidy counterparts. An attempt is made in the ensuing section to determine the extent to which such difference can be attributed to their participation in the subsidy scheme.

4. Results of econometric analysis

Impact of subsidy on productivity

The econometric analysis of the impact of subsidy on productivity of farmers involves the estimation of an endogenous switching regression (ESR) model of farmers' participation in the subsidy scheme and productivity. This is with a view to determining the counterfactual productivity potentials of subsidy scheme participants and non-participants. The Wald tests confirm the overall significance of the variables included in the model. In particular, the likelihood ratio test indicates that the two equations (participation and productivity equations) are not independent (Prob>0.00). The estimated covariances (sigma0 and sigma1) are statistically significant and this is an evidence of endogenous switching indicating that the decision to participate in the subsidy scheme and the productivity outcome are correlated (Table 5). Moreover, the correlation terms in both equations are statistically significant at one-percent level implying that the hypothesis of absence of sample selection bias is rejected. In other words, we accept the hypothesis of sample selection bias. The corollary is that fitting the outcome (productivity) equation through a direct application of OLS to the sample would mean that the selectivity bias is ignored and would have resulted in biased and inconsistent estimates.

We found that farmers' decision to participate in the subsidy scheme on the expectation of better productivity outcome does not significantly depend on their education, labour input, farming experience, distance to the market or whether they reside in urban or rural areas. The significant variables in this regard are age, household size, non-farm income, quantity of fertilizer and seed used, gender, marital status, region and access to credit. The results show that there is a higher probability among older farmers to decide to participate in the subsidy scheme compared to the younger ones. Farmers who are married are also more likely to decide to participate than their unmarried counterparts. The probability is also higher among farmers with better access to credit. Female farmers have a higher probability to participate than their male counterparts. Moreover, we found that there is a lower probability to decide to participate among farm households that use higher quantity of seeds, with higher non-farm income and larger household size. The marginal effects of these variables are computed and presented in column 3 of Table 5. On the average, if the age of a farmer increases by a year the probability of being in the subsidized group is apt to increase by 15.6 percentage points. If a farmer is married the probability of participating in the subsidy scheme increases by 17.3 percentage points compared with their unmarried counterparts while the participation probability of those who have access to credit is apt to increase by 8.8 percentage points compared to those without access. If a farmer is from the north the probability of participation increases by 14.9 percentage points compared with the counterparts in the south; and for a male farmer, the probability of participation is apt to reduce by 9.0 percentage points compared to the female counterparts. In the same vein, a marginal increase in non-farm income is likely to reduce the probability of participation by 4.1 percentage points; whereas a reduction of 5.4 percentage points is likely to be associated with a marginal increase in the use of improved seeds. On the other hand, a marginal increase in the use of fertilizer is likely to increase the probability of participation by 14.7 percentage points. The proportional changes in these variables were also considered and the elasticities presented in column 4 of Table 5 show mixed responses. For instance, a one-percent change in age and fertilizer use is associated with an increase in participation probability of 1.61 and 1.22 percent respectively whereas a one-percent change in household size, quantity of seed used, and non-farm income is associated with a reduction in probability of about 0.78, 1.40 and 0.38 percent respectively. In what follows we examine the how some of these variables affect productivity as well as the subsidy impact.

Table 5: FIML Estimate of the ESR Model of Subsidy Effects on Productivity

Explanatory Variables	Subsidy Participation (1/0)			Endogenous Regression	Switching
				Dependent Variable – Inland productivity	
	Parameter Estimates	Marginal Effects	Elasticities	Subsidized Farmers	Non-Subsidized Farmers
Age (years)	0.486***	0.156***	1.613***	0.041	-0.191*
	(0.146)	(0.046)	(0.485)	(0.106)	(0.111)
Household size	-0.455***	-0.146***	-0.784***	0.188 ***	0.203***
	(0.059)	(0.018)	(0.111)	(0.047)	(0.047)
Farming Experience	0.0032	0.001	0.008	-0.189***	-0.138***
	(0.051)	(0.016)	(0.122)	(0.036)	(0.038)
Non-farm income (₦)	-0.128***	-0.041***	-1.403***	-0.132***	0.090***
	(0.038)	(0.012)	(0.416)	(0.027)	(0.029)
Fertilizer use (Kg)	0.458***	0.147***	1.215***	0.341***	-0.140***
	(0.029)	(0.007)	(0.082)	(0.042)	(0.021)
Seed (Kg)	-0.167***	-0.054***	-0.383***	-0.104***	0.209***
	(0.025)	(0.008)	(0.064)	(0.022)	(0.018)

continued next page

Table 5 Continued

Explanatory Variables	Subsidy Participation (1/0)			Endogenous Regression	Switching
				Dependent Variable – Inland productivity	
	Parameter Estimates	Marginal Effects	Elasticities	Subsidized Farmers	Non-Subsidized Farmers
Labour (man-days)	-0.062	-0.019	-0.097	0.139***	0.283***
	(0.041)	(0.013)	(0.065)	(0.031)	(0.029)
Years of schooling	0.043	0.014	0.064	0.149***	-0.018
	(0.039)	(0.013)	(0.057)	(0.027)	(0.029)
Gender (Male =1; Female =0)	-0.281***	-0.090***	-0.194 ***	-0.252***	0.019
	(0.072)	(0.023)	(0.052)	(0.048)	(0.059)
Marital status (married =1; otherwise = 0)	0.539**	0.173**	0.465**	-0.139	-0.173
	(0.232)	(0.074)	(0.199)	(0.169)	(0.167)
Region (North =1, South=0)	0.463***	0.149***	0.161***	0.206***	0.254***
	(0.071)	(0.022)	(0.022)	(0.045)	(0.060)
Settlement Pattern (rural =1; otherwise = 0)	-0.086	-0.028	-0.036	-0.449***	-0.573***
	(0.080)	(0.026)	(0.035)	(0.055)	(0.063)
Credit; Users = 1	0.275***	0.088***	0.107***		
Non-users =0	(0.055)	(0.017)	(0.020)		
Distance to market (Km)	-0.001	-0.001	-0.009		
	(0.001)	(0.001)	(0.012)		
Constant	-1.305**			10.968***	9.682***
	(0.631)			(0.489)	(0.452)
Model Diagnosis					
sigma0| 0.7984965 (0.0311)					
sigma1 | 0.6983 (0.0317)					
rho0 | -0.8036 (0.0442)					
rho1 | 0.7432 (0.0621)					
Wald chi2(12) = 408.08					
Log likelihood = -2968.69 Prob > chi2 = 0.0000					
Number of obs = 2000					
LR test of independent eqns. : chi2(2) = 36.70 Prob > chi2 = 0.0000					

Source: Author's computation
Note: (1) Figures in parentheses are standard errors; (2) Estimating equation is in double-log form
***significant at one-percent level; **significant at five-percent level; *significant at ten-percent level

With regard to the determinants of farmers' productivity which is analysed in the endogenous switching regression, the hypothesis that the productivity of farmers is not determined by the variables included in the model is rejected in view of the statistically significant coefficients of the variables in the estimated equations shown in columns 5 and 6 of Table 5 for the subsidized and non-subsidized groups of farmers. However, the number of significant variables out of the 12 included in the model, differ between the two groups of farmers; being 10 for the subsidized group and 9 for the non-subsidized group. The difference in the coefficients of the explanatory variables in the outcome (productivity) equations for the subsidized and non-subsidized groups is a further indication of heterogeneity in the sample. The results reveal important information concerning the nature of relationship between the explanatory variables in the ESR model and farmers' productivity. For both groups, the observed household characteristics and farming characteristics are found to be significant determinants of productivity regardless of subsidy. This is not the case with the personal characteristics of the household head such as age, gender, education and marital status. Whereas marital status is not a significant determinant of productivity, age is a significant determinant only in respect of the non-subsidized group; while education and gender are significant determinants of productivity only in respect of the subsidized group. We found that productivity is significantly higher in the north than south but lower in the rural than urban areas regardless of subsidy.

An intriguing result is that some of the explanatory variables whose coefficients are significant in the estimated equations for both groups of farmers (subsidized and non-subsidized) reveal heterogeneous effects on productivity. For instance, a one-percent increase in non-farm income is associated with an increase of 0.09 percent increase in productivity of the non-subsidized farmers, in the case of the subsidized farmers it is apt to decrease productivity by 0.13 percent. In the same vein, a one-percent increase in the quantity of fertilizer used is associated with an increase of 0.34 percent in the productivity of subsidized farmers but a decrease of 0.14 percent in the productivity of non-subsidized farmers. A heterogeneous effect of input use is also evident in the result for seed which shows that a one-percent increase in the quantity of seed used is associated with a decrease of 0.13 percent in productivity of subsidized farmers but an increase of 0.21 percent in the productivity of non-subsidized farmers.

Aside from the direction and magnitude of the effects of the explanatory variables on productivity, the estimated model clearly substantiates the impact of subsidy on productivity of farmers who participated in the subsidy scheme and the counterfactual potential productivity impact for the farmers in the non-subsidized group. Evidently, the correlation parameter of the estimated ESR model has alternate signs in the two equations. It has a positive sign in the equation for subsidized farmers (rho1= 0.7432) implying that (1) subsidy significantly increases productivity among the subsidized farmers; and (2) the subsidized farmers would have had higher productivity than their non-subsidized counterparts had the non-subsidized farmers participated in the subsidy scheme. On the other hand, the parameter has a negative sign (rho0 = -0.8036) in the non-subsidized farmers' equation implying that (1) without subsidy productivity is significantly lower among non-subsidized farmers; and (2) non-subsidized farmers would have had lower productivity than subsidized farmers had subsidized farmers not participated in the subsidy scheme. Evidently, on the average, the results show that subsidized farmers have higher productivity potential than non-subsidized farmers. This is clearly revealed in Table 6 which presents the results of expected productivity of subsidized and non-subsidized farmers as well as their respective counterfactual productivity levels.

Table 6: Productivity impact of subsidy - Treatment effects, heterogeneity and counterfactuals

Sub-sample	Decision Stage		Treatment Effects
	To Participate	Not Participate	
Subsidized Farmers	(a) 56,432.471	(c) 46,546.169	TT = 9,886.302
Non-subsidized Farmers	(d) 16,211.887	(b) 18,841.177	TU -2,629.290
Heterogeneity Effects	BH1 = 40,220.584	BH2 = 27,704.992	TH = 12,515.592

Source: Author's computation

The expected productivity of subsidized and non-subsidized farmers are (a) and (b) that is, ₦56,432.471 and ₦18,841.177 respectively. In view of the inherent differences in the groups these figures cannot form the basis of valid comparison of outcomes. However, a comparison of (a) and (c) indicates that the subsidized group would have had a significantly lower counterfactual productivity level had they not participated in the subsidy scheme. The results show that consequent upon the subsidy scheme productivity of the farmers who participated expectedly increased by ₦9,886.302 (or by 21.24 percent). Similarly, in the case of farmers who did not participate, productivity would have expectedly decreased by ₦2,629.290 (or by -14 percent) if they had participated.

Moreover, the results show that if both groups had participated in the subsidy scheme, those who participated would have had higher productivity (₦40,220.584) (BH1) than their counterparts who did not participate. On the other hand, if both groups did not participate those who participated would still have had ₦27,704.99 higher productivity (BH2) on the average than their counterparts who did not participate. Finally, the transitional heterogeneity effect is positive; this implies that the effect is bigger for farmers that participated in the subsidy scheme compared with their non-participating counterparts.

Impact of subsidy on food security

The ESR model earlier specified is estimated to determine the impact of subsidy on food security. As a measure of food security, we used household dietary diversity score (HDDS). The HDDS has been widely employed in contemporary literature as a proxy indicator for food security of a household as it is highly correlated with caloric, household income and child nutritional status (Hoddinott and Yohannes, 2002; Swindale and Bilinsky, 2005; Webb et al., 2006; Wondimagegn and Tirivavi, 2016). The model is a simultaneous equation system which is estimated using the full information maximum likelihood (FIML) procedure to estimate the selection equation and the outcome equation for the two groups of farmers. The results of the estimation are presented in Table 7. The overall significance of the variables included in the model is confirmed by the Wald test. The likelihood ratio test also confirms that the two equations (subsidy participation and HDDS equations) are not independent (Prob>0.00). The estimated covariances (sigma0 and sigma1) are statistically significant and this is an evidence of endogenous switching indicating that the decision to participate in the subsidy programme and the food security indicator (HDDS) are correlated. Moreover, the correlation terms in both equations are statistically significant. The foregoing implies that the hypothesis of absence of sample selection bias is rejected.

The first stage (probit) results of the ESR model provide estimates of the determinants of household's decision to participate in the subsidy scheme. We found that farmers' decision to participate on account of food security is not significantly dependent on their farming experience, farm size and distance to the market judging by the non-significance of the coefficient of these variables as shown in column 2 of Table 7. In this regard the significant variables are use of credit, education, location (region), use of modern inputs (fertilizer and seed), productivity, non-farm income and household size. Farmers who are more likely to participate are those who use more fertilizer, more productive, reside in the north and have better access to credit. The less likely participants are the more educated, owners of relatively larger farm size, with larger household size, greater users of seeds and those with higher non-farm income as implied by the negative coefficients of these variables. As evidenced by the marginal effects in column 3 of Table 7, the probability to participate is apt to increase by 13.9 percentage points for farmers in the north compared with those in the south; while an increase of about 9.9 percentage points is associated with those having access to credit compared with their counterparts without access. Moreover, a marginal increase in fertilizer use and the yield obtained is associated with an increase in participation probability of 13.7 and 9.4 percentage points respectively. On the other hand, a marginal increase in the use of seed, years of schooling, household size and non-farm income is associated with a reduction in probability of participation of about 4.7, 2.7, 14.6 and 5.1 percentage points respectively. In proportional terms, a one-percent increase in fertilizer use and yield obtained is associated with an increase in participation probability of about 1.35 and 2.88 percent respectively. However, if there is a one-percent increase in use of seed, years of schooling, household size and non-farm income there is apt to be a reduction in participation probability of about 0.44, 0.13, 0.81 and 1.81 percent respectively (column 4 Table 7). Apart from their significance regarding decisions to participate in the subsidy scheme some of these variables are also likely to have direct effect on food security as shown in the results of the analysis of the determinants of food security as part of the simultaneous estimation of the ESR model using FIML method.

Table 7: FIML estimate of the ESR model of subsidy effects on food security

Explanatory Variables	Subsidy Participation (1/0)			Endogenous Regression	Switching
				Dependent Variable – Household Dietary Diversity Score (ln)	
	Parameter Estimates	Marginal Effects	Elasticities	Subsidy Farmers	Non-Subsidy Farmers
Household size	-0.459***	-0.146***	-0.813***	-0.008*	-0.008
	(0.059)	(0.018)	(0.117)	(0.012)	(0.013)
Years of schooling	-0.085**	-0.027**	-0.131**	0.032***	0.037***
	(0.039)	(0.013)	(0.063)	(0.007)	(0.009)
Farming experience	0.019	0.006	0.049		
	(0.045)	(0.014)	(0.112)		
Non-farm income	-0.161***	-0.051***	-1.808***		
	(0.038)	(0.012)	(0.441)		
Quantity of Fertilizer	0.429***	0.137***	1.351***		
	(0.032)	(0.008)	(0.103)		
Quantity of Seed	-0.147***	-0.047	-0.438***		
	(0.024)	(0.007)	(0.073)		
Farm size	-.058	-0.019***	-0.045		
	(0.059)	(0.019)	(0.046)		
Land productivity	0.295***	0.094***	2.875***		
	(0.056)	(0.017)	(0.572)		
Region (North=1, South=0)	0.436***	0.139***	0.154	-0.095***	0.135*
	(0.068)	(0.021)	(0.021)	(0.012)	(0.016)
Credit Users =1	0.314***	0.099***	0.125***		
Non-users =0)	(0.065)	(0.017)	(0.024)		
Distance to market	0.006	0.002	0.009		
	(0.037)	(0.012)	(0.056)		
Non-farm income				0.016**	-0.021**
				(0.007)	(0.009)
Age				-0.012	0.071***
				(0.023)	(0.027)
Gender				-0.019 *	-0.019
				(0.012)	(0.017)
Remittance				0.052***	0.075***
				(0.013)	(0.016)

continued next page

Table 7 Continued

Explanatory Variables	Subsidy Participation (1/0)			Endogenous Regression	Switching
				Dependent Variable – Household Dietary Diversity Score (ln)	
	Parameter Estimates	Marginal Effects	Elasticities	Subsidy Farmers	Non-Subsidy Farmers
Marital status				0.033	-0.117**
				(0.043)	(0.047)
Food expenditure				0.014	0.087***
				(0.009)	(0.008)
Constant				1.807***	1.254***
				(0.119)	(0.147)
Model Diagnosis					
Sigma0| 0.2223386 (0.00679) sigma1 | 0.1636274 (0.0039)					
rho0 | 0.4677271 (0.1124986) rho1 | 0.143621 (0.1125738)					
Wald chi2(9) = 247.53 Log likelihood = -571.68069 Prob > chi2 = 0.0000 Number of obs = 2000					
LR test of indep. eqns: chi2(2) = 25.64 Prob > chi2 = 0.0000					

Note: (1) Figures in parentheses are standard errors; (2) Estimating equation is in double-log form
***significant at one-percent level; **significant at five-percent level; *significant at ten-percent level

We reject the hypothesis that food security of the farmers is not determined by the variables included in the model judging by the statistically significant coefficients of the variables in the estimated equations shown in columns 5 and 6 of Table 7 for the subsidized and non-subsidized groups of farmers. For the subsidy farmers, food security depends significantly on household size, education, region, non-farm income, gender and remittance whereas for the non-subsidy farmers, household size and gender are not significant. Whereas food expenditure, marital status and age are significant determinants of food security for non-subsidy farmers these variables are not significant in the case of subsidy farmers. Some of the variables that are significant for the two groups affect food security in different ways. For instance, subsidy farmers in the north is associated with a reduction in food security level of about 0.10 percent compared with those in the south; whereas the non-subsidy farmers in the north is associated with an increase in food security level of about 0.14 percent compared with those in the south. A one-percent increase in non-farm income is associated with an increase of 0.02 percent in food security level for the subsidy farmers compared with a reduction of 0.02 percent in the case of their non-subsidy counterparts. These findings reflect the nature of heterogeneous effects of the determinants of food security between the two groups of farmers and the extent of heterogeneity in the sample.

In addition to the effects of the explanatory variables on food security, the estimated model also authenticates the impact of subsidy on the food security of farmers who participated in the subsidy scheme and the counterfactual potential food security impact for the farmers in the non-subsidized group. As shown in Table 8, the expected food security level of subsidy and non-subsidy farmers are 8.32 and 8.18 respectively. Although the scores are clearly different, they cannot be justifiably compared in view of the fact that the two groups are inherently different. Comparing (a) and (c), however, we find that the subsidy farmers would have had a significantly lower counterfactual score had they not participated in the subsidy scheme. The result shows that the treatment, (i.e. subsidy) has increased expected food security level by 0.475 (or by 6 percent). On the other hand, the non-subsidy farmers would have increased their expected food security level by 1.018 (or by 12 percent) if they had participated in the subsidy scheme.

Table 8: Subsidy impact on food security - Treatment effects, heterogeneity and counterfactuals

Sub-sample	Decision Stage		Treatment Effects
	Subsidized Farmers	Non-Subsidized Farmers	
Subsidized Farmers	(a) 8.3198	(c) 7.8448	TT = 0.475
Non-subsidized Farmers	(d) 9.1930	(b) 8.1755	TU = 1.0175
Heterogeneity Effects	BH1 = -0.8732	BH2 = -0.3307	TH = -0.5425

Source: Author's computation

Moreover, if both groups had participated in the subsidy scheme, the participants would have had lower food security than their non-participating counterparts (BH1). In the alternative, if both groups have not participated, the current participants would still have had lower level of food security (BH2) on the average compared with their non-participating counterparts. The negative base heterogeneity effect implies that subsidy farmers have lower food security, not possibly due to their decision to participate in the subsidy scheme but possibly due to unobservables. With the adjustment for potential heterogeneity in the sample, it is evident that farmers who decided to participate in the subsidy scheme tend to have food security benefits lower than the average irrespective of their participation status, however, what is important is that they are better off participating than not participating. The investigation of transitional heterogeneity also yields intriguing results. The intention here is to determine if the effect of subsidy is larger or smaller for the farm households that actually participated in the scheme or for the farm households that actually did not participate in the counterfactual case that they did participate (TH). As shown in Table 8, the transitional heterogeneity is found to be negative. This implies that the subsidy effect would have been higher for non-subsidy farmers had they decided to participate in the subsidy scheme.

Impact of subsidy on farmers' nutrient intake adequacy

The analysis is focused on minerals and vitamins intake adequacy measured by mean adequacy ratios (MAR) for each component. The mean adequacy ratio is calculated for minerals (calcium, iron, magnesium phosphorus, potassium and zinc) and vitamins (vitamin A, thiamine (Vitamin B1), riboflavin (Vitamin B2), niacin (Vitamin B3) and ascorbic acid (Vitamin C). The results show that this nutrition outcome is significantly affected by individual socioeconomic characteristics of the farmers as well as their household characteristics. The Wald tests confirm the overall significance of the variables included in the model. We found that the explanatory variables included in the model significantly affect farmers' decision to participate except for education and distance to market. Regarding the mineral adequacy model (Table 9), farmers in the north are more likely to participate than their southern counterparts. The likelihood is higher among farmers with access to credit than those without access. There appears to be a higher probability to decide to participate among farmers that are more experienced with greater use of fertilizer and higher yield. On the other hand, those who have larger farm size, use more improved seed, have larger household size and have more non-farm income are less likely to participate. The marginal effects of the variables are shown in column 3 of Table 9. On the average, if a farmer has access to credit the probability of participating in the subsidy scheme is apt to increase by about 14.7 percentage points; and likewise, the probability of participation in the north is likely to increase by about 18.1 percentage points compared to the south. An additional year of farming experience is associated with an increase in the probability of participation of about 3.8 percentage points. A marginal increase in the use of fertilizer and in yield may also raise probability of participation by 13.3 and 6.2 percentage points respectively. On the other hand, a marginal increase in farm size and in the use of seed may be associated with a reduction in the participation probability of 3.5 and 2.1 percentage points respectively. Also, a marginal increase in non-farm income is likely to reduce participation probability by about 6.4 percentage points. Moreover, an additional member to the household may reduce the participation probability by 13.6 percentage points. The computed elasticity coefficients of the variables in the selection equation are presented in column 4 of Table 9 in respect of the mineral intake adequacy indicator. As regards the probability-increasing variables, we found that a one-percent increase in the number of years of farming, quantity of fertilizer used, and yield (land productivity) is associated with an increase in participation probability of 0.29, 1.31 and 1.92 percent respectively. As regards variables with negative effects on participation, the results show that a one-percent increase in farm size and quantity of seed used is associated with a reduction in participation probability of 0.08 and 0.18 percent respectively whereas an increase of one percent in household size and non-farm income is associated with a reduction in probability of 0.75 and 2.26 respectively.

Table 9: FIML Estimate of the ESR Model of Subsidy Effects on Mineral Intake Adequacy

Explanatory Variables	Subsidy Participation (1/0)			Endogenous Switching Regression	
				Dependent Variable – Minerals Adequacy Ratio (ln)	
	Parameter Estimates	Marginal Effects	Elasticities	Subsidy Farmers	Non-Subsidy Farmers
Household size (no.)	-0.426***	-0.136***	-0.749***	-0.773***	-0.954***
	(0.057)	(0.017)	(0.109)	(0.032)	(0.021)
Farming experience (years)	0.120***	0.038***	0.293***		
	(0.038)	(0.012)	(0.092)		
Non-farm income (₦)	-0.201***	-0.064***	-2.259***		
	(0.038)	(0.012)	(0.433)		
Fertilizer use (Kg)	0.418***	0.133***	1.311***		
	(0.026)	(0.007)	(0.086)		
Seed use (Kg)	-0.065***	-0.021***	-0.183***		
	(0.021)	(0.007)	(0.063)		
Farm size (Ha)	-0.109**	-0.035**	-0.080**		
	(0.051)	(0.016)	(0.039)		
Years of schooling	-0.042	-0.013	-0.065	0.002	0.018
	(0.038)	(0.012)	(0.059)	(0.018)	(0.014)
Land productivity (₦)	0.196***	0.062***	1.915***		
	(0.052)	(0.016)	(0.510)		
Region (North=1, South=0)	0.568***	0.181***	0.194***	-0.275***	-0.116***
	(0.067)	(0.020)	(0.019)	(0.031)	(0.026)
Credit	0.461***	0.147***	0.168***		
(Users =1. Non-users =0)	(0.057)	(0.018)	(0.019)		
Distance to market (Km)	0.042	0.013	0.062		
	(0.031)	(0.009)	(0.046)		
Age (Years)				0.023	0.041
				(0.055)	(0.047)
Gender (Male =1; Female = 0)				0.018	0.031
				(0.027)	(0.028)
Remittance (₦)				0.016	0.137***
				(0.032)	(0.027)
Marital status				0.311***	0.365***
(Married =1; otherwise =0)				(0.105)	(0.080)
Food expenditure (₦)				0.368***	0.229***
				(0.021)	(0.015)

continued next page

Table 9 Continued

Explanatory Variables	Subsidy Participation (1/0)			Endogenous Switching Regression	
				Dependent Variable – Minerals Adequacy Ratio (ln)	
	Parameter Estimates	Marginal Effects	Elasticities	Subsidy Farmers	Non-Subsidy Farmers
Non-farm income (₦)				1.169***	2.084***
				(0.017)	(0.015)
Constant	-1.237*			1.169***	2.084***
	(0.682)			(0.299)	(0.233)
Model Diagnostics					
sigma0 | 0.3559234 (0.0080038) sigma1 | 0.4835174 (0.0191087)					
rho0 | .0732314 (0.0757048) rho1 | -.8344484 (0.0412557)					
Wald chi2(9) = 2877.96 Log likelihood = -1943.4055 Prob > chi2 = 0.0000 Number of obs = 2000					
LR test of indep. eqns: Chi2(2) = 33.11 Prob > chi2 = 0.0000					

Note: (1) Figures in parentheses are standard errors; (2) Estimating equation is in double-log form
***significant at one-percent level; **significant at five-percent level; *significant at ten-percent level

Regarding vitamins intake adequacy, the results show that the decision to participate in the subsidy scheme does not depend on such individual characteristics of farmers as distance to market, education, farm size and farming experience. The significant variables in this regard are household size, non-farm income, use of modern inputs (fertilizer and seed) yield, region and use of credit. Farmers that are more likely to participate are those who use credit, use more fertilizer, have better yield, and live in the north. On the other hand, farmers who have larger household size, higher non-farm income and use more improved seed are less likely to participate on account of dietary (vitamins) intake. The marginal effects of these variables are shown in column 3 of Table 10. We found that having access to credit is associated with an increase of 3.7 percentage points in the probability of participation. If a farmer lives in the north, the likelihood of participation is apt to increase by about 14.7 percentage points compared to a farmer in the south. In the same vein a marginal increase in the use of fertilizer and in yield is associated with an increase in the probability of participation by 6.9 and 5.7 percentage points respectively. On the other hand, a marginal increase in the use of improved seeds and in non-farm income is apt to reduce the probability of participation by about 2.9 and 4.3 percentage points respectively. Furthermore, an additional member to the household may reduce the probability of participation by about 13.8 percentage points. The elasticity coefficients presented in column 4 of Table 10 indicate that one-percent change in household size is associated with 0.61 reduction in the probability of participation; whereas a one-percent change in non-farm income is apt to reduce the probability by 1.21 percent. Also, there can be a reduction of about 0.22 percent in the probability with a one-percent increase in the quantity of improved seeds used. A positive effect is observed regarding fertilizer use and yield. A one-percent increase in the quantity of fertilizer used and in yield is associated with an increase in participation probability of 0.62 and 1.39 percent respectively. The variables included in the model are not only significant determinants of participation in the subsidy scheme some of them, as expected are also likely to affect the farmers' nutrition outcomes as will be seen in the ensuing section.

Table 10: FIML estimate of the ESR model of subsidy effects on vitamin intake adequacy

Explanatory Variables	Subsidy Participation (1/0)			Endogenous Regression	Switching
				Dependent Variable – Vitamins Adequacy Ratio (In)	
	Parameter Estimates	Marginal Effects	Elasticities	Subsidy Farmers	Non-Subsidy Farmers
Household size (no.)	-0.379***	-0.138***	-0.612***	-0.365***	-0.465***
	(0.052)	(0.018)	(0.092)	(0.014)	(0.016)
Farming experience (years)	-0.051	-0.018	-0.113		
	(0.032)	(0.012)	(0.072)		
Non-farm income (N)	-0.118***	-0.043***	-1.207***		
	(0.034)	(0.012)	(0.351)		
Fertilizer use (Kg)	0.191***	0.069***	0.621***		
	(0.022)	(0.007)	(0.074)		
Seed use (Kg)	-0.080***	-0.029***	-0.216***		
	(0.014)	(0.005)	(0.041)		
Farm size (Ha)	-0.027	-0.009	-0.019		
	(0.039)	(0.014)	(0.028)		
Years of schooling	-0.034	-0.012	-0.047	0.002	0.012
	(0.036)	(0.013)	(0.050)	(0.008)	(0.011)
Land productivity	0.156***	0.057***	1.391***		
	(0.032)	(0.011)	(0.293)		
Region (North=1, South=0)	0.404***	0.147***	0.129***	-0.093***	0.087***
	(0.060)	(0.021)	(0.017)	(0.015)	(0.019)
Credit (Users =1. Non-users =0)	0.103**	0.037**	0.039**		
	(0.046)	(0.017)	(0.017)		
Distance to market (Km)	-0.004	-0.001	-0.006		
	(0.025)	(0.009)	(0.035)		
Age				0.109***	0.023
				(0.028)	(0.027)
Gender (Male =1, Female =0)				0.005	0.012
				(0.014)	(0.016)
Remittance				-0.004	0.061***
				(0.017)	(0.015)

continued next page

Table 10 Continued

Explanatory Variables	Subsidy Participation (1/0)			Endogenous Regression	Switching
				Dependent Variable – Vitamins Adequacy Ratio (ln)	
	Parameter Estimates	Marginal Effects	Elasticities	Subsidy Farmers	Non-Subsidy Farmers
Marital staus Married =1; Otherwise = 0)				0.198***	0.246***
				(0.051)	(0.043)
Food expenditure				0.173***	0.132***
				(0.010)	(0.009)
Non-farm income				0.010	-0.028***
				(0.008)	(0.011)
Constant	-0.126			2.459***	3.819***
	(0.507)			(0.142)	(0.159)
sigma0 | .3178368 .0094158sigma1 | .1963542 .0052607					
rho0 | .9428732 .0118482 rho1 | .1996649 .1184112					
Wald chi2(9) = 1029.24 Log likelihood = -870.6208 Prob > chi2 = 0.0000 Number of obs = 2000					
LR test of indep. eqns: Chi2(2) = 112.56 Prob > chi2 = 0.0000					

Note: (1) Figures in parentheses are standard errors; (2) Estimating equation is in double-log form
***significant at one-percent level; **significant at five-percent level; *significant at ten-percent level

Subsidy impact on mineral intake adequacy

As regards mineral adequacy ratio, the Wald tests confirm the overall significance of the variables included in the model. The likelihood ratio test indicates that the two equations (participation and mineral adequacy ratio equations) are not independent (Prob>0.00). The estimated covariances (sigma0 and sigma1) are statistically significant and this is an evidence of endogenous switching indicating that the decision to participate in the subsidy programme and the nutrition outcome indicator outcome are correlated. Moreover, the correlation terms in both equations are statistically significant at one-percent level implying that the hypothesis of absence of sample selection bias is rejected. However, for the two groups of farmers, the correlation parameter of the estimated ESR model has alternate signs in the two equations. It has a negative sign in the equation for subsidized farmers (rho1= -0.8344) implying that (1) subsidy significantly reduces MAR among the subsidized farmers; and (2) the subsidized farmers would have had lower MAR than their non-subsidized counterparts had the non-subsidized farmers participated in the subsidy programme. On the other hand, the parameter has a positive sign (rho0 = 0.0732) in the non-subsidized farmers' equation implying that (1) without subsidy MAR is significantly higher among non-subsidized farmers; and (2) non-subsidized farmers would have had higher MAR than subsidized farmers had subsidized farmers not participated in the subsidy programme. This is clearly revealed in Table 11 which presents the results of expected MAR of subsidized and non-subsidized farmers and their respective counterfactual MAR levels.

With regard to the determinants of farmers' mineral intake adequacy which is analysed in the endogenous switching regression, the hypothesis that this nutrition outcome indicator is not determined by the variables included in the model is rejected in view of the statistically significant coefficients of the variables in the estimated equations shown in columns 5 and 6 of Table 9 for the subsidized and non-subsidized groups of farmers. However, the number of significant variables out of the 9 included in the model, differ between the two groups of farmers; being 4 for the subsidized group and 5 for the non-subsidized group. For both groups we found that age, gender, education and non-farm income are not significant determinants of mineral intake adequacy. Whereas remittance is also not a significant determinant in the case of subsidized farmers, the variable is highly statistically significant for the non-subsidized group. The significant determinants of MAR irrespective of the participation status of farmers are household size, marital status, food expenditure and region. We found that regardless of subsidy, MAR is higher in the south than north. As expected, the effect of food expenditure and marital status are positive while that of household size is negative in both groups of farmers. A one-percent increase in household size is associated with a reduction of 0.77 percent in for the subsidized farmers and 0.95 percent for the non-subsidized farmers. We found that MAR is 0.31 percent higher for married household head among the subsidized group compared with 0.37 percent for the non-subsidized group.

In addition to the direction and magnitude of the effects of the explanatory variables on MAR, the estimated model also ascertains the impact of subsidy on MAR of the subsidized farmers and the counterfactual potential MAR impact for the farmers in the non-subsidized group. The results show that the input subsidy scheme has positive effects on micronutrient intake adequacy of the subsidized farmers. Regarding mineral intake adequacy we found that the expected MARs of subsidized and non-subsidized farmers are as shown in (a) and (b) that is, (a) 33.23 and 48.11 respectively (Table 11). In view of the inherent differences in the groups these figures cannot form the basis of valid comparison of outcomes. However, a comparison of (a) and (c) indicates that the subsidized group would have had a significantly lower counterfactual MAR had they not participated in the subsidy scheme.

Table 11: Subsidy Impact on Nutrient Intake Adequacy and Counterfactuals

Sub-sample	Decision Stage		Treatment Effects
	To Participate	Not Participate	
Minerals Adequacy			
Subsidized Farmers	(a) 33.2349	(c) 20.3118	TT = 12.9231
Non-subsidized Farmers	(d) 24.7766	(b) 48.1057	TU = -23.3297
Heterogeneity Effects	BH1 = 8.4583	BH2 = -27.7939	TH = 36.2528
Vitamins Adequacy			
Subsidized Farmers	(a) 71.3288	(c) 59.2106	TT = 12.1182
Non-subsidized Farmers	(d) 99.3253	(b) 62.7087	TU = 36.6166
Heterogeneity Effects	BH1 = -27.9965	BH2 = -3.4981	TH = -24.4984

Source: Author's computation

The results show that consequent upon the subsidy scheme MAR of the farmers who participated expectedly increased by 12.92 (or by 63.6 percent). Similarly, in the case of farmers who did not participate, MAR would have expectedly decreased by -23.33 (or by -48.51percent) if they had participated. In other words, the treatment effect on the untreated is negative as far as mineral intake adequacy is concerned. This implies that it does not pay the non-subsidized farmers to have participated in the scheme. Moreover, the results show that if both groups had participated in the subsidy scheme, those who participated would have had higher mineral intake adequacy ratio (8.46%) (BH1) than their counterparts who did not participate. On the other hand, if both groups did not participate those who participated would have had a reduction in mineral adequacy ratio -27.79 (BH2) on the average compared with their counterparts who did not participate. Finally, the transitional heterogeneity effect is positive. This reflects the positive treatment effect on the treated; an indication that the effect on mineral intake adequacy is bigger for farmers that participated in the subsidy scheme compared with their non-participating counterparts. Thus, it pays the subsidized farmers to have participated in the scheme on account of its positive nutrition outcome.

Subsidy impact on vitamin intake adequacy

The results of the ESR model in respect of vitamin intake adequacy ratio (VAR) are presented in Table 10. The Wald tests confirm the overall significance of the variables included in the model while the likelihood ratio test indicates that the two equations (participation and vitamin adequacy ratio equations) are not independent (Prob>0.00). The estimated covariances (sigma0 and sigma1) are statistically significant and this is an evidence of endogenous switching indicating that the decision to participate in the subsidy scheme and the vitamin adequacy ratio are correlated. Moreover, the correlation terms in both equations are statistically significant at one-percent level implying that the hypothesis of absence of sample selection bias is rejected. Results of the analysis of the determinants of farmers' vitamin intake adequacy indicate that the we cannot accept the hypothesis that VAR is not determined by many of the variables included in the model due to their statistically significant coefficients in the estimated equations shown in columns 5 and 6 of Table 10 for the subsidized and non-subsidized groups of farmers. Out of the 9 explanatory variables included in the ESR model for VAR, only two variables (gender and education) are statistically insignificant determinants of vitamin intake adequacy for both groups of farmers.

However, the number of variables that are not significant differs between the two groups; being four (gender, remittance, education and non-farm income) for the subsidized farmers and three (age, gender and education) for the non-subsidized group. For the significant variables, the difference in the signs of the coefficients for the subsidized and non-subsidized groups is a further indication of heterogeneity in the sample. Specifically, coefficients of three variables (remittance, region and non-farm income) reveal heterogeneous effects on vitamin intake adequacy. A one-percent increase in remittance is associated with an increase of 0.06 percent in VAR for the non-subsidy group whereas the coefficient of this variable in the subsidized group is negative and not even statistically significant. We also found that VAR for non-subsidy farmers in the north will be higher by about 0.09 percent whereas for subsidized farmers the opposite is the case. Moreover, a one-percent increase in non-farm income is associated with a reduction in VAR for non-subsidy farmers whereas for subsidized farmers the variable has a positive coefficient which is not even statistically significant.

The analysis is extended to the determination of the counterfactuals for both groups of farmers. We found that the effect of the subsidy scheme is positive on both the subsidized and non-subsidy farmers. In other words, it pays the participants to have participated while those who were not subsidized would have had better nutrition outcome if they had participated. As shown in Table 11, the expected VARs of subsidized and non-subsidized farmers are (a) and (b) that is, 71.33 and 62.71 respectively. In view of the inherent differences these figures cannot form the basis of valid comparison of outcomes between the two groups. However, a comparison of (a) and (c) indicates that the subsidized group would have had a significantly lower vitamin adequacy ratio had they not participated in the subsidy scheme. The results show that consequent upon the subsidy scheme VAR of the farmers who participated expectedly increased by 12.12 (or by 20.47 percent). In the case of farmers who did not participate, VAR would have expectedly increased by 36.62 (or by 58.39 percent) if they had participated; implying that the treatment effect on the untreated is positive in the case of vitamin intake adequacy. It would have paid the non-subsidized farmers to have participated in the scheme on account of the possibility of attaining higher levels of vitamin intake adequacy. Furthermore, we found that if both groups had participated in the subsidy scheme, those who participated would have had a reduction in vitamin intake adequacy ratio (-27.99) (BH1) compared with their counterparts who did not participate. In the same vein, if both groups did not participate those who participated would also have had a reduction in vitamin adequacy ratio (-3.49) (BH2) on the average compared with their counterparts who did not participate. Finally, the transitional heterogeneity effect is negative. This reflects the positive treatment effect on the untreated; an indication that the effect on vitamin intake adequacy is higher for the non-subsidy farmers compared with their counterparts that participated in the scheme. Thus, it would have been beneficial for the non-subsidy farmers if they had participated in the scheme since they would have derived higher level of vitamin intake adequacy.

5. Summary, policy implications and conclusions

This study sought to examine the factors influencing smallholder farmers' participation in the fertilizer subsidy scheme in Nigeria and estimate the impact of the scheme on farmers' productivity, food security and nutrition outcomes. One of the key findings of the study is that the subsidy scheme had significant impact on farmers' productivity. We found that subsidy significantly increases productivity among the subsidized farmers; and that the subsidized farmers would have had higher productivity than their non-subsidized counterparts had the non-subsidized farmers participated in the subsidy scheme. The study also revealed that without subsidy productivity is significantly lower among non-subsidized farmers; and they would have had lower productivity than subsidized farmers in a situation where the subsidized farmers had not participated in the subsidy scheme. Evidently, on the average, the results show that subsidized farmers have higher productivity potential than non-subsidized farmers. Another remarkable finding is in respect of food security and nutrition. We found that the subsidy scheme had significant impact on food security of the smallholder farmers. Specifically, the participants are found to be better off participating than not participating. Moreover, the results show that it would have been possible for the non-participants to increase their food security if they had participated in the subsidy scheme. The results in respect of the two nutrition outcomes considered are mixed. As regards mineral intake adequacy we found positive treatment effect on the treated and negative effect on the untreated. The MAR for subsidy farmers increased by 63.6 percent whereas for non-subsidy farmers MAR would have expectedly decreased by -48.51percent if they had participated. For vitamin intake adequacy the subsidy impact is positive. The VAR for subsidy farmers increased by 20.47 percent and for those in the non-subsidy group vitamin adequacy would have increased by 58.39 percent if they had participated.

These findings are intriguing especially in view of the inherent policy implications. The findings corroborate the success of the growth enhancement support scheme (the subsidy scheme) and provides additional evidence that the success was not only on the supply side but also on the demand side. In other words previous evidence of the success of the scheme in Nigeria has been limited to the indicators such as (i) the number of farmers that were registered for the scheme which increased from 3.91 million farmers in 2012 to 9.5 million in 2013 and 10.47 million in 2014; (ii) the number of farmers targeted for the subsidy benefit which continued to increase from

1.09 million in 2012 to 7.24 million in 2013 and 8.30 million in 2014; (iii) the quantity of fertilizer distributed to farmers which increased from 120,903 metric tonnes in 2012 to 466,638 metric tonnes in 2013, and rose phenomenally to 748,834 metric tonnes in 2014 and (iv) the number of farmers who benefited from the subsidy which increased from 728,936 in 2012 to 4.12 million in 2013 and 7.22 million in 2014; on account of which the implementation of the subsidy has been considered to be very successful. On fertilizer subsidy alone, the amount spent by the federal government rose from NGN6.65 billion in 2012 to NGN22.92 billion in 2013 and NGN41.19 billion in 2014. Since the 50 percent subsidy was financed in equal proportion of 25 percent by the federal and state governments; it implies that the total public spending on fertilizer subsidy (by federal and state governments) over the period increased from NGN13.30 billion in 2012 to NGN45.84 billion in 2013 and NGN82.38 billion in 2014. These amounts cannot be regarded as money that has gone 'down the drain'. With the success of the implementation process as captured by these indicators this study found other dimensions of its success in terms of the positive impact of the subsidy scheme on farmers' productivity as well as their food security and nutrition status. Nonetheless, the implementation of the scheme has not been without challenges. There were administrative, technical, financial, social, and political constraints, as well as weak collaborative process between the federal, state and local governments which often led to delays in service delivery.

Our findings seem to be more encouraging than what the literature has offered regarding the impact of subsidy. Previous studies on the impact of subsidy has often focused on food consumption subsidy in terms of lowering food prices for consumers in poor communities and have always declared somewhat negative subsidy effects (Kochar, 2005; Kaushal and Muchomba, 2015). Specifically, on nutrition outcomes Jensen and Miller (2011) investigated household consumption response to a price subsidy, and in particular the impact the subsidy has on nutritional outcomes in two Chinese provinces with subsidies for their locally-relevant staple foods: rice in Hunan, and wheat flour in Gansu. The results show that poor households reduce their intake of calories and several important vitamins and minerals in response to the price subsidy. They concluded that there was no evidence that the subsidy improved nutrition for the poor masses, and that it might in fact even harm them in some cases. Moreover, in a recent article Muchomba and Kaushal (2017) examined the impact of a targeted food price subsidy program in India called the Targeted Public Distribution System (TPDS) on micronutrient intake in low-income families. Their analysis suggests that the exogenous increase in wheat and rice price subsidy lowered calcium intake by 12-14 percent and had negligible to small (often negative) effects on the consumption of most micronutrients. It is, therefore, important that while policy makers are articulating subsidy policies for the poor, they should decide whether the focus should be on the supply side or demand side. In other words, the choice between consumer subsidy and producer subsidy should be well considered at the same time as the implementation strategy and outcome areas are being designed.

Unlike exogenous food subsidy designed to lower consumer prices of food staples, this study finds that farm input subsidy that guarantees improved productivity and profitability of the beneficiaries may well have considerable impact on nutrition outcomes especially for households with low dietary intakes. This is particularly important in the case of Nigeria where poor trends in food and nutrition security are being experienced and regional variations in malnutrition, slow progress in reducing hunger, and new socioeconomic challenges indicate the need for more concerted efforts by key stakeholders to address the food and nutrition insecurity in the country. Available evidence suggests that nearly 13 million Nigerians still suffer from hunger, with wide disparities across geopolitical zones and between urban and rural areas. Nigeria accounts for 14 percent of all annual maternal deaths worldwide and 13 percent of all global deaths of children under the age of five years—indications of the level of food and nutrition insecurity in a country—being second in these respects only to India. (World Bank, 2015). Furthermore, available data rank Nigeria first in Africa and third globally on the incidence of malnutrition (New Telegraph, 2016). Besides, the attainment of Sustainable Development Goal 2 (SDG2) which seeks to end hunger, achieve food security and improved nutrition, and promote sustainable agriculture in 2030 requires that a multiplicity of stakeholders and strategies should be involved. A strategy such as agricultural input subsidy which has been found to have a positive impact in this direction should be a right candidate to support.

In the light of the foregoing it is recommended that policy makers in Nigeria should continue to employ agricultural input subsidy to boost food production and improve productivity. Input subsidy should also be recognized as a potent instrument to promote food and nutrition security (FNS) in the country. Thus, input subsidy decision making process should not be limited only to the line ministry handling agricultural policies; it should be extended to policy makers in the ministries, departments and agencies (MDAs) dealing with food and nutrition security policies in the other line ministries (such as health and education) as well as the ministry of finance, budget and national planning which is the central ministry coordinating FNS policy interventions. Moreover, implementers of subsidy programmes should ensure that potential participants are adequately informed about the various benefits of subsidy beyond the advantages of cost reduction and profitability. Specifically, the potential benefits in terms of improvements in productivity, food security and nutrition outcomes should be communicated to them through extension agents to ensure effective participation and maximum benefits.

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