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Spillover Effects of Targeted Subsidies

An Assessment of Fertilizer and Improved Seed Use in Nigeria

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ABSTRACT

Though there is increasing evidence of the availability and potential of new agricultural technologies in Africa south of the Sahara, effective demand for them is still low. A recent refocus on increasing farmers' use of modern technologies such as improved seed and chemical fertilizer has led to a resurgence of input subsidies for these products in many developing countries. One popular mechanism currently in use is input vouchers. Targeted input vouchers are intended to simultaneously improve the targeting of subsidies and develop demand in private markets. While there is growing evidence of the impact of targeted subsidies on private input demand, as far as we are aware no empirical studies have examined the spillover effects of targeted subsidies for just one input on the use of other complementary inputs with which there is low substitutability. Consequently, this study begins to fill this gap by exploring the effect of increasing access to subsidized fertilizer on farmers' use of improved seed in Nigeria. Using a control function approach within a limited dependent variable framework, we explore the effect of receiving subsidized fertilizer on a farmer's likelihood of using improved seed. The study finds evidence that increased access to subsidized fertilizer increased the likelihood of farmers using improved seed in Kano, Nigeria. This indicates that farmers are re-optimizing their use of other inputs in response to increasing availability of one input. This complicates the ability to isolate the returns to any one input when evaluating programs targeted at just one input. Our results were robust to various model specifications and indicate that there is a clear link between farmers' use of improved seed and fertilizer in Kano, which could be leveraged in the development of input subsidy programs across Africa south of the Sahara.

Keywords: input vouchers, targeted subsidies, improved seed use, fertilizer use, Nigeria, Africa south of the Sahara

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1. INTRODUCTION

Africa south of the Sahara (SSA) is characterized by an agricultural technology paradox: increasing availability of new technologies with low effective demand for them. As of the year 2000, adoption of modern varieties of maize was estimated to be 17 percent of total area harvested in SSA, compared to 90 percent in East and Southeast Asia and the Pacific and 57 percent in Latin America and the Caribbean (Golan, Morris, and Byerlee 2005). Similarly, fertilizer consumption rates across SSA remain low. In 2009, farmers in SSA used only 10.5 kilograms (kg) of fertilizer per hectare (ha) on average, compared with an average of 176 kg of fertilizer per ha in South Asia and 92.2 kg per ha in Latin America and the Caribbean (World Bank 2009).

Persistently low use of modern technologies such as improved seed and chemical fertilizer has led to a resurgence of input subsidies in many developing countries. In contrast to previous fertilizer subsidies, these second-generation programs have focused on voucher schemes to target inputs to poor farmers in a manner that stimulates the development of private input markets. Such voucher schemes are now widespread. Malawi has used input vouchers in its nationwide fertilizer and seed subsidy programs since 1999. Afghanistan (in 2001), Mozambique (in 2002), Zambia (in 2003), Kenya (in 2006), Tanzania (in 2008), Nigeria (in 2004 and since 2008), and Ghana (in 2008 and 2009) present further examples of countries where input vouchers have been recently used (Banful 2010; Longley et al. 2003; Gregory 2006; Minot and Benson 2009; IFDC 2010).

Limited evidence of the effects of targeted vouchers on farmer outcomes exists, and even fewer studies have empirically explored the effects of targeted subsidies on private input markets. A few exceptions are Ricker-Gilbert, Jayne, and Chirwa (2011); Mason (2011); Xu et al. 2009; and Liverpool-Tasie (2012), who examine the effects of fertilizer subsidies on private fertilizer markets in Malawi, Zambia, Zambia (in an earlier period), and Nigeria, respectively. While these studies provide information on the contexts within which targeted fertilizer subsidies may discourage or encourage farmers' participation in the private fertilizer market, they do not consider the potential spillover effects of subsidizing one input on farmers' use of other complementary inputs[1]. Consequently, this study contributes to the existing literature by focusing on how subsidizing one input (alone) can affect farmer use of other complimentary inputs. We explore the effect of increasing farmers' access to subsidized fertilizer on their use of other inputs; particularly improved seed in Nigeria. Finding a strong spillover effect on the use of complementary inputs would imply that it might be cost-effective to provide vouchers for just one input. However, the absence of such spillovers would confirm the need to provide tied vouchers in order to achieve the full benefits of either input (seed or fertilizer).

Understanding the effects of targeted fertilizer subsidies on the use of improved seed in Nigeria could shed light on the extent (if any) of spillover effects of the reduction in the cost of one input on farmers' use of another. Given the high costs associated with voucher schemes and subsidy programs in general, understanding where and whether added costs (such as providing both seed and fertilizer vouchers) could be minimized can contribute to more efficient use of limited government and donor funds. The results of this study are also important because failure to account for possible spillover effects might lead policymakers to underestimate the effect of targeted subsidy programs. As countries adopt input vouchers or scale up existing programs, this study highlights the importance of considering the complementarity between agricultural technologies in the design of agricultural input programs as well as in their evaluation.

The rest of the paper is organized as follows. Section 2 provides a brief review of the literature on complementary inputs with limited substitutability. It also discusses the 2009 voucher program in Kano state, linking its design and implementation to the potential effects it could have on input market development. The third section discusses the analytical framework for the study. The fourth section describes the data, while the fifth provides the study results. Section 6 concludes.

[1] In this study, the term spillover refers to the unintended effects of a targeted subsidy for one input (only) on farmers use of additional complementary inputs. In this case we are looking at how subsidized fertilizer affected the likelihood of improved seed use.

2. BACKGROUND AND OVERVIEW OF THE 2009 VOUCHER PROGRAM IN KANO

The question of how best to promote uptake or adoption of agricultural technology remains a longstanding policy issue for developing countries. This is particularly true in SSA where adoption of new yield-improving technologies has lagged behind that of Asia and other rain fed regions (Gollin, Morris, and Byerlee 2005).Given that increasing evidence of availability of new technologies in SSA occurs alongside low effective demand for them, the adoption process has remained a debatable issue in the literature. Significant effort is being made to understand the technology-adoption decision making process of smallholders and the factors that serve as barriers to agricultural technology adoption (Jack 2011; Tripp 2003; Schiff and Valdés 2002; Liverpool-Tasie and Winter-Nelson 2012).

Iin addition to the traditional challenges such as macroeconomic policy, input and output market inefficiencies (due to poor infrastructure), land and labor market inefficiencies, insufficient access to credit, informational gaps, and risk market inefficiencies (Jack 2011;Bandiera and Rasul 2006; Liverpool-Tasie and Winter-Nelson 2012), the role of access to complementary inputs is also discussed (Smale, Just, and Leathers 1994; Nkonya, Schroeder, and Norman1997; Kaliba, Verkuijl, and Mwangi 2000). While some studies conclude that the decisions to adopt improved seed and fertilizer are made simultaneously (for example, Smale, Just, and Leathers 1994), others show that the decisions are made in a sequential manner (Kaliba, Verkuijl, and Mwangi2000). Regardless, the availability of complementary inputs could play a significant role in a farmer's decision to use certain technologies. Furthermore, sufficient evidence about the importance of fertilizer access in maximizing the returns to improved seed and its consequent adoption has been demonstrated in Kafle's (2010) review of 21 studies examining the adoption of improved maize varieties in developing countries.

Following the 2006 resolve taken by the leadership in Africa (through the Abuja Declaration) to improve the use of fertilizer in order to achieve the region's Green Revolution objectives, many African governments adopted the resolutions and pledged to undertake strategic investments and policy reforms to improve access to and use of quality agricultural inputs. The Federal Government of Nigeria (FGN) also decided to disengage from direct procurement of fertilizer in favor of promoting private-sector participation. Corresponding to this commitment, the FGN piloted a fertilizer voucher system in selected Nigerian states as an alternative way of administering the fertilizer subsidy.

Though the factors that drive technology adoption as well as the effectiveness of targeted input subsidy programs (such as input vouchers) are increasingly being analyzed, no other study that we are aware of has considered the spillover effects of targeted subsidy programs on complementary input markets. Several studies have found evidence that targeted government subsidy programs crowd out private markets (Xu et al. 2009; Ricker-Gilbert, Jayne, and Chirwa 2011), while others have found them to crowd in private market participation (Xu et al. 2009; Liverpool-Tasie 2012). Given the high costs of programs to increase farmers' access to and use of improved inputs, understanding the spillover effects of subsidizing one input on the use of others might shed light on the appropriate type of input voucher program needed. If subsidizing fertilizer increases farmers' use of improved seed without a subsidy for the improved seed, this could indicate that subsidy programs on just one input might be sufficient to increase the uptake of that input as well as other complementary inputs. However, the absence of an effect on the use of key complements might indicate that fertilizer access is not the most limiting factor, such that reducing the constraint associated with that input without adequate consideration of constraints in complementary input sectors might not be sufficient.

This study explores whether spillover effects from the fertilizer voucher program are found in the improved seed sector in Nigeria. It focuses on Kano state, one of the states selected for Nigeria's fertilizer voucher program in 2009.Kano, located in northwestern Nigeria, 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. The primary activities in Kano are commerce and agriculture, and the poverty rate is about 75 percent (NBS 2009).

The 2009 pilot voucher program in Kano was a collaborative effort among the government (federal and state), private-sector suppliers and dealers, and the International Fertilizer Development Center (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). It involved three fertilizer suppliers and more than 150 private-sector agricultural dealers (IFDC 2010). Participating farmers were provided with vouchers, which were redeemable at certified agricultural input dealers within the LGA where they lived. 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) (Liverpool-Tasie, Banful, and Olaniyan 2010). 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.[2]

Participants in the 2009 voucher program were required to be members of an organized farmer group. Each participating farmer group received a single voucher that entitled each of its members to three bags of fertilizer at a discount of NGN 2,000per bag. According to the Nigeria Agri-Market Information Service (NAMIS), fertilizer prices in the 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 prices, respectively (Liverpool-Tasie, Banful, and Olaniyan 2010). 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 farmer 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. Each individual member of the group had to provide a single passport photo to the farmer group executive to present at the voucher distribution, 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 (IFDC 2010).

The structure of the 2009 voucher program in Kano created an opportunity for differential experiences of the voucher program across farmers of the same group. Liverpool-Tasie (2012) showed that the friends and relatives of the farmer 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.

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

3. ANALYTICAL FRAMEWORK

The conceptual framework within which this research is conducted is the agricultural household model. Our study area is rural Nigeria, where financial markets are weak and where villages are often isolated, with limited access to various input and output markets. Consequently, we assume that we are working in an environment characterized by market failures such that market prices no longer reflect the full opportunity cost of various goods, particularly inputs such as improved seed and fertilizer. Consequently, we model the demand decision for improved seed as the result of a constrained utility maximization problem for a household, as characterized in Sadoulet and de Janvry (1995) and deJanvry and Sadoulet (2006). Here, household characteristics are expected to affect household demand for agricultural inputs such as improved seed, and the improved seed demand that stems from the solution to the constrained utility maximization model of Singh, Squire, and Straus (1986) can be expressed as follows:

$$QISeed_i = f(PISeed_i, POutput_i, Z_i, X_i, QFert_s), \tag{1}$$

where $QISeed_i$refers to the quantity of improved seed[3] purchased by farmer *i,*$PISeed_i$ and $POutput_i$refer to the prices of improved seed and the output price for maize, the major crop produced by over 70 percent of households and for which improved seed is available. Z_i refers to other household characteristics and socioeconomic variables, including wealth in terms of livestock and land size, access to credit, and whether individuals own or rent land. $X_i$includes other variables that are known to influence farmer demand for improved seed, such as farm assets, livestock, price of the seed, output price, human capital, distance to markets, and so on. We also include the quantity of subsidized fertilizer acquired in 2009 $QFert_s$,to test whether access to this complementary good has spillover effects on farmers' probability of using improved seed. We control for the presence of irrigation[4] in the farmers' local government area. Improved varieties of maize are known to be responsive to fertilizer. In several cases, the returns to adopting improved seed are significant only when irrigation and fertilizer are used in the production of improved varieties (Laajaj 2012; Shapouri et al. 2010).

Within this framework, the fertilizer subsidy program reduces the price of a complementary input to improved seed and thus potentially increases the returns to adopting improved seed. Thus, this article explicitly tests for the effect of increased access to fertilizer at a discounted price on the probability of using improved seed. From the conceptual model above, we model the effect of subsidized fertilizer on improved seed demand as follows:

$$PISeed_i = \eta_i + \beta X_i + \delta QFert_{si} + Z_i + u_i, \tag{2}$$

where $PISeed_i$ refers to the probability of using improved seed in 2009.$X_i$is a vector of controls that affect demand for improved seed. It includes variables such as access to credit and output prices, as well as household demographic information, socioeconomic characteristics, and variables to capture various transactions costs. $QFert_{si}$refers to the quantity of subsidized fertilizer that farmer *i* received in 2009. $u_i$is a farmer-specific error term, and β and δ are parameters to be estimated.

The goal of this paper is to determine how the acquisition of some quantity of subsidized fertilizer affects a farmer's decision to use improved seed. However, it is likely that the quantity of subsidized fertilizer received by a farmer,$QFert_{si}$in (2) above, is endogenous if there are certain characteristics (not observed by us, the researchers) that affect the quantity of fertilizer farmers receive and are also likely to affect their demand for improved seed. These could be ability or motivation that would make a farmer

[3] Our data show that the majority of improved seed is maize and rice. Thus, we run one set of estimations for maize and rice together and then one for maize alone.

[4] We use availability of irrigation in all our estimations instead of farmers' use of irrigation, which has some elements of choice and can potentially be endogenous.

more likely to participate in the voucher program[5] (and receive more subsidized fertilizer) but also more likely to adopt the use of other productivity-enhancing technologies such as improved seed. This would make estimates of the effect of the quantity of subsidized fertilizer on the use of improved seed by a farmer biased. This paper addresses the endogeneity of the quantity of subsidized fertilizer variable in the probability of using improved seed using a control function approach (Imbens and Wooldridge 2007; Wooldridge 2008).

Given equation (2), the control function approach requires the estimation of the reduced form of the endogenous variable ($QFert_{si}$) as

$$QFert_s = Z\gamma + v. \tag{3}$$

By definition, E(Zv) = 0and E(Zu_i) = 0 because u_i and v are both uncorrelated with Z. However, endogeneity of $QFert_s$means that $u_i$and v are correlated. This can be expressed as

$$u_i = \rho_1 v + e_{i.} \tag{4}$$

Putting equation (4) into equation (2) we get

$$PISeed_i = \eta_i + \beta X_i + \delta QFert_{si} + \rho_1 v + e_i, \tag{5}$$

where v is another regressor and $\rho_1$another parameter to be estimated.

Given the binary nature of improved seed use in this study, we can express equation (2) as follows:

$$PISeed_i = 1(\eta_i + \beta X_i + \delta QFert_{si} > u_i \geq 0), \tag{6}$$

where

$$u_i | \text{z} \sim \text{Normal}(0,1). \tag{7}$$

Applying the Blundell-Smith (Smith and Blundell 1986) and Rivers-Vuong (Rivers and Vuong1988) approach, one could make a homoscedastic normal assumption on the reduced form for $QFert_{si}$:

$$QFert_s = Z\gamma + v \qquad v \sim N(0, \tau^2), \tag{8}$$

where v is the error term of the reduced form. Rivers and Vuong (1988) also require (u_i) to be independent of Z.Imbens and Wooldridge (2007) demonstrate a simpler two-step approach, which is convenient for testing H0 ($\rho_1 = 0$)$i.e$ $QFert_s$ is exogenous) is also available, and works if we replace the normality assumption in (6) and the independence assumption with

$$\text{D(ui|v}, Z) \sim \text{Normal } (\theta_1 v, 1 - \rho_1^2) \tag{9}$$

where $\theta_1 = (\rho_1/\tau^2)$ is the regression coefficient. Under this assumption, we can write equation (5) as

$$(P(ISeed_i = 1|Z, QFert_{si}) = \Phi\big(\beta_{\rho 1} X_i + \delta_{\rho 1} QFert_{si} + \theta_{\rho 1} v\big) \tag{10}$$

where each coefficient is multiplied by $(1 - \rho_1^2)^{-1/2}$.

Thus, this two-step approach involves first running an ordinary least squares estimation of$QFert_s$ on Z, to obtain the residuals$\hat{v}$. Then a probit of $ISeed_i$ on X_i, $QFert_s$, and$\hat{v}$ is run to estimate the scaled coefficients.

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

The exclusion restriction associated with the use of this approach is that a subset of $Z, (X)$ appears in equation (10). Our endogenous variable ($QFert_s$) takes on a corner-solution nature as many farmers may optimally choose not to acquire subsidized fertilizer. Consequently, following Ricker-Gilbert, Jayne, and Chirwa (2011); Wooldridge (2002); and Wooldridge (2008), this study estimates the first-stage regression of the quantity of subsidized fertilizer received by a farmer ($QFert_{si}$) using a Tobit model.After estimating equation (3), the generalized residual is constructed as

$$\widehat{gr}_i = -\hat{\tau}\, 1[QFert_{si} = 0]\, \lambda\, (-Z_i\hat{\gamma}) + 1[QFert_{si} > 0](QFert_{si} - Z_i\hat{\gamma}), \qquad (11)$$

where $\hat{\tau}$ and $\hat{\gamma}$ are the Tobit maximum-likelihood estimations and λ is the inverse Mills ratio. Then the generalized residuals are included in the second-stage estimations (Wooldridge 2008). For the second-stage estimations, linear probability and probit models are estimated. In both models, the generalized residuals are included as covariates in line with the discussion above.

The linear probability model (LPM) is used largely to enable us to directly obtain coefficient estimates rather than the estimation of scaled coefficients that are obtained with the probit model, which then need to be transformed. This study recognizes that there are potential pitfalls in the use of the LPM. For this particular research question, we consider these limitations to be relatively small and manageable. One limitation is that some of the predicted values from the LPM could be out of the zero-to-one range. Since the focus of this study is on the average marginal effect of subsidized fertilizer receipt on the use of improved seed, this should not be a problem, as both the LPM and the probit model generally produce similar coefficient estimates at the mean (Wooldridge 2002).To address the second potential challenge with the LPM, which is heteroskedasticity (which invalidates statistical inference), the standard errors in our models are robust to heteroskedasticity. Furthermore, to account for the fact that multiple household members could have participated in the voucher program, all standard errors are clustered at the household level in all models. Finally, to serve as a robustness check, we still estimate the probit model as well as the instrumental variables probit model for comparison of results. We also include the traditional LPM and probit results to demonstrate the effect of addressing the endogeneity of the quantity of subsidized fertilizer acquired in the estimation of its effect on improved seed use.

When using the control function approach, identification requires that an instrument be used to estimate equation (3), which is appropriately excluded from the primary equation (2). Farmers in Kano were required to be members of farmer groups to participate in the voucher program. However, once a group had met the requirements for participation in the voucher program, the farmer group president, treasurer, or secretary could redeem the voucher on behalf of the group and receive the fertilizer that the group members were entitled to. The expectation was that the fertilizer would then be distributed to all the farmer group members.

According to the voucher program sharing rule, each farmer was supposed to receive three bags of fertilizer: two bags of NPK and one bag of urea. However, anecdotal evidence revealed that some farmers complained that the quantity of fertilizer they received was less than what they were promised. The study data show that the number of bags of subsidized fertilizer received by survey respondents who participated in the program ranged from less than half a bag to significantly more than the program's stated three bags per farmer. Furthermore, a study of the voucher program (Liverpool-Tasie 2012) found that being linked to the farmer group president increased the quantity of fertilizer individual farmers received within their farmer groups, even though it did not determine the likelihood of a farmer receiving a dummy variable equal to one if the respondent was a relative of the farmer group president, secretary, or treasurer as an instrument for the quantity of subsidized fertilizer that a farmer received. Sociopolitical capital was also used by Ricker-Gilbert, Jayne, and Chirwa (2011) in their estimation of the crowding-out effects of targeted subsidies in Malawi. We assume that although being related to the farmer group leadership would affect the quantity of fertilizer received by a farmer, being related to the group leadership would not likely be correlated with unobserved characteristics that are likely to drive farmer purchase of improved seed from the private markets, such as farmer ability or motivation. Thus, after controlling for other characteristics that could be correlated with a household's relationship to the farmer group leadership, such as integration into markets, it is expected that this variable satisfies the exclusion restriction of not being correlated with the error term of equation (2) and is thus an appropriate instrument. Consequently, the instrumental variable (being related to the farmer group leadership) is appropriately excluded from our estimation of equation (2).In all second-stage estimations, p-values are obtained by bootstrapping at 1,000 repetitions (except where otherwise stated) to account for the fact that the generalized residual was obtained from a first-stage regression estimation.

4. DATA

The data used in this article come from a survey of 640 households in Kano (northwest Nigeria). Kano state is an appropriate region to study fertilizer-seed market relationships because it has experienced recent expansion of proven new seed varieties that are fertilizer responsive. The savanna vegetation in Kano allows for the production of various crops including groundnut, guinea corn, maize, sugarcane, rice, sorghum, and different kinds of vegetables. Over the last 20 years, there has been increased production of maize and rice in Kano and other savanna areas of northern Nigeria, largely due to the introduction of earlier-maturing varieties (including extra-early-maturity maize) as well as the popularization of hybrids (Oba Supa 1and 2) developed by the International Institute for Tropical Agriculture (IITA) and of NERICA (New Rice for Africa) (Ajeigbe et al.2010; Sasakawa Africa Association 2010), which has permitted successful cultivation in areas with short rainy seasons. Producers using improved seed and adequate quantities of fertilizer are recording yield levels of close to 4 tons per hectare (t/ha), compared to 1.5 t/ha 15 years ago (Ajeigbe et al.2010; Sasakawa Africa Association 2010).

Interviewed households were drawn 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 variation that could affect the level of exposure farmers had to the voucher program as well as other cultural, infrastructural, or administrative differences that affect farmers' access to improved seed. Households were selected from the randomly selected LGAs in Kano. A list of villages was compiled based on information supplied by LGAs and the Kano Agricultural Development Agency. 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 (see table A.1).[6] Households within each village were randomly selected, but with the 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 how to be mindful to consider the whole village in their selection of those households to interview. Survey coordinators paid surprise field visits to some enumerators to ensure that training instructions were adhered to. Details of the sampling procedure 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 farmer groups and other community associations, their leadership positions in their farmer groups 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.

The proportion of farmers using improved seed among respondents increased by about five percentage points between 2008 and 2009 (see Table 4.1). This increase appears to be largely driven by farmers who received subsidized fertilizer in 2009. While the percentage of farmers using improved seed among respondents who did not receive subsidized fertilizer changed by only 1percent between 2008 (before the voucher program) and 2009 (when the program was piloted), it changed by about 5 percent among those who received subsidized fertilizer in 2009.

[6] 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 4.1—Improved seed use in 2009 by subsidized fertilizer receipt in Kano

	Did not receive subsidized fertilizer	Received subsidized fertilizer	Total sample
Used improved seed in 2009	0.450	0.587	0.551
	(0.492)	(0.492)	(0.497)
Used improved seed in 2008	0.440	0.543	0.516
	(0.497)	(0.498)	(0.499)

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

Table 4.2 reveals that the average amount of fertilizer received by respondents was 2.85 bags, which is close to the amount provided by the voucher program (3 bags). However, there was a wide variation in the amount of subsidized fertilizer actually acquired, ranging between 0 and 6 bags. The average respondent in the sample was married and about 35 years old. Landholdings range between 0.75 and 10 herewith about 10 percent of households renting in their farmland.

Table 4.2—Summary statistics of study variables

Variable	Mean	Lowest 10%	Highest 10%
Number of 50 kg bags of subsidized fertilizer received (bags)	2.85		
	(5.32)	0	6
Farmer member of a group that purchased fertilizer together in 2008	0.89		
	(0.32)	0	1
Farmer related to the farmer group leadership (1/0)	0.66		
	(0.47)	0	1
Distance of respondent to major market in the state (km)	33.01		
	(20.19)	4.87	57.38
Naive price for maize based on representative price four months prior to farming season (NGN/kg)	52.06		
	(18.80)	49.5	55
Price for improved variety of maize seed (NGN/kg)	200.00	150	200
	(22.50)		
Member of a group that provided credit to members in 2008 (1/0)	0.28		
	(0.48)	0	1
Household size	3.89		
	(1.47)	2	7
Age (years)	34.24		
	(13.33)	19	53
Sex (1 = male)	0.51		
	(0.50)	0	1
Number of years of education	7.6		
	(3.25)	6	12
Marital status (1/0)	0.85		
	(0.36)	0	1
Land area in 2008 (hectares)	4.36		
	(6.06)	0.75	10
Used improved seed in 2008 (1/0)	0.52		
	(0.50)	0	1
Rented agricultural land (1/0)	0.1		
	(0.30)	0	1
Household owns a motorcycle (1/0)	0.065		
	(0.48)	0	1
Total tropical livestock units	6.86		
	(20.20)	0	11.1

Source: Generated by authors using Stata.
Note: Figures in parentheses are standard deviation.

Similar to Ricker-Gilbert, Jayne, and Chirwa (2011), we develop a naive expectation of the average real maize and rice prices for the six months prior to the planting season, which in Kano was November 2008 to April 2009. The price of maize 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, while that for rice ranged from NGN 82 per kg to NGN 108.32 per kg for those in the lowest and highest 10 percent of the price distribution, respectively. We also use the reported price of improved seed at the main local government market (Ajao 2009).The average price of improved rice seed was NGN 207.19, while the average price of improved maize seed was NGN 187.19. The reported price paid for fertilizer purchased in the private market was about NGN 80 per kg.

5. STUDY RESULTS

To identify the factors associated with subsidized fertilizer receipt, equation (3) is estimated using a Tobit model. Results of this are shown in Table 5.1. The first-stage results reveal that participating in the voucher program is the strongest determinant of the quantity of subsidized fertilizer a recipient receives. Whether the recipient was in a farmer group that purchased fertilizer together was also highly correlated with the quantity of subsidized bags received. Interestingly, wealth and education variables do not appear to be a significant determinant of the number of bags recipients received. However, the LGA in which the farmers lived was an important factor, probably indicating that particular characteristics of the LGAs, such as their governance and administration, wealth, and proximity to the state capital, might have affected the amount of fertilizer available to all farmers and the manner in which fertilizer was distributed. The instrumental variable—whether the respondent was a relative of the farmer group president, secretary, or treasurer—is significantly and positively associated with the number of bags received. The average partial effects (APE) were estimated[7] and reveal that being a relative of one of the farmer group leaders increased the number of bags received by about 1.5, and this was significant at 1 percent.[8] Given that the first-stage model in this study is a corner-solution model, there is no known test for instrumental variable (IV) strength in nonlinear models. Consequently, we test the strength of our IV by the partial correlation of "being a relative of the farmer group leadership" in the reduced-form equation (Ricker-Gilbert, Jayne, and Chirwa 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. As mentioned earlier, there is no reason to expect that a farmer's relationship to the farmer group president would affect the farmer's participation in the private improved seed market after controlling for other factors. Thus, it is considered appropriately excluded from the second-stage estimations.[9]

Table 5.1—First stage estimation

Number of bags of subsidized fertilizer received	Coefficient	t-statistics	P>t
Participated in the voucher program	5.372***	4.09	0
Farmer member of a group that purchased fertilizer together	2.394***	2.74	0.006
Holds a leadership position in the village	-0.694	-1.6	0.111
Age of respondent (years)	-0.004	-0.22	0.826
Male (1/0)	0.211	0.63	0.528
Married (1/0)	0.615	1.46	0.146
Years of education	-0.049	-0.75	0.454
Land area (hectares)	-0.058	-0.87	0.386
Related to farmer group leadership (instrument)	***1.716****	***2.03***	***0.042***
Someone in household owned a motorcycle (1/0)	0.247	0.36	0.722
Total tropical livestock units	-0.003	-0.3	0.762
Rents land (1/0)	1.49	1.08	0.282
Bagwai	-	-	-
Takai	-1.106	-0.63	0.528
Dambatta	-0.068	-0.05	0.958
Dala	-2.988*	-1.75	0.08
Karaye	-3.938**	-2.01	0.045
Ungogo	-2.049	-1.34	0.179

[7] These were estimated using the margins command in Stata and are available from the authors upon request.

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

[9] 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 5.1—Continued

Number of bags of subsidized fertilizer received	Coefficient	t-statistics	P>t
Gezawa	3.003	1.28	0.199
Gabasawa	-4.451***	-3.44	0.001
Rano	-8.099***	-3.38	0.001
Kura	-3.843***	-2.69	0.007
Constant	-3.186	-1.53	0.126
Number of observations	1,402		
Pseudo R-square	0.06		

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

Results from the second-stage regressions are displayed in Table 5.2. We first run the second-stage estimations for maize only because it is the major crop[10] of the area and the main crop for which fertilizer and improved seed are often used. We find evidence that the quantity of subsidized fertilizer affects the likelihood of a farmer using improved maize seed. This result persists irrespective of the estimation method used. The results from using the control function approach with either the LPM or the probit model are the most similar in terms of marginal effects. An additional bag of subsidized fertilizer increased the probability of a farmer using improved seed by about 4 percent in the LPM. This result is statistically significant at 1 percent. The marginal effects are small in magnitude, indicating that there are other more limiting constraints to farmers' use of improved seed. However, the consistent statistical significance of the fertilizer variable suggests that fertilizer access is important in the decision to use improved seed. Ignoring the significance of access to fertilizer when evaluating the voucher program underestimates the effect of the program on farmers' input use.

Table 5.2 reveals that access to irrigation is very important in farmers' decisions to use improved maize seed. Having access to irrigation in the LGA increased a farmer's probability of using improved seed by about 20 percent in the LPM. Thus, irrigation appears to be a more limiting factor in the use of improved seed for maize. As expected, where significant, a higher maize output price is positively associated with the probability of using improved seed, while a higher input price is negatively associated with the use of improved maize seed. Farmers who had legal rights to their farmed land were also more likely to use improved seed.

The results presented in Table 5.2 reveal that farmers who belonged to farmer groups that extended credit tended to be less likely to use improved maize seed. This might reflect the use of credit for other non-farming activities or for needs associated with other crops. Sixty-four percent of farmers who said they belonged to a farmer group that extended credit to members also stated that their primary activity was not farming. Farmers with larger landholdings and more working members tended to be more likely to use improved seed.

[10] Dry maize grain production has shifted to the savanna, especially the Northern Guinea Savanna, from the forest zone because of the availability of streak- and drought-resistant maize varieties for these ecologies (Iken and Amusa 2004). In 2009, Kano state was the second largest producer of maize after Kaduna state, showing the growing importance of maize in the state (NFRA 2009).

Table 5.2—Second-stage estimations for maize only

	Linear probability model without controlling for endogeneity of subsidized fertilizer		Linear probability model controlling for endogeneity of subsidized fertilizer		Probit model without controlling for endogeneity of subsidized fertilizer		Probit model controlling for endogeneity of subsidized fertilizer	
Variables	**Coefficient**	**p-value**	**Coefficient**	**p-value**	**Coefficient**	**p-value**	**Coefficient**	**p-value**
Number of subsidized bags of fertilizer received	0.000	0.991	0.029***	0.000	0.001	0.917	0.038***	0.000
Distance to main market	0.008***	0.003	0.006**	0.036	-0.002	0.976	0.017	0.259
Price of maize (NGN/kg)	0.000**	0.021	0.000	0.212	-0.001***	0.006	0.000***	0.001
Price of improved maize seed (NGN/kg)	-0.010***	0.000	-0.009***	0.000	0.016	0.474	0.002	0.609
Irrigation available in LGA (1/0)	0.094	0.108	0.196***	0.003	0.365	0.240	0.177**	0.027
Member of a farmer group that gives credit to members	-0.125***	0.008	-0.133***	0.005	-0.393**	0.012	-0.133***	0.008
Household size	0.013	0.429	0.006	0.692	0.041	0.461	0.055	0.743
Age of respondent (years)	0.002	0.661	0.002	0.694	0.008	0.636	0.001	0.706
Age of respondent squared (years)	0.000	0.370	0.000	0.413	0.000	0.388	0.000	0.487
Male (1/0)	0.007	0.748	0.010	0.664	0.028	0.734	0.012	0.631
Years of education	0.003	0.552	0.004	0.403	0.010	0.610	0.004	0.499
Land area (hectares)	0.007**	0.029	0.007*	0.054	0.024***	0.003	0.007**	0.049
Number of working members in household	0.032**	0.020	0.032**	0.046	0.099**	0.034	0.027*	0.087
Total tropical livestock units	-0.004***	0.000	-0.004***	0.000	-0.017***	0.001	-0.004*	0.072
Has legal right to sell land being farmed	0.076	0.117	0.086*	0.075	0.331*	0.085	0.111**	0.011
Generalized residual			-0.181***	0.000			-0.229***	0.000
Constant	-2.447	0.143	-0.960	0.572	22.304	0.041		
LGA dummies included	YES		YES		YES		YES	
Number of observations	1406		1371		1406		1371	
Pseudo R^2 or adjusted correlation coefficient	0.272				0.258			

Source: Generated by authors using Stata.

Notes: *, **, and *** indicate p-values significant at 1%, 5%, and 10%, respectively. 500 bootstrap replications were run.

Contrary to expectations, farmers further away from markets were more likely to use improved seed, and those with more livestock were less likely to use improved seed. Distance may be capturing the fact that the program requiring fertilizer suppliers to have sales points in every LGA might have made it possible for normally isolated farmers with stronger than average interest in using improved seed to gain access to improved seed. The coefficients on the livestock variable might indicate that households with large numbers of livestock are more likely to be engaged in herding and thus less likely to make investments in agriculture, such as using improved seed. Because land area, another indicator of wealth, is positively and significantly associated with improved seed use, it is likely that livestock ownership here is capturing more than just wealth. The livestock variable is skewed, with the bottom 25 percent of the distribution having 1 tropical livestock unit (TLU) or less and the top 90 percent having about 25 TLUs. The median value is about 2.5 TLUs.

Comparing the results where the endogeneity of subsidized fertilizer acquired is not accounted for (columns 1 and 3) with those where it is accounted for (columns 2 and 4), we see that the marginal effects of subsidized fertilizer access are actually larger when the endogeneity of subsidized fertilizer acquired is addressed. The significance of the generalized residual in both the LPM and probit model, which include it as regressor, confirms the endogeneity of the quantity of subsidized fertilizer received and simultaneously controls for it.

For comparison, we estimate the effect of subsidized fertilizer on improved seed use generally. This includes both maize and rice. From Table 5.3, we can see that the number of bags of subsidized fertilizer received by a respondent positively affects their likelihood of improved seed use and the estimates here are similar to those for the estimation including maize only.

These finding of spillover effects from targeting one input on farmers use of other inputs in Nigeria are similar to those of Beamer et al (2013) who find that increasing female farmers access to fertilizer in Mali increased their use of complementary inputs such as herbicides and hired labor. They demonstrate that increased availability of one input is likely to cause farmers to re optimize their use of other complementary inputs and highlight the complications that such spillover effects introduce when evaluating program effects.

Table 5.3—Second-stage estimations for maize and rice

	Linear probability model without controlling for endogeneity of subsidized fertilizer		Linear probability model controlling for endogeneity of subsidized fertilizer		Probit model without controlling for endogeneity of subsidized fertilizer		Probit model controlling for endogeneity of subsidized fertilizer++	
Probability of purchasing improved seed	**Coefficient**	**p-value**	**Coefficient**	**p-value**	**Coefficient**	**p-value**	**Coefficient**	**p-value**
Number of subsidized bags of fertilizer received	0.008**	0.025	**0.027*** **	0.009	0.013**	0.022	**0.039** **	0.015
Distance to main market	-0.016***	0.000	0.015***	0.000	-0.097***	0.000	-0.030*	0.063
Price of maize (NGN/kg)	0.000	0.106	0.000***	0.000	0.000***	0.001	0.000***	0.001
Price of improved maize seed (NGN/kg)	-0.021***	0.000	-0.009***	0.000	-0.017***	0.000	-0.002	0.678
Price of rice (NGN/kg)	0.000***	0.000	0.000	0.666	0.000***	0.000	0.000	0.454
Price of improved rice seed (NGN/kg)	0.018***	0.000	-0.014***	0.001	0.015***	0.008	0.005	0.565
Irrigation available in LGA (1/0)	0.289***	0.001	-0.191*	0.070	-0.830***	0.000	0.146	0.609
Member of a farmer group that gives credit to members	0.009	0.876	0.011	0.828	0.010	0.888	0.012	0.881
Household size	0.021	0.144	0.014	0.342	0.032	0.145	0.022	0.391
Age of respondent (years)	0.002	0.680	0.002	0.665	0.001	0.919	0.000	0.967
Age of respondent squared (years)	0.000	0.512	0.000	0.520	0.000	0.723	0.000	0.809
Male (1/0)	-0.027	0.248	-0.025	0.281	-0.046	0.169	-0.041	0.241
Years of education	0.002	0.711	0.003	0.631	0.003	0.762	0.003	0.710
Land area (hectares)	0.009**	0.025	0.008**	0.042	0.012**	0.020	0.012	0.274
Number of working members in household	0.005	0.697	0.004	0.749	0.005	0.777	0.006	0.791
Total tropical livestock units	-0.003***	0.000	-0.003**	0.012	-0.005***	0.000	-0.004**	0.021
Has legal right to sell land being farmed	0.064	0.182	0.068	0.152	0.131*	0.093	0.141	0.105
Constant	11.692	0.000	-7.870	0.000				
Generalized residual			-0.115	0.048			-0.161	0.060
LGA dummies included	YES		YES		YES			
Number of observations	1406		1371		1406		1371	
Pseudo R^2 or adjusted correlation coefficient	0.400		0.406		0.342		0.357	

Source: Generated by authors using Stata.

Notes: *, **, and *** indicate p-values significant at 1%, 5%, and 10%, respectively. 500 bootstrap replications were run.

6. CONCLUSION

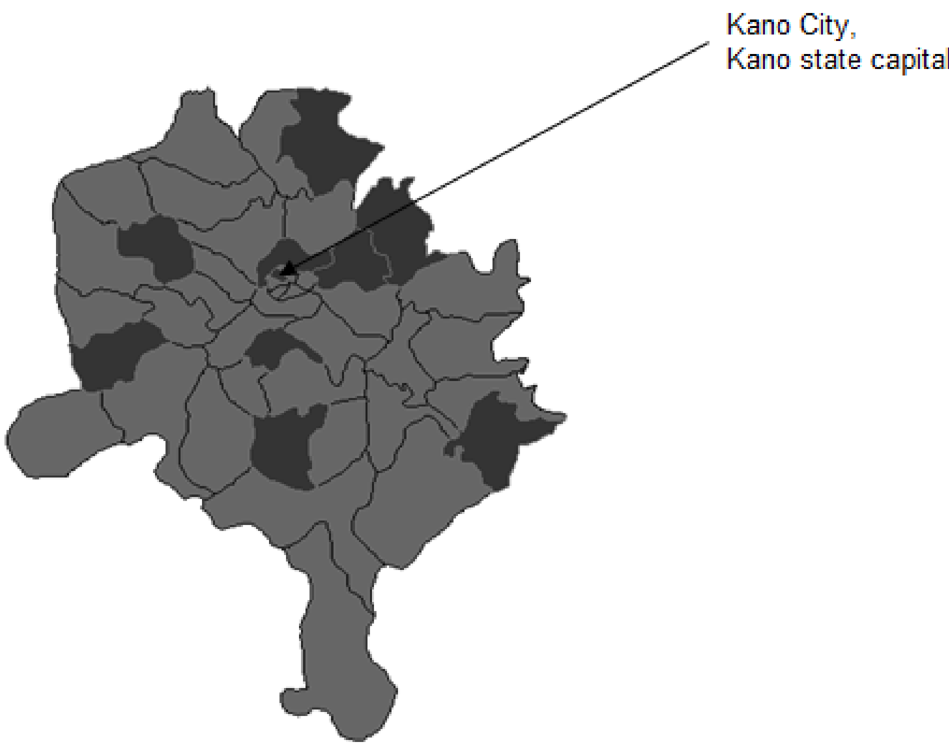
This paper used a control function approach to estimate the effect of increased access to subsidized fertilizer on improved maize seed use in Nigeria. We find that increased access to subsidized fertilizer increased the likelihood of farmers using improved seed in Kano, Nigeria. Our results were robust to various model specifications. An additional bag of subsidized fertilizer increased farmers' likelihood of using improved seed by about 4 percent. Considering the likely yield differential between traditional and improved varieties, a 4 percent increase in the likelihood of using such varieties could have a substantial effect on production. The marginal effects from this study are statistically significant at 1 percent and indicate that there is a clear link between farmers' use of improved seed and fertilizer in Kano.

An evaluation of the effect of increased access to subsidized fertilizer on farmers in Kano that fails to account for the spillover effect of such access on improved seed use will underestimate the effect of the programs or strategies that enabled that increase. The results of our study show that there is an important link between farmers' use of improved seed and fertilizer in Kano. Like Beaman et al (2013) we also find evidence that farmers tend to re-optimize their use of complementary inputs when access to one input is increased. These results also indicate that further studies on the importance of fertilizer uptake and use of improved seed are needed. The significant and positive effects of increased fertilizer access on improved seed use could indicate that properly developed and administered programs that guarantee farmers' access to cheaper fertilizer might naturally stimulate improved seed use without the added program costs of providing improved seed at a discounted price as well. This would likely only be true where a well-developed market for improved seed existed. To confirm this, however, further studies in areas where good-quality improved seed is available (whether at a discounted price or not) are necessary to explore in greater detail the complementarity between fertilizer access and improved seed use.

APPENDIX: SAMPLE SELECTION

The domain for this analysis is smallholders in Kano state, 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 Kano state. 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), 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.

Our measurement units are the households and household members surveyed in Kano state. 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 states would have if subsidized fertilizer were equally distributed across households would be 97 kg. 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 on average receive about 29.1 kg 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 should have received three bags (150 kg). 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:

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

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 Kano states, applying the same formula indicates that we need between 250.

For further confirmation, the minimum sample calculation also was conducted using secondary data from other studies. A 2007 study cites 41 kilogram per hectare (kg/ha) as the average fertilizer use for Kano State (Maiangwa et al. 2007). A discussion with Kano's Agricultural research development authority informs that average land size in Kano of about 1.9 ha. This amounts to about 78 kg 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 90 percent of the vouchers had been distributed in Kano). 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 state amounting to about 640 households. The 640 sample size 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. The respondents were largely household heads, their spouses, other adult household members, and for a few questions, children and youth in the household.

Table A.1—Distribution of sample households across the 10 local government areas in Kano

Kano			
Local government area	**Number of households surveyed**	**Local government area**	**Number of households surveyed**
Bagwai	64	Ungogo	91
Takai	64	Gezawa	83
Dambatta	60	Gabasawa	60
Dala	82	Rano	49
Karaye	37	Kura	50
Total		**640**	

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

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