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Targeted Subsidies and Private Market Participation

An Assessment of Fertilizer Demand in Nigeria

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ABSTRACT

Though input vouchers are being publicized as a mechanism to simultaneously target subsidies and develop demand in private markets, limited empirical evidence of their effect on private input demand exists. Few empirical studies, if any, exist on the effect of *targeted subsidies* on private input demand in Nigeria or West Africa . Consequently this study begins to fill this gap by estimating the effect of a targeted input subsidy on farmer participation in the private fertilizer market in Nigeria. Using a double hurdle model and a control function approach, this study explores the effect of increasing access to subsidized fertilizer on farmer participation in the private fertilizer market in Kano, Nigeria. The study finds evidence that farmers who received subsidized fertilizer in 2009 tended to have less assets than their counterparts who did not. Within this context, although receiving subsidized fertilizer did not appear to increase the probability of participating in the private fertilizer market, it did increase the quantity of fertilizer purchased from the private market once the decision to participate had been made. It appears that one benefit of the voucher program was that it developed links between rural farmers and input suppliers. Furthermore, where private fertilizer markets are weak, results indicate that there could be significant gains from the temporary use of voucher programs to create links between input suppliers and farmers.

Keywords: input vouchers, crowding in, crowding out, targeted subsidies, Nigeria, Sub-Saharan Africa

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1. INTRODUCTION

Historical increases in agricultural productivity have often been linked with significant increases in chemical fertilizer use. Consequently, the low yields in African countries are often attributed to the low rates of fertilizer use (Morris et al. 2007), supporting a call or rationale for government subsidies (Ellis 1992, Sachs 2004, Crawford et al. 2006). Though often discouraged due to poor performance and high costs, fertilizer subsidy has returned to the forefront of agricultural policy in many developing countries. This return to emphasis on fertilizer subsidy calls for a different approach: the use of smart subsidies that are well targeted and temporary. In this light, agricultural input vouchers are increasingly being employed across developing countries to address problems of low agricultural productivity and food security by increasing the timely access to inputs. Vouchers are being touted as mechanisms to simultaneously target subsidies, develop demand in private markets, and encourage relationships between agricultural input dealers and financial institutions (Gregory 2006, Minot and Benson 2009).

When an input subsidy has a positive effect on input purchases from the private market, the subsidy is said to crowd in commercial purchases. However, when subsidizing an input has a negative effect on private commercial purchases, then the subsidy is said to be crowding out or displacing commercial activity. There is limited evidence of the impact of targeted subsidies on farmer participation in private fertilizer markets generally. Two exceptions are Xu et al. (2009) and Ricker-Gilbert et al. (2011), who explore this issue in Zambia and Malawi, respectively. However, there are no studies that we are aware of that have considered this issue in West Africa. This study contributes to this limited evidence by exploring whether targeted input subsidy creates demand in private markets in Nigeria.

Nigeria is the most populous country in Africa (about 158 million people) and the second largest economy (World Bank 2010). Although a large share of its population is engaged in agriculture, agricultural productivity is low and more than 50 percent of the population lives on less than US$2 a day. Consequently, the potential effect of productivity-enhancing strategies (such as increased and efficient use of improved technologies like fertilizer) on food security and welfare are large, and understanding the processes through which this can happen is important. Furthermore, despite the low rate of fertilizer consumption (about 7.7 kilogram per hectare [kg/ha] in 2008[1]), Nigeria alone accounted for 23 percent of the entire fertilizer consumption in Sub-Saharan Africa in 2008/2009 (IFDC 2009). This compares to 23 percent of total demand from the rest of West Africa, 40 percent attributed to Kenya, Ethiopia, Tanzania, Zambia, and Malawi and 14 percent attributed to all the other countries in the region. Consequently, understanding the effects of targeted subsidies on the private fertilizer market in Nigeria is necessary, and comparing such effects to those of other smaller countries that are also key players in the region's fertilizer market (such as Malawi and Zambia) is expedient.

Some complexities that arise when studying private input demand in a context like this are the corner solution nature of input demand and the potential endogeneity of our key variable of interest: the quantity of subsidized fertilizer received. The corner solution challenge arises because it might be optimal for many farmers not to participate in the private fertilizer market. Thus, although it is common to find many respondents recording zero input purchased, the quantity purchased for those who do is relatively continuous. Endogeneity of the quantity of subsidized fertilizer acquired occurs because there might be unobserved characteristics that affect the quantity of subsidized fertilizer farmers receive, which might also drive the quantity of fertilizer they purchase from the private market. Using data collected from respondents in more than 600 households across 10 randomly selected local government areas (LGAs[2]) in Kano, this study addresses both issues within an instrumental variables framework. I apply a control function approach to a double hurdle and Tobit model to account for the endogeneity of subsidized fertilizer receipt and address the corner solution nature of input demand. This study also explores the heterogeneity of crowding in/out effects across farmers depending on their wealth as measured by assets.

[1] World Bank 2008.

[2] Local government areas (LGAs) are administrative units under each of Nigeria's 36 states, constituting the third tier of the administrative structure in Nigeria.

This provides important insight into the level of distortions (if any) and guides any refinements needed for improving targeting or changing the size of the subsidy.

Results from this study analyzed closely alongside the program design (size of subsidy) and implementation (effectiveness of targeting) provide useful information on how fertilizer voucher programs can be structured to ensure that they are able to increase farmer access to affordable and timely inputs in a manner that promotes rather than distorts private fertilizer market development. Ricker-Gilbert et al. (2011) show that in a context where richer farmers with more land and higher assets received more subsidized fertilizer, fertilizer subsidy tended to crowd out commercial markets. Liverpool-Tasie et al. (2010) show that participants in a pilot voucher program in Nigeria tended to have fewer assets and were more likely to be renting agricultural land rather than owning it. However, no evidence exists as to whether crowding out effects maintain under this situation. This study provides this evidence. Our results indicate that although receiving subsidized fertilizer did not appear to increase the probability of participating in the private fertilizer market, it did increase the quantity of fertilizer purchased from the private market once the decision to participate had been made. It appears that one benefit of the voucher program was that it developed links between rural farmers and input suppliers. The results from this study inform how crowding in/out effects of targeted subsidies are different under different targeting regimes. Given that many developing countries, particularly in Sub-Saharan Africa, adopt the use of input vouchers or scale up already existing programs, this study highlights some key issues to be considered to expand the dimensions of success of input voucher programs. It informs about conditions under which fertilizer subsidy (even when provided through targeted programs) would be likely to crowd in/out private commercial markets.

The rest of the paper is organized as follows. Section 2 provides a brief discussion of fertilizer vouchers and private market development focusing on Nigeria. Section 3 provides a description of the 2009 voucher program in Kano state, linking its design and implementation to the potential effects it could have on the private market. Sections 4 and 5 discuss the conceptual and empirical frameworks within which this analysis is done. Section 6 describes the data, and section 7 provides the study results. Section 8 presents further considerations of the empirical findings, and section 9 concludes.

2. BACKGROUND AND LITERATURE

Targeted Fertilizer Subsidies and Private Fertilizer Market Development

Although the positive relationship between chemical fertilizer use and agricultural productivity has led to the promotion of fertilizer subsidies, fertilizer subsidies have been subject to strong criticisms over the years. These criticism range from the traditional efficiency argument (based on the rationality of farmers and the assumption of perfect factor and output markets) of their distortionary effects on farmer optimal fertilizer use (Shultz 1964) to the many criticisms of the costs and administrative challenges associated with subsidies (Donovan 2004, Nagy and Edun 2002, Banful 2010). Because of rising concerns about food security associated with increasing food prices, there has been a resurgence of fertilizer subsidies in developing countries. This return of government intervention in fertilizer markets has called for a move away from the traditional and ineffective subsidy approach of the past. It calls for a new and temporary approach focused on properly targeting fertilizer to poor farmers in a manner that stimulates private fertilizer market development. This often involves the use of fertilizer vouchers. In recent years, various forms of input voucher programs have been created and implemented in developing countries. Malawi has used input vouchers in its nationwide fertilizer and seed subsidy programs since 1999. Afghanistan (in 2001), Mozambique (in 2002), Zambia (in 2003), Tanzania (in 2008), and Ghana (in 2008 and 2009) are other examples where input vouchers have been recently used (Longley et al. 2003, Gregory 2006, Minot and Benson 2009, IFDC 2010).

Fertilizer subsidies have been shown to crowd out private commercial fertilizer sales in certain contexts (Ricker-Gilbert et al. 2011, Xu et al. 2009). Others have found evidence that fertilizer subsidies might encourage fertilizer use (Duflo et al. 2011). The presence and extent of crowding in/out effects of fertilizer subsidies depend on several factors. These include the size of fertilizer demand (Dorward 2009) and the level of development of the private sector (Xu et al. 2009). Xu et al. (2009) found that where the private sector is well developed, crowding out effects are larger. However, in poorer areas where private commercial markets are weak, subsidies tend to crowd in as they create demand.

Where demand is traditionally low, a targeted subsidy can stimulate fertilizer use among farmers for which a credit constraint on fertilizer demand is binding. Similarly, increased and guaranteed demand through vouchers could have economies-of-scale effects on fertilizer suppliers (Dorward 2009). Newly created links between input suppliers and farmers could induce fertilizer provision in areas previously excluded in a manner that makes the product available (where previously absent) or reduces costs associated with fertilizer procurement due to shorter distances to access the input, for example. Consequently, this increased supply could potentially stimulate the adoption of fertilizer use or increase fertilizer consumption (even if it does not stimulate its adoption) for farmers already using the input but who face high costs due to transport or supply shortages.

Crowding in/out effects are also likely to depend on the nature of the subsidy, including its size and targeting (Duflo et al. 2011). Larger subsidies that meet a big proportion of total demand could reduce the need for (or extent of) private market participation. Regressive subsidies (that largely benefit the wealthy) and very large subsidies are more likely to distort private commercial markets. This is supported by Ricker-Gilbert et al. (2011), who found that the quantity of subsidized fertilizer received by farmers increased with their wealth. This puts them in a world where targeting was either not successful or not directed at the poorest households. In this context, they found evidence of crowding out, which increased with the wealth of farmer. One main contribution of this paper is its ability to capture the effect of a targeted subsidy that supposedly reached poorer households (arguably those who would normally not participate in the market at all or whose quantity of participation might be very small). A study by Liverpool-Tasie et al. (2010) that uses the same data as for this study found that participants in the voucher program tended to have lower asset values and also tended to be renters rather than owners of agricultural land. This paper exploits this characteristic of the voucher program to explore whether crowding out or crowding in effects obtained under this circumstance.

Fertilizer Vouchers and Private Fertilizer Market Development in Nigeria

Fertilizer consumption in Nigeria is low, at 7.7 (kg/ha) of arable land in 2008 (World Bank 2008).[3] This is despite the Nigerian government's longstanding and prominent engagement in procuring and distributing fertilizer at subsidized rates since the early 1970s. Although the fertilizer subsidy programs absorb a large proportion of the national budget, the impact of the programs on agricultural productivity has been mixed at best and the programs have not created sustained increases in fertilizer consumption (Banful and Olayide 2010). The government-led procurement and distribution of subsidized fertilizer in Nigeria has been characterized as persistently delivering fertilizer late with significant diversion of fertilizer from the intended beneficiaries (Nagy and Edun 2002). Leakages of subsidized fertilizer into the regular market were common, leading to market price distortions as well as providing arbitrage opportunities. In 1997, the fertilizer sector was abruptly liberalized. However, the private sector was neither experienced nor developed enough to respond to the government's sudden exit from the sector, and fertilizer use fell from a peak of 1.2 million metric tons 992 to 56,700 metric tons (mt) in 1997 (Banful and Olayide 2010, IFDC 2010). This saw the reintroduction of the federal government subsidy at 25 percent of cost in 1999, with many of Nigeria's state governments also adding their own subsidies. This has led to multiple fertilizer prices across Nigerian states, with a wide range in the extent of subsidies. In 2007, some states had fertilizer subsidies up to 75 percent of the market price (Banful and Olayide 2010). The extent of fertilizer subsidy across Nigerian states has served as a disincentive for the private sector to build a fertilizer distribution system or a retail sales network. Unable to compete with government prices, most fertilizer suppliers in Nigeria have focused on the government as their major buyer, to the detriment of the poor farmers. Not only are farmers left subject to the inefficiencies associated with government-purchased fertilizer (including late delivery and poor quality) but also this is in some cases the only fertilizer farmers have access to (Nagy and Edun 2002; IFDC 2011). These challenges encouraged the promotion of fertilizer vouchers in Nigeria. Although fertilizer subsidy is not novel, the use of vouchers to target smallholder farmers and develop private fertilizer markets is relatively new. The use of vouchers to provide federal and state government-subsidized fertilizer was piloted in a few sites in two states in 2004 and again between 2008 and 2010. However, 2009 was the first time that a voucher program was administered across an entire state in Nigeria.

The voucher program piloted in 2009 was expected to improve the targeting of the longstanding fertilizer subsidy program and, through provision of guaranteed markets and capacity-development trainings, support the development of the private fertilizer retail sector. The program was organized by the federal government, respective state governments, and the implementing agency, International Center for Soil Fertility and Development (IFDC). It was implemented in two states, Kano and Taraba. The program was meant to model smart subsidies that allow for targeting of rural smallholder farmers and develop a private sector supply and distribution channel so that the federal government could withdraw from procurement and distribution (IFDC 2011). Although the effectiveness of the program in increasing farmer access to affordable and good-quality fertilizer on time has been studied (Liverpool-Tasie et al. 2010), no study on the effectiveness of the program in developing the private fertilizer market has been conducted. This study fills this gap. Although efforts are underway to expand the voucher program to all 36 states of Nigeria, this paper provides important information about whether the voucher program in Kano was able to achieve the aim of developing demand for fertilizer in private markets. It informs on the extent to which targeted subsidy programs could be used to efficiently promote fertilizer use and agricultural productivity growth in Nigeria.

[3] This is compared to well over 100 kg/ha in India, Pakistan, and the United States and closer to 200 kg/ha in the UK.

Although focusing on one state in Nigeria seems to limit the external validity of the results, this paper highlights important characteristics of input voucher program design that are applicable more generally in developing countries and particularly in Sub-Saharan Africa. The diversity of agroecology and farming practices, culture, governance, and administration in Nigerian states is high, often in dimensions comparable to different countries. Given that fertilizer subsidy rates and administration practice are also very different across Nigerian states, the potential need for policy development and implementation at the state level, rather than solely at the federal level, is an important consideration. This paper provides state-specific empirical evidence of the voucher program effect on private market participation that could be extended to other states and countries. It also informs (more generally) about conditions under which fertilizer subsidies would be likely to have similar effects.

3. THE 2009 VOUCHER PROGRAM IN KANO STATE

Kano state is located in northwestern Nigeria. It is the most populous Nigerian state, with about 9.4 million residents (National Population Commission 2006). It is largely inhabited by the Hausa ethnic group. Two other important population groups are the Fulani (a smaller ethnic group) and recent immigrants from southern Nigeria, who largely reside in a part of the capital city called Sabon Gari (USAID 2008). The primary activities in Kano are commerce and agriculture, and the poverty rate in Kano is about 75 percent (NBS 2009). The 2009 voucher program in Kano was a collaborative effort among the government (federal and state), the private sector suppliers and dealers, and the IFDC. The program was designed to deliver subsidized fertilizer to 140,000 smallholder farmers across the 44 local government areas (LGAs) of the state (IFDC 2010).

Three fertilizer suppliers and more than 150 private sector agro dealers participated in the program. Participating farmers were provided with vouchers, which were redeemable at certified agricultural input dealers within their LGA of residence. The value of the voucher was an NGN 2,000 discount per bag on two bags of nitrogen, phosphorus, and potassium (NPK 15:15:15) and one bag of urea (46 percent nitrogen). Farmers were required to pay the difference between the market price and the NGN 2,000 discount per bag. The total subsidy provided by the federal and state governments amounted to about NGN 522 million.[4] The federal government paid its portion of the NGN 2,000 subsidy per bag directly to each supplier based on the amount of each product it had been asked to provide (IFDC 2010). This meant that vouchers were allocated to match the indented product and suppliers to specific dealers in the various LGAs, limiting farmer choice of the source of the product. In most cases, there were different certified agricultural input dealers for NPK and urea, increasing the transaction costs associated with redeeming the vouchers. However, the fact that the participating suppliers were restricted provided for the traceability of a poor-quality product.

Participants in the 2009 voucher program in Kano were required to be members of a farmer group. Each participating farmer group received a single voucher that entitled each of its members to an NGN 2,000 discount on three bags of fertilizer. According to the Nigeria Agri-Market Information Service (NAMIS), fertilizer prices in central markets in Kano were about NGN 3,000 for a 50 kg bag of NPK 15:15:15 and NGN 3,200 for a 50 kg bag of urea. Thus, the voucher value was slightly over 60 percent and 65 percent of the NPK and urea market price, respectively. For verification, farmer groups were required to bring their certificate of registration to verify their group's authenticity (IFDC 2010). Due to the long history of farmers operating within farm groups in Kano, a single voucher was issued to the entire farmer group and the subsidized fertilizer for all members of the group had to be purchased as a group. Individual members of the group had to provide one single passport photo to the farm group executive to present at the voucher distribution day, but the members of the group were not required to be present for the group's voucher to be provided to the group leadership. Each voucher in Kano entitled a farmer group to receive fertilizer bags, numbering three times the number of farmer group members. Any of the group leadership could redeem the group's voucher because individual members were not required to be present when the voucher was being redeemed (IFDC 2010).

This structure of the 2009 voucher program in Kano created an opportunity for differential experience of the voucher program across farmers of the same group. Anecdotal evidence drawn from complaints on the field indicated that individuals got different quantities than the three bags they had been promised. Liverpool-Tasie et al. (2010) showed that the friends and relatives of the farm group president received more bags of fertilizer than those without such links. This study capitalizes on this characteristic of the program in its identification strategy.

[4] This amounts to US$335,483.90 at NGN 155 = $1.

4. CONCEPTUAL FRAMEWORK

Under the assumption of perfect markets, market prices are exogenous to a household and all products (output and inputs) are tradables. Consequently, market prices reflect the true opportunity cost of products and serve as the prices upon which household consumption and production decisions are based. In such settings it does not matter whether a household consumes its own products or sells them and buys its necessary consumption items with the resultant income; consequently, we can treat the household's production and consumption decisions as solved sequentially. First, households determine what to produce given output and input prices as well as household-specific characteristics, determining the household's income, which then serves as part of its budget constraint in its consumption decisions.

In rural Nigeria, where rural financial markets are very thin and where villages are often isolated with limited access to various input and output markets, the technology choice by a farmer can be modeled as a constrained utility maximization problem, as in Singh, Squire, and Strauss (1986). In this context, the utility maximization problem that results is:

$$Max_c \ U(c, z^h) \tag{1}$$

This maximization is subject to various constraints, including a cash income constraint, a credit constraint, a production technology constraint, and a price constraint (to reflect its endogeneity), and the necessary equilibrium condition for nontradables. As in the traditional analysis, c refers to the goods consumed and z^h is a vector of farmer characteristics, such as farm size, age and gender, farm implements, and access to credit and education. As described in Sadoulet and de Janvry (1995), the solution to this constrained maximization problem yields reduced form specifications of demand for inputs and technologies and supply of outputs. The input demand for input *i* can be expressed as:

$$q_i = q(p_i^*, z^{hq}), \tag{2}$$

where q_i <0 because we are dealing with an input, z^{hq} refers to household characteristics associated with the need for input i, and p_i^* refers to the endogenous prices for the relevant input. In this study, the resulting reduced form input demand for fertilizer corresponds to the quantity of fertilizer a farmer decides to use and his consequent interest in the fertilizer voucher program through which some portion of that need could be met at a discounted price.

In addition to household characteristics, this study incorporates the fact that farmers have two channels through which they receive fertilizer: the private market and the government. We explicitly test for an effect of increasing farmer access to subsidized fertilizer through a fertilizer voucher program on farmer participation in the private fertilizer market. Consequently, the input demand model of interest stemming from the solution to the constrained utility maximization model of the Singh, Squire, and Strauss model (1986) can be expressed as

$$QFert_p = f(QFert_s, PFert, P_{output}, K, A, Z), \tag{3}$$

where $QFert_p$ refers to the quantity of fertilizer purchased from the private sector distribution channel by farmer *i*, $QFert_s$ refers to the quantity of subsidized fertilizer received by farmer *I*, and $PFert$ and P_{output} refer to the prices of fertilizer and the major crop (maize) produced by more than 70 percent of households. *K* and *A* are access to credit and land size, respectively, and *Z* refers to other household characteristics and socioeconomic variables. We include various controls in line with standard practice in fertilizer demand models (Ricker-Gilbert et al. 2011, Liverpool and Winter-Nelson 2010, Holloway et al. 2008, Bellemare and Barrett 2006, Winter-Nelson and Temu 2005, Holloway et al. 2005, Croppenstedt et al. 2003, Key et al. 2000, de Janvry et al. 1991).

5. EMPIRICAL FRAMEWORK AND ESTIMATION STRATEGY

From the conceptual model above, we estimate the effect of subsidized fertilizer on private sector fertilizer demand as follows:

$$QFert_{pi} = \eta_i + \beta X_i + \delta QFert_{si} + u_i, \quad (4)$$

where $QFert_{pi}$ refers to the quantity of fertilizer purchased by farmer *i* from the private market in 2009. X_i is a vector of controls that affect private sector fertilizer demand, and $QFert_{si}$ refers to the quantity of subsidized fertilizer that farmer *i* received in 2009. u_i is a farmer-specific error term and $\beta$and $\delta$are parameters to be estimated. We start with a random coefficient model framework, where unobserved heterogeneity (η_i) is allowed to interact with endogenous explanatory variables. Our primary interest is in estimating the parameter δ, which indicates the presence and extent of crowding in or out of private fertilizer markets. It measures the effect of the quantity of subsidized fertilizer received by farmer *i* on the quantity of fertilizer the farmer buys from the private fertilizer market. X_i includes household demographic information, socioeconomic characteristics, and variables to capture access to credit and transaction costs.

The decision not to use inputs is often an optimal choice where use is not profitable at prevailing market prices (Coady 1995). Consequently, a zero observation for the quantity of an input used is likely to be a corner solution indicating an optimal choice rather than an unobserved one. This precludes the use of Ordinary Least Squares (OLS) estimations because the constraint of y≥0 automatically implies that we do not have constant marginal effects and $E(\frac{Y}{X},\ Y > 0) \neq \beta X$. It also precludes Heckman (1999)–type selection models because rather than a case where zeros represent nonparticipation in the input market and are considered unrelated to the quantity of input purchased, observed zero quantities of fertilizer demanded are the result of either participation or quantity demand decisions and potential participants may have zero quantities of fertilizer actually purchased. This study explores both the double hurdle approach (which maintains the appropriate assumption about our zero values but still makes it possible to account for potentially different factors that affect participation in a market and the extent of participation, conditional on participating) and the Tobit model (which addresses the corner solution but considers the factors driving the two processes to be the same). This study follows on past precedence of estimating input demand models like Coady (1995), Croppenstedt et al. (2003), Xu et al. (2009), Liverpool and Winter-Nelson (2010), and Ricker-Gilbert et al. (2011) with the controls included in the input demand model.

In equation (4), following Roy (1951) and Cameron and Trivedi (2005, 2009), $QFert_{pi} = 0$ is determined by the density $f_1(.)$ such that $P(QFert_{pi}) = 0 = f_1(0)$ and $P(QFert_{pi}) > 0$ is determined by $f_2\left(QFert_{pi}|QFert_{pi}\right) > 0 = f_2(QFert_{pi})/1 - f_2(0)$. The associated likelihood function whose log is maximized can be expressed as:

$$L = \prod_{i/QFert_i=0}\{f_1(0)\ \}\prod_{i/Qfert_i\neq 0}\left\{\frac{1-f_1(0)}{1-f_2(0)}f_2\left(QFert_{pi}\right)\right\}. \quad (5)$$

Although equation (4) is concerned with estimating delta, the quantity of subsidized fertilizer received by a farmer $QFert_{si}$ is potentially endogenous if there are unobserved characteristics that affect the quantity of fertilizer a farmer receives that also are likely to affect his demand for nonsubsidized fertilizer. For example, if more motivated farmers are better coordinated with other farmers, they would be more likely to participate in the voucher program[5] (and receive more subsidized fertilizer) and also be more likely to already be using fertilizer and thus purchase more fertilizer from the market. Alternatively, if high-performing farmers are influential in their community, this could enable them to receive more

[5] Farmers had to be in organized farm groups in Kano to be able to participate in the voucher program.

bags of subsidized fertilizer than their peers but could (as above) also make them more likely to have already been using fertilizer and thus more likely to participate in the commercial fertilizer market. Either of these would make estimates of the effect of the quantity of subsidized fertilizer on the quantity of nonsubsidized fertilizer purchased by a farmer biased.

This study addresses the endogeneity of the quantity of subsidized fertilizer variable in crowding out (in) estimations using a control function approach for a double hurdle model. When using the double hurdle model with an endogenous regressor (quantity of subsidized fertilizer in this case), Cameron and Trivedi (2009) demonstrated a two-step estimation procedure that can be implemented to derive consistent estimates of parameters associated with endogenous variables.

Given

$$QFert_{pi} = \beta_1 X_{1i} + \delta QFert_{si} + u_i \tag{6}$$

and

$$QFert_{si} = \alpha_1 X_{1i} + \alpha_2 X_{2i} + \varepsilon_i, \tag{7}$$

X_{2i} refers to exogenous variables that affect the quantity of subsidized fertilizer that a farmer receives but do not affect his demand for fertilizer from the private market. All other variables remain as earlier defined and α_1 and α_2 are additional parameters to be estimated.

Endogeneity of $QFert_{si}$ implies that u_i and ε_i are correlated, which can be modeled as:

$$u_i = \rho\varepsilon_i + \mu_i, \tag{8}$$

where $\mu_i \sim [0, \sigma_\mu^2]$ is independent of $\varepsilon_i \sim [0, \sigma_\varepsilon^2]$. Endogeneity of $QFert_{si}$ implies $\rho \neq 0$.
For expository purposes, let us assume that with a count-dependent variable (number of bags of fertilizer), we can start with a Poisson[6] model, where $QFert_{pi} \sim$ poisson (θ), and

$$\theta_i = E(QFert_{pi}/QFert_{si}, X_{1i}, u_i) = \exp(\beta_1 X_{1i} + \delta QFert_{si} + u_i), \tag{9}$$

$QFert_{si}$ is endogenous.

Substituting equation (9) into equation (4) gives

$$\theta_i = \exp(\beta_1 X_{1i} + \alpha_1 X_{1i} + \alpha_2 X_{2i} + \rho\varepsilon_i) e^{\mu}. \tag{10}$$

The expectation of equation (10) with respect to μ can be expressed as:

$$E_\mu(\theta) = \exp(\beta_1 X_{1i} + \delta QFert_{si} + u_i) * \mathrm{E}(e^{\mu}) = \exp(\beta_1 X_{1i} + ln\mathrm{E}(e^{\mu}) + \delta QFert_{si} + \rho\varepsilon_i), \tag{5.8}$$

$ln\mathrm{E}(e^{\mu})$ can be absorbed into the constant term (one of the X_{1i}s), leaving us with

$$\theta/QFert_{si}, X_{1i}, \varepsilon_i = \exp(\beta_1 X_{1i} + \delta QFert_{si} + \rho\varepsilon_i), \tag{11}$$

such that ε_i becomes an additional regressor in this model with the log term being absorbed into the constant.

[6] This can be conveniently applied to a negative binomial regression in the double hurdle models to take advantage of its flexibility in the event that the dependent variable is over-dispersed, thus violating the Poisson model assumption of mean = variance.

Cameron and Trivedi (2009) demonstrate that consistent estimates of δcan be achieved by a simple two-step procedure. This involves running a first-stage regression (as in a traditional instrumental variables approach) of the endogenous variable ($QFert_{si}$) on a set of exogenous variables. The predicted value of the error term of this first-stage regression ($\widehat{\varepsilon_i}$) is then included in the actual $QFert_{pi}$ model. The p-values are obtained via bootstrapping to account for first-stage reduced form estimation of subsidized fertilizer.

More specifically for this study and given the corner solution nature of $QFert_{pi}$, this study estimates:

$$E(QFert_p|QFert_s, Z, r) = E(QFert_p|QFert_s, Z_1, r) = \Phi(Y\beta + r) \tag{12}$$

and

$$QFert_s = Z\gamma + v \tag{13}$$

where $Y$is a general, nonlinear function of ($QFert_s, Z_1$) and $r$is an omitted factor that is likely correlated with $QFert_s$. The exclusion restriction associated with the first part of equation (13) is that a subset of Z, (Z_1) appears in $E(QFert_p|QFert_s, Z, r)$. Following Imbens and Wooldridge (2007) and Wooldridge (2008), I estimate a first-stage regression of the quantity of subsidized fertilizer received by a farmer ($QFert_{si}$) using a Tobit model. Then the generalized residual is constructed as:

$$\widehat{gr}_i = -\hat{\tau}\ 1[QFert_{si} = 0]\ \lambda(-Z_i\hat{\gamma}) + 1[QFert_{si} > 0](QFert_{si} - Z_i\hat{\gamma}), \tag{14}$$

where $\hat{\tau}$ and $\hat{\gamma}$ are the Tobit maximum likelihood estimations and λ is the inverse Mill's ratio. Then the generalized residuals are included in the second-stage estimations (Wooldridge, 2008).

For the second-stage estimations, double hurdle and Tobit models are considered to address the corner solution nature of participation in the private fertilizer market. The model estimated in this paper follows Cameron and Trivedi (2009). The double hurdle model is assumed to reflect the two-stage decisionmaking process of fertilizer demand. In our case, the first step is the decision to purchase fertilizer from the private market or not, and the second step is the decision about the quantity of fertilizer to purchase from the private market once the decision to participate has been made. The double hurdle model relaxes the assumption that the zeros and the positive values come from the same data-generating process. The model assumes that the zeros are determined by the density $f_1(.)$ such that$P(QFert_{pi})$=0 = $f_1(0)$ and $P(QFert_{pi})$>0 is determined by $1 - f_1(0)$. The positive quantities come from the truncated density $f_2(QFert_{pi}|QFert_{pi} > 0)$= $f_2(QFert_{pi})$/{1-$f_2(0)$}, which is multiplied by$P(QFert_{pi})$>0 to ensure that the probabilities sum up to 1. Since the two parts of the model are functionally independent, the maximum likelihood estimation of the hurdle model is achieved by separately maximizing the two terms in the likelihood, one corresponding to the zeros and the other to the positive values. Consequently, the first part uses the full sample, and the second part uses only the positive observations. In both hurdles, the generalized residual and its interaction with the quantity of subsidized fertilizer are included as covariates in line with the control function approach (Imbens and Wooldridge 2007, 2008).

Identification when using the control function approach requires an instrument used to estimate equation (7), which is appropriately excluded from our primary equation (4). In Kano, the voucher program required farmers to be coordinated in groups to participate in the voucher program. Once a farm group had been approved for participation in the voucher program, any of the farm group president, treasurer, or secretary could redeem the voucher on behalf of the group and consequently secure the group's fertilizer. The expectation is that the fertilizer is then distributed to all farm group members. It is possible that deviations from the program-sharing rule (three bags each for every farm group member in Kano: two bags of NPK and one bag of urea) could be reflecting an equilibrium-sharing rule within the group. However, anecdotal evidence revealed numerous complaints from farmers about the quantity of fertilizer they received being less than they were promised. Furthermore, studies of the voucher program

(Liverpool-Tasie et al. 2010) found that being linked to the farm group president increased the quantity of fertilizer individual farmers received within their farm groups. Consequently, this study uses a variable that captures whether the respondent was a relative of the farm group president, secretary, or treasurer as an instrument for the quantity of subsidized fertilizer that a farmer received. Although being related to the farm group leadership would affect the quantity of fertilizer received by a farmer, being related to the group leadership is not likely to be correlated with unobserved characteristics that are likely to drive commercial fertilizer demand, such as farmer ability. Consequently, this variable satisfies the exclusion restriction of not being correlated with the error term of equation (1) and is considered an appropriate instrument. The instrumental variable (being related to the farm group leadership) is consequently excluded from our estimation of equation (1). In all second-stage estimations, p-values are obtained via bootstrapping at 500 repetitions (except where otherwise stated) to account for the fact that the generalized residual was obtained from a first-stage regression estimation.

6. DATA

The data used in this study come from a survey of 640 households in Kano (northwest Nigeria). Interviewed households were chosen from 10 randomly selected local government areas (LGAs), administrative units under each state constituting the third tier of the administrative structure in Nigeria. The 10 selected LGAs in each state represented potential LGA variations that could affect the level of exposures farmers had to the voucher program as well as other cultural, infrastructural, or administrative differences that affect farmer access to fertilizer apart from the program. Households were chosen from the randomly selected LGAs in Kano. A list of villages was compiled based on information supplied by the LGAs and the Kano State Agricultural and Rural Development Authority. Eighty villages were then randomly selected from this list. The number of villages in each LGA was selected to reflect the population differences across LGAs. The field staff in Kano interviewed in pairs, with each pair interviewing eight households in about eight villages.[7] Households within each village were randomly selected but with due consideration that at least one out of the four households interviewed participated in the voucher program. In both states, enumerators were trained extensively in randomly selecting households in a village and being mindful about the whole village in their selection of households. Survey coordinators paid surprise field visits to some enumerators to ensure that training instructions were adhered to. Details of the sampling procedure and survey methodology are included in the appendix.

The survey respondents were largely household heads, their spouses, other adult household members, and, for a few questions, children and youth in the household. Respondents were interviewed about their participation in various farm groups and other community associations, their leadership positions in their farm group and local communities, their farming practices (input use, sources, and prices), and their participation in the 2009 voucher program. Household demographic information was also collected. Because more than one household member could have participated in the voucher program, standard errors are clustered at the household level in all estimations.

Participation in the private fertilizer market differs significantly across respondents who participated in the voucher program and those who did not. Table 6.1 shows that both the proportion of respondents that purchased fertilizer from the private market and the quantity purchased were significantly higher among those who participated in the voucher program than those who did not. However, there was substantial participation in the private market irrespective of the program; about 70 percent of respondents who did not participate in the voucher program still purchased fertilizer from the private market. Table 6.2 shows that the average extent of participation ranged from about 0.3 bags (15 kg) from the lowest 10 percent of the sample (0 bags were bought by the lower 5 percent) to about 12 bags (600 kg) for the highest 10 percent.

Table 6.1—Private sector participation by participation status in the 2009 voucher program

	Nonparticipants	Voucher Program Participants
Purchased fertilizer from the private market (1/0)	0.720	0.937*
	(0.449)	(0.243)
Number of 50 kg bags of nonsubsidized fertilizer (bags) purchased	4.177	7.683*
Received subsidized fertilizer	0.387	1.000*
	(0.488)	(0.00)
Number of 50 kg bags of subsidized fertilizer received (bags)	1.224	3.699*
	(3.581)	(5.962)

Source: Generated by author with data from the fertilizer voucher program evaluation survey.
Note: * The means are statistically significantly different at 5% or less.

[7] Eight households in eight villages gives us about 64 households per pair. With 10 pairs of field staff, this gives us our 640 households in Kano state.

Table 6.2—Descriptive statistics of study variables

Variable	Mean	Lowest 10%	Highest 10%
Number of 50 kilogram (kg) bags of nonsubsidized fertilizer (bags) purchased	6.51		
	(12.99)	0.30	12.00
Number of 50 kg bags of subsidized fertilizer received (bags)	2.85		
	(5.32)	0.00	6.00
Farmer member of a group that purchased fertilizer together in 2008	0.89		
	(0.32)	0.00	1.00
Farmer related to the farm group leadership (1/0)	0.66		
	(0.47)	0.00	1.00
Reported price paid for fertilizer in 2009 (NGN per 50 kg bag)	4,038.19		
	(575.23)	3,500	46,00
Distance of respondent to major market in the state (km)	33.01		
	(20.19)	4.87	57.38
Naive price based on representative price four months prior to farming season (NGN/kg)	52.06		
	(18.80)	49.50	55.00
Member of a group that provided credit to members in 2008 (1/0)	0.28		
	(0.48)	0.00	1.00
Household size	3.89		
	(1.47)	2.00	7.00
Age (years)	34.24		
	(13.33)	19.00	53.00
Sex (1 = male)	0.51		
	(0.50)	0.00	1.00
Number of years of education	7.60		
	(3.25)	6.00	12.00
Marital Status (1/0)	0.85		
	(0.36)	0.00	1.00
Land area in 2008 (hectares)	4.36		
	(6.06)	0.75	10.00
Used improved seed in 2008 (1/0)	0.52		
	(0.50)	0.00	1.00
Rented agricultural land (1/0)	0.10		
	(0.30)	0.00	1.00
Household owns a motorcycle (1/0)	0.065		
	(0.48)	0.00	1.00
Total livestock units (TLUs)	6.86		
	(20.20)	0.00	11.10

Source: Generated by author with data from the fertilizer voucher program evaluation survey.

Notes: Standard deviation are in parentheses.

* Significant differences in means of voucher program participants and nonparticipants at a significant level of 5% or less.

Table 6.1 also shows that a significant portion of respondents received subsidized fertilizer even though they did not participate in the voucher program. Slightly less than 40 percent of respondents who did not participate in the 2009 voucher program still received subsidized fertilizer. Discussions with farmers in the fields and reports from enumerators informed that there was another fertilizer subsidy program in Kano in 2009. This program gave one bag of fertilizer to each recipient at a fixed price of

NGN 1,000.[8] Table 6.1 shows that although the average number of bags of fertilizer received by program participants was about 3.6 bags (compared to the 3 bags the program stipulated), it was about 1.2 bags for nonparticipants, what we would expect if they participated in the alternative program mentioned above.

The average respondent was a member of a farm group that tended to purchase inputs together and lived about 33 kilometers away from the major trading market in the state. Similar to Ricker-Gilbert et al. (2011), this study develops a naive expectation of the average real maize price for the six months prior to the planting season, which in Kano was November 2008 to April 2009. The price ranged from NGN 52 per /kg for respondents in the lowest 10 percent of the price distribution to NGN 55 per /kg for those in the highest 10 percent. The reported price paid for fertilizer purchased in the private market was about NGN 80 per ./kg The average household size was about four people headed by a married male.

[8] Although supposedly targeted, to confirm that the results of this study could be attributed to the 2009 fertilizer voucher program under study, the analysis was also conducted on only the subsample of respondents who participated in the voucher program and the results maintain. First-stage regression results maintain when we only consider nonparticipants and indicating that being related to a farm group president might have affected one's ability to benefit from the other program as well.

7. ANALYSIS AND RESULTS

To identify the factors affecting the quantity of subsidized fertilizer respondents received, equation (7) is estimated using a Tobit model to account for selection into the voucher program. Results of this are shown in Table 7.1. The first-stage results reveal that voucher program participation is overwhelmingly the strongest factor associated with the quantity of subsidized fertilizer a recipient receives. Whether the recipient was in a farm group that purchased fertilizer together was also highly correlated with the quantity of subsidized bags received. Apart from satisfying the criterion for participation in the voucher program, this may reflect that farm groups were also more likely to participate in the other fertilizer subsidy program in the state. Wealth and education variables do not appear to be a significant determinant of the number of bags recipients received, but the local government area (LGA) where farmers lived was. The instrumental variable, "Whether the respondent was a relative of the farm group president, secretary, or treasurer," is significantly and positively associated with the number of bags received. The average partial effects (APE) were estimated[9] and reveal that being a relative of one of the farm group leaders increased the number of bags received by about 1.5, and this was significant at 1 percent.[10] Given that the first-stage model in this study is a corner solution model, there is no known test for IV strength in nonlinear models. Consequently, we test the strength of our IV by the partial correlation of the "being a relative of the farm group leadership" in the reduced form equation (Ricker-Gilbert et al. 2011). The high t statistic (2.03) and p-value of 0.04 are evidence that the IV is strongly correlated with the endogenous variable. Logically, there is no reason to expect that one's relationship to the farm group president would affect one's participation in the private market after conditioning on other factors. Thus, it is considered appropriately excluded from the second-stage estimations.[11]

[9] This was estimated using the margins command in STATA and is available from the author upon request.

[10] When calculating the APE, the standard errors and p-values were generated using the delta method.

[11] Two additional crude attempts to justify exclusion were made. The first was looking at the correlation coefficient between the IV and the quantity of fertilizer purchased from the private market, which was about 0.03 bags. The second attempt included looking at the correlates of the quantity of fertilizer purchased in the private market by running regressions and including the IV variable in the list of control variables. It was never significantly different from zero.

Table 7.1—First-stage regression results of Tobit model

Bags of subsidized fertilizer	Coefficient	t statistics	P>t
Participated in the voucher program	5.372***	4.090	0.000
Farmer member of a group that purchased fertilizer together	2.394***	2.740	0.006
Holds a leadership position in the village	-0.694	-1.600	0.111
Age of respondent (years)	-0.004	-0.220	0.826
Male (1/0)	0.211	0.630	0.528
Married (1/0)	0.615	1.460	0.146
Years of education	-0.049	-0.750	0.454
Land area (hectares)	-0.058	-0.870	0.386
Related to farm group leadership (Instrument)	***1.716****	***2.030***	***0.042***
Someone in household owned a motorcycle (1/0)	0.247	0.360	0.722
Total livestock units (TLUs)	-0.003	-0.300	0.762
Rents land (1/0)	1.490	1.080	0.282
Bagwai	-	-	-
Takai	-1.106	-0.630	0.528
Dambatta	-0.068	-0.050	0.958
Dala	-2.988*	-1.750	0.080
Karaye	-3.938**	-2.010	0.045
Ungogo	-2.049	-1.340	0.179
Gezawa	3.003	1.280	0.199
Gabasawa	-4.451***	-3.440	0.001
Rano	-8.099***	-3.380	0.001
Kura	-3.843***	-2.690	0.007
Constant	-3.186	-1.530	0.126
N	1,402		
Pseudo R-square	0.06		

Source: Generated by author using STATA.
Note: *, **, and *** indicate p-values significant at 1%, 5%, and 10%, respectively.

To determine whether the subsidized fertilizer in Kano was targeted along poverty lines, the probability of receiving subsidized fertilizer is estimated using a probit model. Table 7.2 presents these results. It confirms that wealth was negatively correlated with participation. Respondents with larger landholdings and those who lived in a household with a motorcycle were less likely to receive subsidized fertilizer. This is consistent with Liverpool-Tasie et al. (2010) and indicates that the voucher program was targeted at poor farmers. However, it also reveals that recipients of subsidized fertilizer outside of the program under study had fewer landholdings and other assets. This indicates that we are in the context where the recipients of subsidized fertilizer tend to be relatively poorer than nonrecipients. This is important because in this case one would expect distortions to the private market to be absent or less than when wealthier farmers receive subsidized fertilizer.

Table 7.2—Determinants of receiving subsidized fertilizer (probit model)

Bags of subsidized fertilizer	Coefficient	z statistics	P>z
Participated in the voucher program	0.824***	3.500	0.000
Farmer member of a group that purchased fertilizer together	0.088	0.400	0.691
Holds a leadership position in the village	-0.083	-0.320	0.747
Age of respondent (years)	0.007	1.390	0.166
Male (1/0)	-0.011	-0.100	0.923
Married (1/0)	-0.114	-0.660	0.511
Years of education	0.051**	2.170	0.030
Land area (hectares)	-0.035**	-2.470	0.014
Related to farm group leadership	-0.159	-0.720	0.474
Someone in household owned a motorcycle (1/0)	-0.821***	-2.800	0.005
Total livestock units (TLUs)	0.004	0.790	0.427
Rents land (1/0)	0.451	1.220	0.223
Constant	1.982	3.060	0.002
Number of observations	1,034		
Pseudo R-square	0.297		

Source: Generated by author using STATA.
Notes: *, **, and *** indicate p-values significant at 1%, 5%, and 10%, respectively.

Next, the generalized residual ($\widehat{gr}_i$) is constructed using the maximum likelihood estimates from the Tobit regression and the inverse Mill's ratio as defined in equation (9). The generalized residual is then included in the second-stage estimation. Our empirical model equation (4) allows unobserved heterogeneity (η_i) to interact with the endogenous explanatory variable. Thus, following Imbens and Wooldrige (2007) and Garen (1984), the generalized residual is also interacted with the quantity of subsidized fertilizer received to recover consistent estimates of (δ) in equation (1). Consequently, in the second-stage we estimate:

$$QFert_{pi} = \eta_i + \beta X_i + \delta QFert_{si} + \rho_1 \widehat{gr}_i + \rho_2 \widehat{gr}_i * QFert_{si} + u_i, \quad (15)$$

where all variables are as earlier defined and ρ_1 and ρ_2 are the coefficients associated with the generalized residual and its interaction with the quantity of subsidized fertilizer received. The significance of these variables in the second-stage results both tests and controls for the endogeneity of the quantity of subsidized fertilizer received (Rivers and Vuong 1988, Smith and Blundel 1986, Vella 1993).

As mentioned earlier, given that our sample sometimes has several respondents per household, standard errors in all estimations are clustered at the household level to account for intrahousehold correlation. Furthermore, to account for the generalized residuals, bootstrap ping at 500 repetitions was done for all estimations (except where stated). For the second-stage estimations of private fertilizer demand, this study explores two options. First, a double hurdle model is estimated. This model explicitly considers the corner solution problem caused by nonparticipation in the private fertilizer market and allows the determinants of selection to be different from the determinants of commercial fertilizer. Given that more than 80 percent of our sample participates in the private commercial market, we do not expect to have very strong corner solution effects. Another argument for the use of a double hurdle in input demand models is that it allows the process that determines the decision to participate to be different from that which determines the extent of participation. Such variables as distance may affect the decision to participate, but it is thought that once the decision to participate has been made, distance should not play a

significant role in the quantity of inputs purchased. However, it is possible that even after the decision to participate has been made, individuals further away from the market (and with sufficient capital) might prefer to buy more (to minimize the average cost of inputs) than a farmer who is closer to the market. Because this study does not see a strong need to distinguish between the processes of participation and the extent of participation (quantity), both the double hurdle model and the Tobit model are estimated for the second stage and results are compared.

Results from the second-stage regressions are displayed in Table 7.3. There is no evidence that the quantity of subsidized fertilizer plays a role in the decision to participate in the private commercial fertilizer market. This is not surprising given the large fraction of participants in the private market. The only variable (apart from the location dummies) that is significantly different from zero at 10 percent or less is the price of fertilizer, which decreases the likelihood of participation, as one would expect. The limited significance of many variables is likely driven by the limited variation in our sample in terms of participation in the private market. Data on fertilizer use in Nigeria have indicated that more than 50 percent of households in Kano reported using some fertilizer (Fadama III Baseline Survey 2010).

However, the fact that so many respondents in our sample participated in the private commercial market in 2009 might be further evidence of the impact of the voucher program on fertilizer availability across the state. Through the vouchers, the program provided a guaranteed market for private suppliers. By nature of the program's implementation, suppliers were required to have some presence in all the LGAs at certain periods to distribute the subsidized fertilizer as determined by the program. If suppliers supplied quantities beyond the amount needed in the program in the various local governments, this could explain the high level of participation revealed in the data.[12] Input suppliers being physically present in the local government could have had significant implications on fertilizer access for many farmers. In addition to just making the product available in areas where input suppliers might have been previously absent, it could have significantly reduced the price paid and/or transportation costs associated with procuring fertilizer.

Table 7.3—Second-stage estimation results of private fertilizer market participation

	Hurdle 1+participation in private market		Hurdle 2 Quantity of fertilizer purchased from market		Tobit estimations	
	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
Number of subsidized bags of fertilizer received	0.1589	0.382	1.001**	0.044	0.826*	0.095
Farmer member of a group that purchased fertilizer together	0.4183	0.237	4.057	0.133	4.1975	0.122
Price of fertilizer	-0.0002*	0.102	0.001	0.32	0.0007	0.513
Distance to main market (km)	0.0104	0.577	-0.264**	0.017	-0.4374**	0.008
Price of maize (NGN/kg)	0.0001	0.439	0.000	0.982	0.0005	0.772
Member of a farm group that gives credit to members	0.2708	0.557	-1.558	0.533	-0.123	0.958
Household size	-0.0553	0.572	1.137*	0.102	1.0663	0.132
Age of respondent (years)	-0.0056	0.540	-0.036	0.461	-0.0433	0.341
Male (1/0)	0.1052	0.515	0.635	0.472	1.1329	0.243
Years of education	0.0279	0.522	0.042	0.856	0.0098	0.965

[12] It should be noted that the extent of participation varies significantly in the sample. Many farmers purchased less than half of a 50 kg bag. The quantity purchased ranges from a third of a 50 kg bag at the lowest 10 percent of private market fertilizer purchases to 12 bags for the highest 10 percent of the distribution.

Table 7.3—Continued

	Hurdle 1+participation in private market		Hurdle 2 Quantity of fertilizer purchased from market		Tobit estimations	
	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
Married (1/0)	0.0607	0.790	-0.445	0.734	-1.0143	0.463
Land area (hectares)	0.0211	0.768	1.077***	0.002	1.0806***	0.003
Uses improved seed (1/0)	-0.2963	0.325	1.402	0.423	1.137	0.501
Rents land (1/0)	-0.0408	0.950	-5.776	0.249	-3.3459	0.47
Someone in household owned a motorcycle (1/0)	-0.2408	0.482	1.406	0.43	0.9589	0.576
Total livestock units (TLUs)	0.0198	0.635	0.103	0.407	0.1291	0.264
Generalized residual	-0.3632	0.243	-0.501	0.818	-0.2807	0.895
Generalized residual *bags of subsidized fertilizer	-0.0117	0.652	-0.143*	0.049	-0.1132	0.115
Constant	-4.9925	0.625	-0.625	0.993	-10.43	0.909
LGA dummies included	YES		YES		YES	
Number of observations	925		880		925	
Pseudo R-square or adjusted correlation coefficient	0.149		0.274		0.040	

Source: Generated by author using STATA.

Notes: *, **, and *** indicate p-values significant at 1%, 5%, and 10%, respectively. 250+ bootstrap replications were run.

Next we focus on the extent of participation in the private market, once the decision to participate has been made. As can be seen in later columns of Table 7.3, the second hurdle estimations reveal evidence of crowding in. Once the decision to participate in the private fertilizer market has been made, the quantity of subsidized fertilizer received significantly increases the quantity of fertilizer purchased in the private market. The results between the Tobit model and the double hurdle model are very similar. This is probably due to the limited corner solution nature of the private fertilizer demand variable in our data. Taking the more conservative effect from the Tobit model, the average marginal effect of 0.826 implies that every bag of subsidized fertilizer received adds an extra 0.8 bag to the mean number of bags of fertilizer purchased in the private market.[13] Both the double hurdle and the Tobit results indicate that receiving subsidized fertilizer crowds in commercial fertilizer by increasing the amount purchased for participants in the commercial market (but not by increasing the probability that farmers participate in the private fertilizer market).

These results are quite large. They appear to indicate that the importance of fertilizer use is not unknown to farmers in Kano. Rather, farmers tend not to have access to the product. The positive effect of subsidized fertilizer on the quantity of fertilizer purchased from the private market (and not on the probability of participating) appears to indicate that one main benefit of the voucher program was ensuring that fertilizer was available at the various LGAs of the states. This probably reduced the costs associated with fertilizer procurement and increased the links between farmers and input suppliers. Thus, these results are consistent with Xu et al. (2009), who found evidence of crowding in where private markets are weak. Although there was active participation in the private fertilizer market in Kano in 2009, anecdotal evidence during data collection indicates that this was not the norm and not the case in previous years. Many farmers claimed that they had not received fertilizer for many years prior to the program. Additional information from the implementing agency (IFDC) indicates that input suppliers in Kano sold quantities larger than the amount sold through the voucher program. The voucher program provided an

[13] This average marginal effect is the marginal effect of the quantity of subsidized fertilizer calculated at the mean quantity of subsidized fertilizer received using STATA.

incentive to input suppliers through the guaranteed demand from the voucher as well as through providing a guaranteed profit margin. Thus, they indirectly subsidized the transaction costs associated with fertilizer distribution.[14]

Other factors that affect the extent of participation in the private market are distance, household size, and land area, which is not unusual. Apart from facing higher transaction costs for input access, respondents located far away from the major trading markets are likely to face lower output costs (farm gate) and higher transaction costs to market their output. Larger landholdings indicate potentially larger quantity of fertilizer needed, and larger household size could indicate higher need for the benefits of fertilizer on output or could indicate more labor available for farming. The interaction term between the generalized residual and the quantity of subsidized fertilizer received is endogenous and corrected for in the second-stage estimation model.

This study finds that recipients of subsidized fertilizer in Kano in 2009 tended to have fewer assets than nonrecipients. Within this framework, results reveal that there is less likely to be crowding out effects of a fertilizer subsidy. Ricker-Gilbert et al. (2011) found evidence of crowding out when wealthier farmers benefited more from the subsidy. However, this study finds evidence of crowding in where less wealthy farmers tended to receive subsidized fertilizer. Consequently, this study finds that voucher programs could be effective ways to stimulate the development of private commercial markets in rural areas. Through providing input suppliers a guaranteed market in rural areas, input suppliers have an incentive to establish sales depots in rural, more distant locations than they might ordinarily do so (given demand uncertainty and costs of setting up shop). Thus, voucher programs could assist in the creation of links between farmers and input suppliers. Such an approach to developing private input markets has potential sustainability advantages. As input suppliers become aware of the extent of demand in various rural locations, they will naturally satisfy those markets even in the absence of the voucher program. However, the success of this will most likely depend on the transaction costs associated with the distribution of inputs to rural farmers in the absence of the program. Where poor infrastructure persists and the voucher program or other support to cushion associated costs for input suppliers is absent, the transaction costs associated with providing fertilizer increase; thus, farmers in distant and less accessible locations could still potentially face challenges accessing fertilizer.

[14] Studies have shown transportation costs to account for about twenty five percent of fertilizer costs in West Africa (Bumb et al. 2012).

8. FURTHER CONSIDERATIONS

The results have shown evidence of crowding in of private commercial fertilizer in Kano. It is believed that this is largely driven by the fertilizer voucher program implemented in the state in 2009. However, as discussed earlier, the data revealed that alternative sources of subsidized fertilizer existed in Kano in 2009. Table 7.2 presents the characteristics of farmers who received subsidized fertilizer in 2009 estimated using a binary response probit model. The results shows that even after controlling for participating in the 2009 voucher program in Kano, those who received subsidized fertilizer in 2009 tended to have smaller landholdings and fewer assets. This indicates that participants in both of the subsidy programs tended to be poorer. However, to confirm that the voucher program played a significant role in the crowding in effects found, we conduct the entire analysis again for only those who participated in the 2009 voucher program. Table 8.1 shows that the crowding in results are maintained and even stronger. Relevant variables from the analysis with the entire sample also maintain.

Table 8.1—Second-stage estimation results of private fertilizer market participation using only 2009 voucher program participants

	Hurdle 1+		Hurdle 2		Tobit estimations	
	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
Number of subsidized bags of fertilizer received	-0.010	0.855	2.422**	0.048	2.328*	0.067
Farmer member of a group that purchased fertilizer together	-	-	7.121	0.113	6.605	0.140
Price of fertilizer	0.000	0.607	0.003	0.276	0.003	0.341
Distance to main market (km)	-0.017	0.380	-0.727*	0.063	-0.743*	0.055
Price of maize (NGN/kg)	0.000	0.115	-0.003	0.631	-0.004	0.520
Member of a farm group that gives credit to members	1.163	0.046	-1.900	0.677	-0.457	0.917
Household size	0.058	0.647	1.812	0.107	1.585	0.128
Age of respondent (years)	0.001	0.887	-0.053	0.479	-0.061	0.418
Male (1/0)	-0.004	0.983	0.053	0.967	0.678	0.586
Years of education	0.028	0.521	0.183	0.549	0.081	0.788
Married (1/0)	-0.257	0.161	0.222	0.914	-0.207	0.913
Land area (hectares)	0.003	0.876	1.136***	0.003	1.125**	0.007
Uses improved seed (1/0)	-0.355	0.293	2.582	0.315	1.743	0.472
Rents land (1/0)	0.303	0.550	-12.059	0.181	-8.382	0.328
Someone in household owned a motorcycle (1/0)	-0.452	0.371	-0.787	0.735	-1.813	0.412
Total livestock units (TLU)	0.021	0.010	0.114	0.484	0.146	0.500
Generalized residual	-0.130	0.150	-1.637	0.151	-1.656	0.147
Generalized residual *bags of subsidized fertilizer	0.008	0.088	-0.020	0.325	-0.017	0.415
Constant	15.671	0.061	179.374	0.634	220.936	0.519
Number of observations	710		578		599	
Pseudo R-square or adjusted correlation coefficient	0.149		0.31		0.04	

Source: Generated by author using STATA.

Notes: *, **, and *** indicate p-values significant at 1%, 5%, and 10%, respectively. +250 bootstrap replications were run.

To account for diminishing returns to fertilizer application because multiple members of a household could have received subsidized fertilizer, the double hurdle and Tobit models are also run, including a dummy indicating whether the respondent belonged to a family with multiple recipients of subsidized fertilizer. The crowding in results maintain (shown in Table 8.2). Having multiple recipients of subsidized fertilizer did not significantly affect the quantity of fertilizer purchased from the private market. However, accounting for multiple recipients of subsidized fertilizer slightly reduced the magnitude of the effect of subsidized fertilizer on private purchases from one bag to about 0.88 bag in the double hurdle model and from 0.826 to 0.819 in the Tobit model.

Table 8.2—Second-stage estimation results of private fertilizer market participation accounting for multiple participants per household

	Hurdle 1+		Hurdle 2		Tobit estimations	
	Coefficient	**p-value**	**Coefficient**	**p-value**	**Coefficient**	**p-value**
Number of subsidized bags of fertilizer received	0.153	0.418	0.884*	0.099	0.819*	0.093
Farmer member of a group that purchased fertilizer together	0.413	0.245	4.029	0.132	4.194*	0.100
Price of fertilizer	0.000	0.113	0.001	0.302	0.001	0.434
Distance to main market (km)	0.010	0.584	-0.265**	0.016	0.151	0.792
Price of maize (NGN/kg)	0.000	0.457	0.000	0.956	0.001	0.861
Member of a farm group that gives credit to members	0.269	0.568	-1.566	0.532	-0.484	0.836
Household size	-0.057	0.562	1.106	0.107	0.945	0.131
Age of respondent (years)	-0.006	0.532	-0.037	0.448	-0.043	0.338
Male (1/0)	0.110	0.500	0.729	0.419	1.152	0.209
Years of education	0.028	0.527	0.034	0.882	0.000	0.999
Married (1/0)	0.066	0.776	-0.349	0.792	-0.679	0.615
Land area (hectares)	0.021	0.774	1.070***	0.002	1.076***	0.004
Uses improved seed (1/0)	-0.295	0.335	1.376	0.430	0.864	0.599
Rents land (1/0)	-0.037	0.955	-5.675	0.253	-3.562	0.430
Someone in household owned a motorcycle (1/0)	-0.243	0.474	1.425	0.424	0.698	0.690
Total livestock units (TLUs)	0.020	0.638	0.101	0.417	0.127	0.249
Generalized residual	-0.341	0.308	0.019	0.994	0.135	0.955
Generalized residual * bags of subsidized fertilizer	-0.011	0.667	-0.138*	0.060	-0.125*	0.065
Multiple recipients of subsidized fertilizer in the household (1/0)	0.055	0.746	1.057	0.269	1.249	0.163
Constant	-4.868	0.639	1.057	0.269	-63.984	0.845
LGA dummies included	YES		YES		YES	
Number of observations	925		880		925	
Pseudo R-square or adjusted correlation coefficient	0.1487		0.273		0.036	

Source: Generated by author using STATA.

Notes: *, **, and ** indicate p-values significant at 1%, 5%, and 10%, respectively. +250 bootstrap replications were run.

Next, this study also considers the heterogeneity of crowding in effects across farmer wealth and asset levels. We consider the heterogeneous effects of the quantity of subsidized fertilizer on farmer participation in the private market across the various quartiles of the distribution of various assets, landholdings, total livestock units, and education. The first panel of table 8.3 shows that crowding in effects did not appear to differ much across asset categories. Although farmers with larger landholdings purchased more fertilizer from the market, the effect of the quantity of subsidized fertilizer received on this amount was not significantly different for households across the different quartiles of landholdings. Similarly, we do not find significant variation across households with different levels of education (second panel of table 8.3). Across the distribution of livestock assets, we find that compared to households in the lowest quartile of livestock assets, the extent of participation was lower for households in the second and third quartiles, though this was only significant at 5 percent or below for those in the third quartile (third panel of table 8.3). For households in the largest quartile, the effect of quantity of subsidized fertilizer appears to be positively correlated with the quantity purchased from the private market, but this is not statistically significant. Consequently, it appears that although wealthier farmers might be more likely to participate in the private commercial fertilizer market, we do not find strong evidence that the effect of access to subsidized fertilizer has a differential effect on this decision across respondents with different landholdings.

Table 1.3—The effect of the quantity of subsidized fertilizer on private fertilizer market participation across wealth quartiles

	Double Hurdle		**Tobit estimations**	
	Coefficient	**p value**	**Coefficient**	**p value**
Lowest quartile of land holdings	-	-	-	-
Second quartile of land holdings	0.319	0.188	0.338	0.158
Third quartile of landholdings	0.316	0.355	0.471	0.157
4th quartile of landholdings	0.414	0.435	0.383	0.467
	Double Hurdle		**Tobit estimations**	
	Coefficient	**p value**	**Coefficient**	**p value**
Lowest quartile of total livestock units	-	-	-	-
Second quartile of total livestock units	-0.109	0.596	-0.046	0.802
Third quartile of total livestock units	-0.494	0.031	-0.525	0.023
Fourth quartile of total livestock units	0.349	0.502	0.262	0.592
	Double Hurdle		**Tobit estimations**	
	Coefficient	**p value**	**Coefficient**	**p value**
Lowest quartile of years of education	-	-	-	-
Second quartile of years of education+	-	-	-	-
Third quartile of years of education	1.113	0.119	1.029	0.126
Fourth quartile of years of education	0.176	0.405	-0.051	0.847

Source: Generated by author using STATA

Note: *,** and ** indicate p values significant at 1%, 5% and 10% respectively

9. CONCLUSION

Input subsidies have returned to take a prominent place in the agricultural development and food security agenda. This return calls for temporary and well-targeted subsidy approaches that ensure that the poor smallholder farmers receive inputs and also helps develop private input markets. Consequently, there is an increase in the use of input vouchers and a subsequent urgent need for evidence on the effect of these programs on farmer access to the input as well as on the private commercial fertilizer markets.

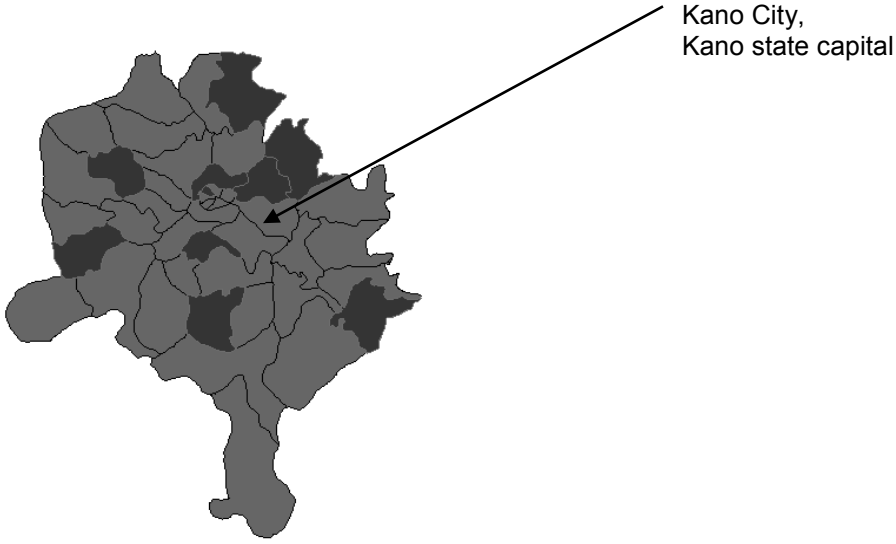
This study contributes to meeting this need by estimating the effect of a fertilizer voucher program in Nigeria on farmer participation in the private fertilizer market. Using a double hurdle model (to account for the corner solution nature of fertilizer demand) and a control function approach to address the endogeneity of the quantity of subsidized fertilizer received by farmers, this study explores the effect of increasing access to subsidized fertilizer on farmer participation in the private fertilizer market in Kano, Nigeria. The study finds evidence that farmers who participated in the 2009 voucher program tended to have fewer assets than nonparticipants. Within this context, the study finds that although receiving subsidized fertilizer did not appear to increase the probability of participating in the private fertilizer market, once the decision to participate had been made, every bag of subsidized fertilizer increased the quantity of fertilizer purchased from the private market by 0.8 bag. Thus, the study found evidence of crowding in rather than crowding out.

The generally high participation rate among respondents in the private market in 2009 appears to indicate that the importance of fertilizer use is known to farmers in Kano but access to the product is the main challenge. The study results indicate that one main benefit of the 2009 voucher program was to develop links between rural farmers and input suppliers. The establishment of retail points closer to farmers ensured that fertilizer was available in several rural locations probably previously unreached or reached with very high transaction costs. These results indicate that where fertilizer subsidies are well targeted to the poor, there is less likely to be distortionary effects of fertilizer subsidies. Furthermore, where private fertilizer markets are weak, there could be significant gains from the temporary use of voucher programs to create links between input suppliers and farmers. Given that the pilot program cushioned some of the transaction costs associated with reaching some remote locations, it is important that governments fulfill their role to provide the necessary infrastructure to minimize these costs so that when government- or development organization–led voucher programs end, the private sector can still profitably meet the demand of rural farmers. Furthermore, as subsidy programs are expanded, increased attention has to be paid to the targeting mechanism to ensure that there is no elite capture of the process as the program becomes better understood in the rural areas.

APPENDIX: SAMPLE SELECTION

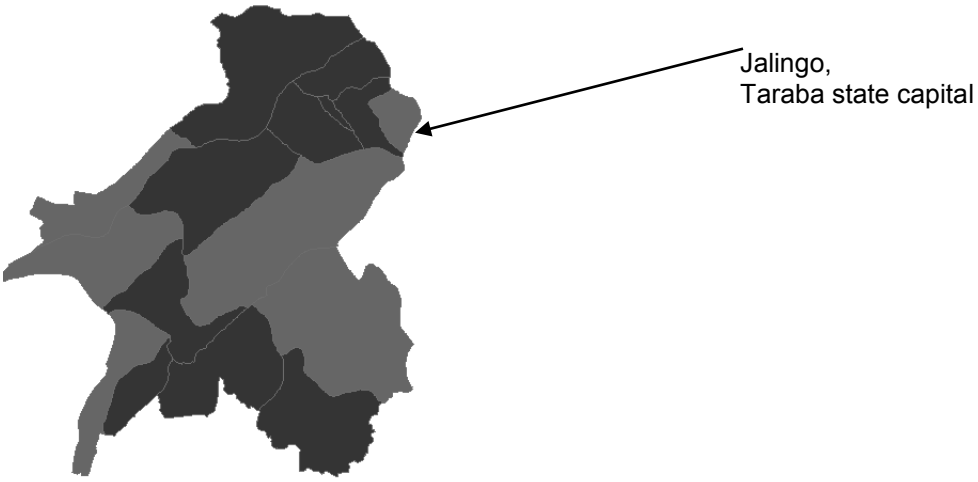
The domain for this analysis is smallholders in Kano and Taraba states, the subpopulations for which we want survey estimates of the outcome of participation in the voucher program. We randomly selected 10 local government areas (LGAs) each in both states. To ensure a level of generalization was possible from our survey, we confirmed that the 10 LGAs selected represented potential LGA variation, such as proximity to state capitals (Kano City and Jalingo), population, and accessibility road availability and quality, as can be seen in Figures A.1 and A.2.

Figure A.1—Surveyed local government areas in Kano



Source: Generated by author
Note: Surveyed LGAs are highlighted

Figure A.2—Surveyed local government areas in Taraba



Source: Generated by author.
Note: Surveyed LGAs are highlighted.

Our measurement units are the households and household members surveyed in both states. The key variables of interest that were used to determine the minimum sample size necessary for our analysis are quantity of subsidized fertilizer used as well as price of fertilizer purchased. We used the formula given in the sampling guide provided by the Food and Nutrition Technical Assistance (FANTA) for calculating the minimum necessary sample size. Our calculations were done to ensure with 95 percent confidence that estimated differences between program participants and nonparticipants (or participants over time) are not purely by chance and to have 80 percent confidence that an actual change or difference will be detected (power of the test) (Magnani 1997).

Data on fertilizer consumption by state was not readily available. Thus, our minimum sample size requirements were estimated using approximations from available data as follows: For quantity of fertilizer used, Banful and Olayide (2009) reveal that the average quantity of fertilizer that farmers in Kano and Taraba states would have if subsidized fertilizer were equally distributed across households would be 97 kg and 117 kg, respectively. However, Nagy and Edun (2002) estimate that only about 30 percent of subsidized fertilizer reaches small farmers at the subsidized price. Thus, we can estimate that farmers in Kano and Taraba on average receive about 29.1 kg and 35.1 kg each of subsidized fertilizer through the traditional distribution mechanism. The goal of the voucher program was to increase the quantity of subsidized fertilizers farmers received through the use of vouchers rather than the previous government-controlled distribution mechanism. Participating farmers in Kano and Taraba should have received three bags (150 kg) and four bags (200 kg), respectively. Using these figures, we can estimate that the sample size needed to identify the changes due to the program required samples of between 30 and 35 households on the quantity of subsidized fertilizer used in each state using the following FANTA formula:

$$n = D[(Z\alpha+Z\beta)^2*([\![sd]\!]_1^2+[\![sd]\!]_2^2)/(X2 - X1)^2], \quad (A.1)$$

where n is the required minimum sample size per survey round or comparison group; D is the design effect for cluster surveys indicating the factor by which the sample size for a cluster sample would have to be increased in order to produce survey estimates with the same precision as a simple random sample (we use the default value of 2 as suggested by Magnani 1997); $X1$ is the estimated level of fertilizer a household has access to prior to the program; $X2$ is the expected level of subsidized fertilizers households have access to after participation; $sd1$ and $sd2$ are the expected standard deviations for the indicators for the comparison groups being compared; $Z\alpha$ is the z-score corresponding to the degree of confidence with which it is desired to be able to conclude that an observed change of size ($X2 - X1$) would not have occurred by chance (statistical significance); and $Z\beta$ is the z-score corresponding to the degree of confidence with which it is desired to be certain of detecting a change of size ($X2 - X1$) if one actually occurred (statistical power).

For the standard deviation, we used estimates on the ratio of mean to standard deviation of fertilizer use from a subsample of largely cereal-producing households in another northern state, Kaduna, in 2008 (IFPRI 2008). The mean to standard deviation ratio was 1.07. This ratio was applied to our mean quantity of subsidized fertilizer before and after the voucher program to get the associated standard deviations. Even if there was no diversion of subsidized fertilizer in both states, applying the same formula indicates that we need between 170 and 250 respondents in Taraba and Kano, respectively.

For further confirmation, the minimum sample calculation also was conducted using secondary data from other studies. A 2007 study cites 41 kg per hectare (ha) as the average fertilizer use for Kano State (Maiangwa et al. 2007). Discussions with Kano's Agricultural research development authority informs that average land size in Kano of about 1.9 ha . This amounts to about 78kg per household. Using the same standard deviation as above, we estimated the new minimum size necessary to satisfactorily capture a change in quantity of fertilizer used from 78 kg per household to about 150 kg (the three subsidized bags to be available through the program). It is estimated that a sample size of 118 is necessary.

For price of fertilizer, we used the August 2009 price of urea (that was the date at which about 80 percent and 90 percent of the vouchers had been distributed in Taraba and Kano, respectively). The price of urea at Dawanau market in Kano was about NGN 3,200 per 50 kg bag (NGN64/kg). The vouchers were individually worth a total value of NGN 2,000 per 50 kg bag. Thus, the benefit of receiving the voucher should translate to a NGN 2,000 difference in the price of urea. Using this in the above formula to calculate the minimum sample size with standard deviation calculated again using the ratio of the mean to standard deviation of prices paid by farmers in Kaduna, we estimate that the minimum sample size would be about 80 households in Kano. Recognizing that farmers in more remote rural areas are likely to pay higher prices for their fertilizer, we simulated the price estimates and find that even if urea prices were 50 percent higher in the rural areas (NGN 4,500 per bag), the minimum sample size would be about 210.

Solely based on population, our sample should be composed of 80 percent of households in Kano and 20 percent in Taraba. However, to ensure adequate number of full respondents per state, the population difference of our 1,000 households between the two states is reflected by a 640/360 split, which reflects the state proportions within the total voucher program target group and is greater than the minimum desired sample size based on the most demanding sample size requirements based on earlier discussed calculations. Consequently, we surveyed 1,000 households; 640 in Kano and 360 in Taraba. The respondents were largely household heads, their spouses, other adult household members, and for a few questions, children and youth in the household.

REFERENCES

Banful, A. 2010. Old Problems in New Solutions? Politically Motivated Allocation of Program Benefits and the "New" Fertilizer Subsidies. IFPRI Discussion Paper 1002. Washington, DC: International Food Policy Research Institute.

Banful, A. B., and O. Olayide. 2010. Perspectives of Varied Stakeholders in Nigeria on the Federal and State Fertilizer Subsidy Programs. IFPRI Nigeria Strategy Support Program Working Paper. Washington, DC: International Food Policy Research Institute.

Bellemare, M., and C. Barrett. 2006. "An Ordered Tobit Model of Market Participation: Evidence from Kenya and Ethiopia." *American Journal of Agricultural Economics* 88 (2): 324–337.

Bumb, B. L., M. Johnson, and P. A. Fuentes. 2012. *Improving Regional Fertilizer. Markets in West Africa*. IFPRI Policy Brief 20. Washington, DC: International Food Policy Research Institute.

Cameron, A. C., and P. K. Trivedi. 2005. *Microeconometrics, Methods and Applications*. New York: Cambridge University Press.

Cameron, A.C., and P. K. Trivedi. 2009. Microeconometrics Using STATA. College Station, TX: Stata Press.

Coady, D. P. 1995. "An Empirical Analysis of Fertilizer Use in Pakistan." *Econometrica* 62 (246): 213–224.

Crawford, E. W., T. J. Jayne, and V. Kelly. 2006. "Alternative Approaches for Promoting Fertilizer Use in Africa."World Bank Agriculture and Rural Development Discussion Paper 22. Washington, DC: World Bank.

Croppenstedt, A., M. Demeke, and M. Meschi. 2003. "Technology Adoption in the Presence of Constraints: The Case of Fertilizer Demand in Ethiopia." *Review of Development Economics* 7 (1): 58–70.

de Janvry, A., M. Fafchamps, and E. Sadoulet. 1991. "Peasant Household Behaviour with Missing Markets: Some Paradoxes Explained." *The Economic Journal* 101 (409): 1400–1417.

Donovan, G. 2004. *Fertilizer Subsidy in Sub-Saharan Africa: A Policy Note*. Draft Paper. Washington, DC: World Bank.

Dorward, A. 2009. "Rethinking Agricultural Input Subsidy Programmes in a Changing World." Paper prepared for the Trade and Markets Division of the Food and Agriculture Organization of the United Nations and presented at School of Oriental and African Studies. April, 2009.

Duflo, E., M. Kremer, and J. Robinson. 2011. "Nudging Farmers to Use Fertilizer: Theory and Experimental Evidence from Kenya." *American Economic Review* 101 (6): 2350–2390.

Ellis, F. 1992. *Agricultural Policies in Developing Countries*. Cambridge, UK: Cambridge University Press.

Fadama III Baseline Survey. 2010. Dataset collected by the Fadama Development Project, a World Bank–funded project across Nigeria's 36 states.

Garen, J. 1984. "The Returns to Schooling: A Selectivity Bias Approach with a Continuous Choice Variable." *Econometrica* 52 (5): 1199–1218.

Gregory, I. 2006. "The Role of Input Vouchers in Pro-Poor Growth." Selected sections from a background paper prepared for the African Fertilizer Summit, Abuja, Nigeria, June 9–13.

Heckman, J., R. LaLonde, and J. Smith. 1999. "The Economics and Econometrics of Active Labor Market Programs." In Handbook of Labor Economics. Vol. 3, edited by O. Ashenfelter and D. Card, 1865–2097. Amsterdam, Netherlands: North Holland Publishing.

Holloway, G., C. Barrett, and S. Ehui. 2005. "The Double Hurdle Model in the Presence of Fixed Costs." *Journal of International Agricultural Trade and Development* 1 (1): 17–28.

Holloway, G., S. Ehui, and A. Teklu. 2008. "Bayes Estimates of Distance-to-Market: Transactions Costs, Cooperatives and Milk-Market Development in the Ethiopian Highlands." *Journal of Applied Econometrics* 23: 683–696.

Imbens, G., and J. Wooldridge. 2007. "What's New in Econometrics?" Summer Institute 2007. Accessed January 5, 2012. www.nber.org/minicourse3.html.

International Fertilizer Development Center (IFDC). 2009. Update of fertilizer supply and demand –Sub Saharan Africa. Presentation at the IFA Africa Forum, Cairo –Egypt, February 2009.

International Fertilizer Development Center (IFDC). 2010. Project Implementation Manual (PIM) for 2009 Fertilizer Voucher Programme in Kano and Taraba States. Washington, DC: IFDC.

International Fertilizer Development Center (IFDC). 2011. "Fertilizer Reaching Farmers' Hands." Accessed April 1, 2012.www.ifdc.org/Changing_Lives/Changing_Lives_Case_Studies/Fertilizers_Reaching_Farmers_Hands, _Nigeria_Ferti.

Key, N., E. Sadoulet, and A. de Janvry. 2000. "Transactions Costs and Agricultural Household Supply Response." *American Journal of Agricultural Economics* 82 (2): 245–59.

Liverpool, L. S. O., and A. Winter-Nelson. 2010. "Poverty Status and the Impact of Formal Credit on Technology Use and Wellbeing Among Ethiopian Smallholders." *World Development* 38 (4): 541–554.

Liverpool-Tasie, L. S. O., A. B. Banful, and B. Olaniyan. 2010. An Assessment of the 2009 Fertilizer Voucher Program in Kano and Taraba, Nigeria. IFPRI Nigeria Strategy Support Program Working Paper 17. Washington, DC: International Food Policy Research Institute.

Longley, C., R. Kachule, M. Madola, I. Maposse, B. Araujo, T. Kalinda, and H. Sikwibele. 2003. Agricultural Input Vouchers: Synthesis of Research Findings from Malawi, Mozambique, and Zambia. Food, Agriculture and Natural Resources Policy Analysis Network (FANRPAN). Pretoria, South Africa. Retrieved from: www.fanrpan.org/documents/d00236/Agricultural_Input_Vouchers_SA.pdf

Magnani Robert, 1997. *Sampling Guide.* Food and Nutrition Technical Assistance (FANTA) publication, December 1997.

Maiangwa, M.G, Ogungbile, , A.O., Olukosi, J.O. and Atala, T.K(2007). Adoption of Chemical Fertilizer for Land Management in the North-West Zone of Nigeria Tropical Agricultural Research and Extension, Vol 10 (2007).

Minot, N., and T. Benson. 2009. *Fertilizer Subsidies in Africa: Are Vouchers the Answer?* IFPRI Policy Brief 60. Washington, DC: International Food Policy Research Institute.

Morris, M., V. A. Kelly, R. J. Kopicki, and D. Byerlee. 2007. *Fertilizer Use in African Agriculture: Lessons Learned and Good Practice Guidelines*. Washington, DC: World Bank.

Nagy, J. G., and O. Edun. 2002. Assessment of Nigerian Government Policy and Suggested Alternative Market Friendly Policies. Draft, September 26, 2002. Washington, DC: International Fertilizer Development Center.

National Bureau of Statistics (NBS). 2009. Annual Abstract of Statistics 2009. Abuja.

National Population Commission, Nigeria. 2006. National Population Census. Accessed April 1, 2012. www.population.gov.ng/index.php?option=com_content&view=article&id=89.

Ricker-Gilbert, J., T. S. Jayne, and E. Chirwa. 2011. "Subsidies and Crowding Out: A Double-Hurdle Model of Fertilizer Demand in Malawi." *American Journal of Agricultural Economics* 93 (1): 26–42.

Rivers, D., and Q. H. Vuong. 1988. "Limited Information Estimators and Exogeneity Tests for Simultaneous Probit Models." *Journal of Econometrics* 39 (3): 347–366.

Roy, A. 1951. "Some Thoughts on the Distribution of Earnings." *Oxford Economic Papers* 3 (2): 135–145.

Sachs, Jeffrey (2004) "The Case for Fertilizer Subsidies for Subsistence Farmers." Working Paper, the Earth Institute at Columbia University.

Sadoulet, E., and A. de Janvry. 1995. *Quantitative Development Policy Analysis*. Baltimore, MD: Johns Hopkins University Press.

Schultz, T. W. 1964. *Transforming Traditional Agriculture*. New Haven, CT: Yale University Press.

Singh, I., L. Squire, and J. Strauss. 1986. Agricultural Household Models. Baltimore, MD: Johns Hopkins University Press.

Smith, R. J., and R. W. Blundell. 1986. "An Exogeneity Test for a Simultaneous Equation Tobit Model with an Application to the Labor Supply." *Econometrica* 50 (3): 679–685.

United States Agency for International Development (USAID). 2008. A Study of the Cowpea Value Chain in Kano State, Nigeria, form a pro-poor and gender perspective. Research report under the USAID (GATE) project. Accessed on February 1, 2012 from www.nigeriamarkets.org/files/GATE_Cowpeas_Final[1].pdf

Vella, F. 1993. "A Simple Estimator for Simultaneous Models with Censored Endogenous Regressors." *International Economic Review* 34 (2): 441–457.

Winter-Nelson, A., and A. Temu. 2005. "Impacts of Prices and Transactions Costs on Input Usage in a Liberalizing Economy: Evidence from Tanzania." *Agricultural Economics* 3 (3): 243–253.

World Bank. 2008. World Development Indicators. Accessed March 20, 2012. http://data.worldbank.org/data-catalog/world-development-indicators.

World Bank. 2010. World Development Indicators. Accessed May 12, 2012. http://data.worldbank.org/data-catalog/world-development-indicators.

Wooldridge, J. M. 2008. Quasi-Maximum Likelihood Estimation and Testing for Nonlinear Models with Endogenous Explanatory Variables. Working Paper. Michigan State University

Xu, Z., W. J. Burke, T. S. Jayne, and J. Govereh. 2009. "Do Input Subsidy Programs 'Crowd In' or 'Crowd Out' Commercial Market Development? Modeling Fertilizer Demand in a Two-Channel Marketing System." *Agricultural Economics* 40 (1): 79–94.

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