NIGERIA
Strategy Support Program II

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE
IFPRI
Supported by the CGIAR

WORKING PAPER NO. 23 | December 2012

Impact of Fertilizer Subsidies on the Commercial Fertilizer Sector in Nigeria

Evidence from Previous Fertilizer Subsidy Schemes[1]

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We examine whether and how much previous fertilizer subsidy schemes in Nigeria crowded-in or crowded-out the private-sector fertilizer. We apply a system of endogenous Tobit regressions which account for interlinkages between the subsidized fertilizer market, the commercial fertilizer market, and the open-market fertilizer price. We use data from two separate agricultural household surveys, one of which is a pseudo-panel. We find that:

1) higher subsidy rates might have depressed the non-subsidized open-market fertilizer price;
2) a majority of farmers use either commercial or subsidized fertilizer, but rarely both sources;
3) one kg of subsidized fertilizer supplied reduces demand for commercial fertilizer by between 0.19 and 0.35 kg;
4) the characteristics of the ideal beneficiaries under a fertilizer subsidy scheme in Nigeria are quite different from the beneficiaries under previous schemes; and
5) fertilizer demand is not affected by price.

We conclude that the success of any new fertilizer subsidy scheme in Nigeria partly depends on effectively reducing the crowding-out effects of the subsidy on the commercial fertilizer sector. This can be done through both improved targeting of beneficiaries and effective complementary policies that raise the financial return to fertilizer use among intended beneficiaries.

***Keyword*: fertilizer subsidy, crowding-out, system of endogenous Tobit regressions, bivariate sample selection, correlated random effect, Nigeria**

[1] We greatly appreciate the comments from participants of the seminar at the International Food Policy Research Institute and International Fertilizer Development Center in Nigeria. We are also grateful for the Department of Fertilizer, Federal Ministry of Agricultural & Rural Development for sharing with us the information of port charges for fertilizer at Lagos port. We also thank Renato Folledo, Sheu Salau, Hyacinth Edeh, and Akeem Ajibola for their excellent research support. All remaining errors are ours.

INTRODUCTION

Developing a competitive commercial sector for supplying agricultural inputs like fertilizer is critical for sustainable agricultural sector growth. Agricultural input subsidies, including those on fertilizer, have been one of the widely used policy instruments in developing countries to develop a vibrant private sector for the supply of such inputs, as well as for raising farmers' income and agricultural productivity. The effectiveness of such subsidy programs has attracted much discussion in the literature. Public input subsidies are rarely the best policy for developing the commercial input sector as it leads to Pareto inefficient resource allocation. This tends to induce overuse of inputs and creates uncompetitive private agro-dealers who cannot survive without a permanent subsidy. However, subsidies can be a second best policy if their use can address various market failures (Stiglitz 1987). Moreover, subsidies can be a second best policy for the development of the commercial input sector, if the use of subsidies on inputs can crowd-in the commercial sector by addressing key market failures. However a key condition of the use of subsidies for such purposes is that the subsidies help the sector to grow sustainably so there will be no need for subsidies in the longer term.

Fertilizer subsidies can crowd-in the private fertilizer sector if the subsidies serve to sensitize farmers as to the benefits of the use of fertilizer on their crops and boost demand for the input, thereby helping private fertilizer dealers handle larger volumes of fertilizer and raise their profitability through economies of scale. However, fertilizer subsidies may crowd-out the private fertilizer sector if fertilizer demand is not price elastic due to rapidly decreasing marginal returns on its use or if subsidies are received by those who are already using fertilizer bought from private non-subsidized sources. Recent literature suggests that subsidies on fertilizer generally result in a crowding-out of private fertilizer suppliers in various countries in Africa south of the Sahara (Ricker-Gilbert et al. 2011; Xu et al. 2009).

Estimation of crowding-in or out is challenging, however, because the extent of crowding-in or out depends on the market structure of the subsidized good, the presence of leakages of subsidized fertilizer to those who were not intended to receive the benefit of subsidy[2] and the potential endogeneity of the price of fertilizer in the private sector. These issues often are not explicitly discussed in past studies on the impact of fertilizer subsidies. The fertilizer market structure and interlinkage with the subsidy scheme is particularly important for a country like Nigeria which has a vast geographical area that leads to potentially wide variations in fertilizer prices, diversity in agroecologies, and significant involvement of state governments in subsidy policy implementation. Historically, subsidy schemes in Nigeria have led to the evolution of a highly complex fertilizer distribution structure characterized by the existence of parallel markets for private and public sector subsidized fertilizer, respectively, where the private-sector fertilizer price level is often affected by the fertilizer subsidy.

Analyzing the effect of crowding-out of private fertilizer suppliers under such a complex fertilizer distribution structure provides a useful baseline for any new fertilizer strategy and policy of the Nigerian government, particularly one in which the government plans to completely pull out of fertilizer procurement and distribution and let private input traders participate in fertilizer distribution. Additionally, in the proposed new fertilizer policy, subsidized fertilizer is to be targeted for poor farmers and will be given using vouchers in order to minimize leakage of subsidized fertilizer to non-beneficiaries. Though voucher-based fertilizer distribution has been implemented only on a small scale in Nigeria until recently (Liverpool-Tasie et al. 2010b), the Nigerian government is planning to scale up the voucher-based fertilizer distribution program under the Agricultural Transformation Agenda (ATA) (FGN 2011; Adesina 2011). In this context, a study on the impact of the subsidy on the participation of private input traders in fertilizer marketing will provide empirical evidence for formulating implementation strategies for the new fertilizer policy to ensure that the private-sector traders are crowded-in under the subsidy program and will form a baseline for evaluating the impact of the new fertilizer subsidy program.

We build on earlier studies by analyzing similar crowding-in/out effects of fertilizer subsidies in Nigeria under previous subsidy schemes. The objectives of our study are twofold. We first discuss key fertilizer market characteristics in Nigeria. This includes an examination of the effect of subsidies on fertilizer prices in the open market. We find that open market prices of fertilizer are affected by the federal and the state level fertilizer subsidy. Understanding the effect of fertilizer subsidies on the open market fertilizer price provides important insights into the process of crowding-in/out.

We then estimate the crowding-in and crowding-out effects of fertilizer subsidies on the procurement of fertilizer from commercial sources. We use farm household data from a pseudo-panel in order to examine the fertilizer use of Nigerian farmers over time. We apply a system of endogenous equations model with limited dependent variables in order to account for the complex interlinkages between the demand for subsidized fertilizer and commercial fertilizer. This method allows us

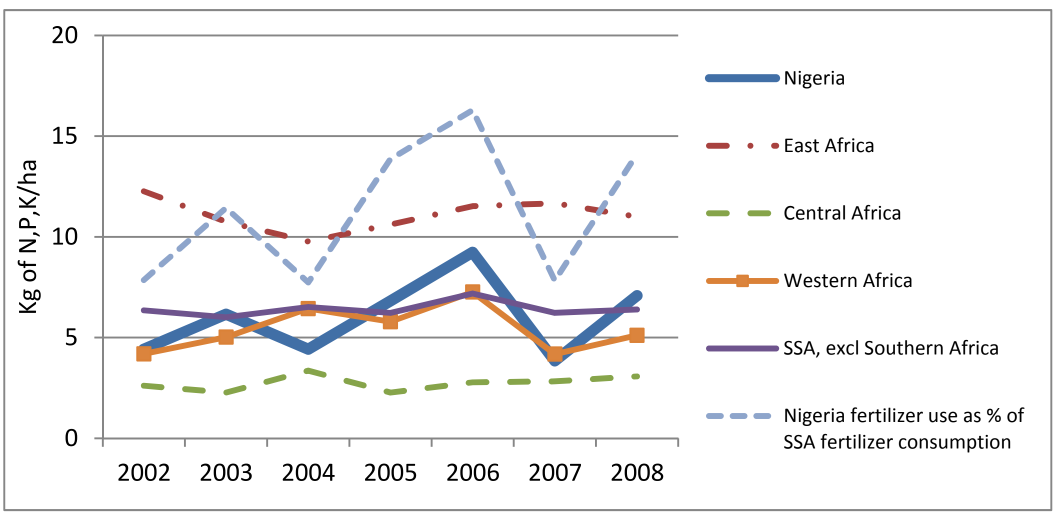
[2] Leakage is, in one way, measured as the proportion of beneficiaries who are not intended to benefit from the subsidy (Coady et al. 2004).

to obtain consistent estimate of the extent of crowding-in/out of the private fertilizer input supply sector due to the previous fertilizer subsidy schemes.

AGRICULTURE SECTOR, FERTILIZER POLICY, AND FERTILIZER MARKET IN NIGERIA

Nigeria's land-based sectors play a major role in the country's efforts to promote economic growth, reduce poverty, and help achieve food, climate, and environmental security. Such multiple wins are possible if production landscapes are properly managed. Agriculture, forests, and fisheries together contribute about 32 percent of the gross domestic product (GDP) in Nigeria. Moreover, the sector employs about 60 percent of the working rural population (World Bank 2012). Additionally, the Nigerian agricultural sector contributed more than 50 percent of its GDP growth 2000–07 (Headey et al. 2010). This underscores the key role of agriculture in Nigeria's efforts to transform the economy. However, agricultural GDP growth in Nigeria has largely been due to area expansion rather than to increased productivity. Indeed, agricultural yields in Nigeria have been stagnant or declining, raising concerns about the sector's sustainability and rural poverty reduction efforts in general. The large contribution of the agricultural sector and the large share of the working population employed in the sector underscore that agricultural development must be part of any poverty reduction strategy in Nigeria. As part of efforts to transform the agricultural sector, the new Nigeria government of President Jonathan initiated the ATA which aims to support the overall transformation agenda (TA) of the government (FGN 2011; Adesina 2011). The overall objective of the TA specific to the agricultural sector is to achieve food self-sufficiency by virtually eliminating importation of those foods for which Nigeria has a comparative advantage to produce and by revitalizing exports of key agricultural products. As one component of efforts to achieve such goals, the ATA aims to reform the fertilizer subsidy scheme in order to increase fertilizer use. Fertilizer use in Nigeria is considered low with around 6 kg in nutrients applied per hectare of farmland annually between 2005 and 2009. This rate is similar to that of other West African countries and below the average rate applied in East Africa (Figure 1).

Figure 1: Fertilizer use in Nigeria, 2002–08



Source: Calculated from FAO (2012).

Table 1 shows estimates for 2010 of the shares of land devoted to specific crops and the share of all fertilizer used in Nigeria on those crops. Maize and rice are notable for higher levels of fertilizer application.

Table 1. Major crops with fertilizer application in Nigeria – (Jan – Aug 2010)

Crops	% of cropland[b]	Share (%)
Sorghum	17.0	20.9
Maize	9.4	18.3
Beans / cowpea	10.0	13.6
Rice	6.0	12.9
Millet	11.6	11.4
Cassava	9.2	4.5
Yam + water yam	7.6	3.6
Ground nut	6.1	3.2
Soybean	1.4	1.7
Sesame	0.7	0.9
Cotton	1.3	0.3
Oil palm tree	8.2	0.3
Sugar cane	0.2	0.3
Cocoa	3.2	0.2
Ginger	0.3	0.1
Cashew	0.8	0.0

Source: Authors' calculation from LSMS data & from FAOSTAT (share of cropland).
[a]Although fertilizer use for dry season crops in some regions may not be included due to the selection of sampling period in the LSMS survey, we believe they account for a small share and do not affect the findings in this table.
[b]Average crop area in 2005–2010.

Previous fertilizer subsidy programs

Fertilizer subsidies have been one of the major policy instruments used to increase agricultural productivity in Nigeria. Historically, fertilizer subsidies accounted for about 40 percent of the total federal budget for agriculture, although this was small given that FGN generally allocated less than 3 percent of its budget to agriculture (Mogues et al. 2008). Subsidized fertilizer was distributed through complex channels (Figure 2). Detailed descriptions of fertilizer market structure as well as its development are provided in Gregory (2008), Banful et al. (2010), Banful & Olayide (2010) and Liverpool-Tasie et al. (2010).

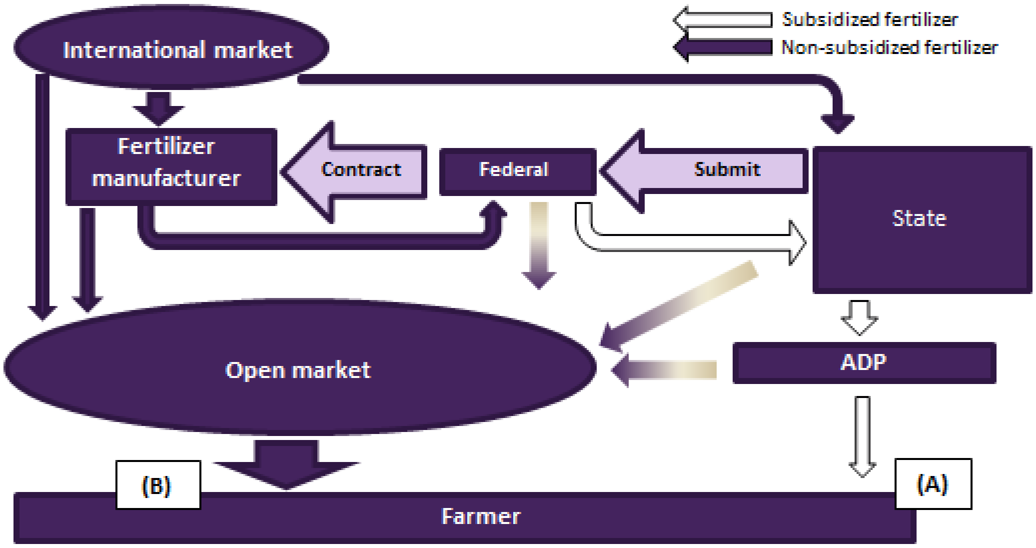
There were two main channels through which a farmer could procure fertilizer.

1. Under channel A in Figure 2, each state government submitted a request to the federal government to procure a certain quantity of fertilizer based on the demand projections in their states. The federal government then determined the actual total quantity to be procured based on actual budget allocations and issued tenders to the private-sector fertilizer manufacturers. Private fertilizer manufacturers obtained fertilizer, particularly NPK, from the international market, and supplied fertilizer to the federal government. The federal government then distributed fertilizer to three Ministry of Agriculture warehouses in each state (Gregory 2008). The federal government calculated pan-territorial delivered prices for NPK, Urea, and SSP based on national freight equalization and deducted 25 percent from the price when delivering to each state. Each state then distributed fertilizer to farmers through outlets, mainly the Agricultural Development Project (ADP), after applying an additional state-level subsidy ranging from zero to 50 percent of the federally subsidized price.

2. Under the second channel (Channel B in Figure 2), un-subsidized fertilizer is obtained from the open market, where fertilizer is bought directly from the international market or private manufacturers. In 2009 and 2010, the supply of 400,000 and 900,000 tons, respectively, of inorganic fertilizer (NPK, Urea, and SSP combined) was obtained from the open market through procurement awards to fertilizer manufacturers in Nigeria under the federal subsidy program. Of this, 371,063 and 586,145 tons, respectively, were actually supplied by the contracted manufacturers.[3] Nigeria has 34 million hectares of arable land (FAO 2012), and these quantities of subsidized fertilizer translate to per hectare application rates of approximately 11–17 kg/ha, which should have covered a substantial share of the actual fertilizer used (6 kg/ha measured as nutrients in Figure 1).

[3] Communication with the Department of Fertilizer, Federal Ministry of Agriculture & Rural Development in 2011.

Figure 2. Old fertilizer subsidy scheme in Nigeria



Source: Authors.

The private sector was involved in previous subsidy schemes in fertilizer manufacturing and blending and in distribution and retailing. In 2006 there were about 25 private fertilizer manufacturers or blenders (Banful and Olayide 2010). Distributions and retailing of fertilizer in the commercial sector were done by agro-dealers in Nigeria, which numbered around 10,000 in 2008, mostly small-scale, out of which about 500 were trained and working closely with major manufacturers (Gregory 2008). These private input dealers buy fertilizer either from the private manufacturers or the state Ministry of Agriculture and sell to farmers (Banful and Olayide 2010).

Under a well-functioning fertilizer subsidy scheme, in which the subsidy has an economic justification, providing more subsidized fertilizer through channel A should also increase the fertilizer demanded and supplied through channel B (crowding-in). Various factors, however, lead to an environment in which the fertilizer subsidy may instead “crowd-out” the commercial fertilizer. In Nigeria, a third informal channel existed in which subsidized fertilizer was diverted from channel A and sold in the open market by farmers or dealers who are well-connected with ADP, federal, or state level government officials (Banful et al. 2010). This third channel may crowd-out of the fertilizer supply market those commercial traders who can only sell fertilizer through the commercial channel. Past studies in Nigeria indicate that poor targeting of fertilizer subsidies might have induced these leakages and led to the situation where the subsidy was ineffective in meeting the potential demand by the intended beneficiaries (Banful et al. 2010). Additionally, late delivery and adulteration of fertilizer were common problems (Banful et al. 2010), potentially discouraging farmers from adopting subsidized fertilizer and reaping its benefits. The fertilizer procurements at the federal level were also unreliable and changed almost annually, resulting in wide swings of supply of subsidized fertilizer (Nagy and Edun 2002). Frequent fertilizer policy changes, combined with the poor targeting of subsidies and leakages of subsidized fertilizer, made the private sector less likely to invest in input market development, further crowding-out the private sector.

The new fertilizer subsidy program

The new fertilizer subsidy program under the ATA, called the Growth Enhancement Support (GES), sets ambitious goals of increasing fertilizer use from the current level of approximately 13 kg/ha to 50 kg/ha (FMARD 2011). The main intended shifts in GES from previous subsidy schemes are to target beneficiaries through vouchers and to hand over the distribution of subsidized fertilizer to private dealers from the government. This contrasts with previous subsidy schemes in which the government directly participated in the procurement and distribution of subsidized fertilizer through the agricultural development project (ADP) and other agencies.

The GES aims to benefit 20 million farmers by 2020 by providing subsidies equivalent to ₦5,000 each year for four years.[4] The plan, starting from 2012, is that the farmers will be divided into four cohorts of five million farmers each, begin-

[4] This program will literally cover all households in Nigeria. The National Planning Commission estimated that the total number of households in Nigeria was about 18 million in 2010.

ning with the very poorest subsistence farmers (Table 2). Further studies are needed to assess who actually received subsidized fertilizer in 2012, the first year of GES. Under the plan, each participating farmer is supposed to receive approximately 100 kg of fertilizer each year during the four years of the subsidy program. This will be implemented by providing a 50 percent subsidy throughout the country, in which the federal and state government will each contribute 25 percent of the subsidy. However, the new policy does not show how it will provide incentives for use of organic inputs.

Table 2: Fertilizer subsidy cohorts

Five million farmer cohorts	2012	2013	2014	2015	2016	2017	2018	2019	2020
	Value of subsidy (Naira)								
Cohort 1	5000	5000	5000	5000					
Cohort 2		5000	5000	5000	5000				
Cohort 3			5000	5000	5000	5000			
Cohort 4				5000	5000	5000	5000		

Source: Authors' illustrations based on the descriptions in FMARD (2011).

To improve targeting and reduce leakage, fertilizer vouchers will be issued using an electronic voucher system based on mobile phone technology. FMARD estimated that 94 percent of targeted beneficiaries were reached in a pilot of the program in Taraba state (Adesina 2011). The first four years of the program will focus on lifting farmers from a subsistence production orientation to one of commercial production. At the end of the four years of participation in the subsidy scheme, for each cohort, farmers are expected to graduate into the commercial market. This will be followed by a commercialization phase and enhancement of the market orientation of the farmers. This commercialization phase is expected to run for 4 to 10 years (Adesina 2011). The total cost of the fertilizer subsidy program is expected to be ₦400 billion or US$2.5 billion.

There are a few potential paths where the new subsidy scheme can help develop the private fertilizer sector. Handing over the distribution of fertilizer from the government to the private agro-dealers can potentially increase the quantity of fertilizer handled by these agro-dealers, enable an expansion of their business, and enable them to exploit economies of scale. In this context, the new fertilizer subsidy scheme may have more potential in developing the private fertilizer sector than previous subsidy schemes. Even under previous subsidy schemes, however, the subsidy could have helped develop the private fertilizer sector through the increased demand from farmers who were sensitized to the benefits of fertilizer. Increased fertilizer demand allows private fertilizer manufacturers or agro-dealers to expand their business, invest in capital assets, and reduce per-unit costs of fertilizer supply. Increased demand may also facilitate the importation and domestic transportation of fertilizer in bulk quantity, further reducing unit costs (World Bank 2007, 150-151). If farmers make sufficient savings from reduced production costs due to a fertilizer subsidy or increased sales from increased use of fertilizer, the subsidy could help farmers graduate into and sustain input-intensive production systems with high fertilizer demand, even after the withdrawal of the subsidy program. The subsidy would have created a sustainable enabling environment for the private fertilizer sector to operate. Our paper therefore focuses on how farmers' demand for fertilizer from non-subsidized sources was affected by the subsidy.

EMPIRICAL ANALYSIS OF THE SUBSIDY AND FERTILIZER PRICES UNDER PREVIOUS SUBSIDY SCHEMES

In this section, we empirically assess the interlinkages between fertilizer subsidies and open market fertilizer prices, in order to evaluate the crowding-in or crowding-out effect on the private fertilizer sector by previous fertilizer subsidy programs in Nigeria. The data used in this study were derived from two sources:

(i) Pooled cross-section data from the National Survey on Agricultural Export Commodities (NSAEC). The NSAEC data was collected jointly by the Central Bank of Nigeria (CBN), the National Bureau of Statistic (NBS), the Federal Ministry of Agriculture and Rural Development (FMARD), and the Federal Ministry of Commerce and Industry (FMCI) in 2003, 2005, 2006, and 2007. The export crops, as defined for the survey, included cashew, cassava, cocoa, coffee, cotton, garlic, ginger, groundnut, gum arabic, kolanut, oil palm rubber, sesame seed, sheanut, sugar cane, and tea. However, farmers growing these crops can have been expected to also apply the fertilizer to other crops that they produce, including food and other non-export crops.

(ii) The Nigeria Living Standard Measurement Survey - Integrated Survey on Agriculture (LSMS) data set of 2010.

Both datasets are appropriate for our study as they report the quantity of fertilizer purchased from both commercial and public sources. The LSMS data is a nationally representative dataset which covers all types of farmers in Nigeria. Although the NSAEC data only covers export crop growers, findings from the data are still relevant to the whole fertilizer market in Nigeria since export crop farmers are located throughout Nigeria. According to the LSMS data, export crops growers in Nigeria use more fertilizer on average than other farmers as they also grow staple crops and possibly apply more fertilizer to those crops.[5] Approximately 14 percent of Nigerian farmers produce these export crops, but they use approximately 27 percent of all fertilizer used in Nigeria [a].

It was possible to determine whether the farmer purchased subsidized or commercial fertilizer using the sources from where they reported acquiring their fertilizer. In Table 3 we classify the public and commercial sources noted in each data set. For the NSAEC data, the major sources of subsidized fertilizer were the State Ministries of Agriculture, the ADPs, Agro Service Centers, and Farm Service Centers. In the LSMS data, 87 percent of subsidy recipients purchased subsidized fertilizer, while 21 percent reported to have received free fertilizer (shares may not add up to 100% as some farmers use more than one source). The total percentage adds to more than 100 percent because some farmers received fertilizer from more than one source. In the LSMS data, government institutions, such as the ADP and Agro Service Centers, which were used by the government to distribute subsidized fertilizer, were the source of subsidized fertilizer for 82 percent of recipients, while individual political leaders also supplied 19 percent of the recipients with such fertilizer (Table 4). Free fertilizer was given by various government sources, friends, and others, potentially including NGOs (Table 4).

Table 3. Public and commercial sources

NSAEC data		LSMS data	
Public source	Commercial source	Public source	Commercial source
• Ministry (extension services) • Agro service center • Farm service center	• Cooperative society • Local market • Other source	• Government • Political Leader • All free fertilizer (regardless of the source)	• Market (local / main) • Friends / neighbors • All the other

Source: NSAEC data and LSMS data.

Table 4. Breakdown of subsidized sources in LSMS data

	Purchased from public source	Free fertilizer
Government	82%	25%
Political leader	19%	5%
Relative / friends / neighbors		37%
Other		37%

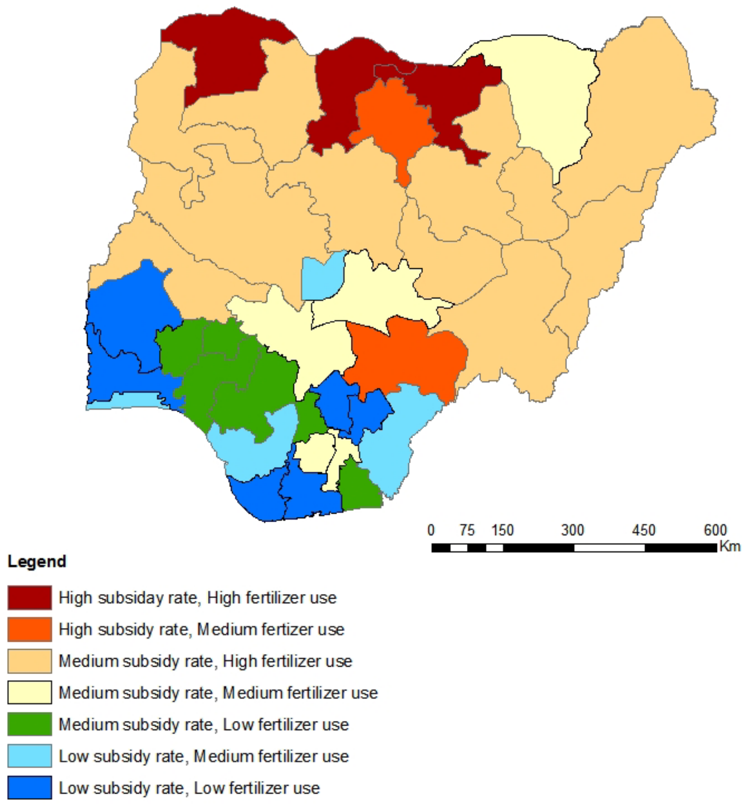
Source: Authors' calculation.
[a]Shares may not add up to 100% as some farmers use more than one source.

Within Nigeria, fertilizer use historically is higher in states with generous fertilizer subsidies, based on the level of estimated state subsidy rates in 2008 (Banful et al. 2010). For example, no state with fertilizer subsidy rates of more than 30 percent reported low fertilizer use. Likewise there was no state with low subsidy rates of less than 10 percent, which reported high fertilizer use (Figure 3). This demonstrates the effect of the state-level fertilizer subsidies on fertilizer use.

The spatial pattern of high fertilizer use states and low fertilizer use states stands in contrast to expected patterns derived from fertilizer transport costs. Long distances from the port in Lagos to the northeastern and northwestern zones would have led to greater transaction costs and reduced demand for fertilizer in those states distant from Lagos. For example, Alene et al (2008) observed that remoteness of fertilizer sources could reduce market supply by over 40 percent and consequently demand. However, fertilizer uses in the northern states – where the most generous subsidies are given – have been historically high with and without fertilizer subsidies. The low soil fertility in the northern states contributes to the high fertilizer use, while fertilizer use in the southern states with high soil fertility is low (Figure 4).

[5] Table 2 suggests that the small share of fertilizer use for export crops is simply due to the small area to which these crops are planted in Nigeria compared to major staple crops.

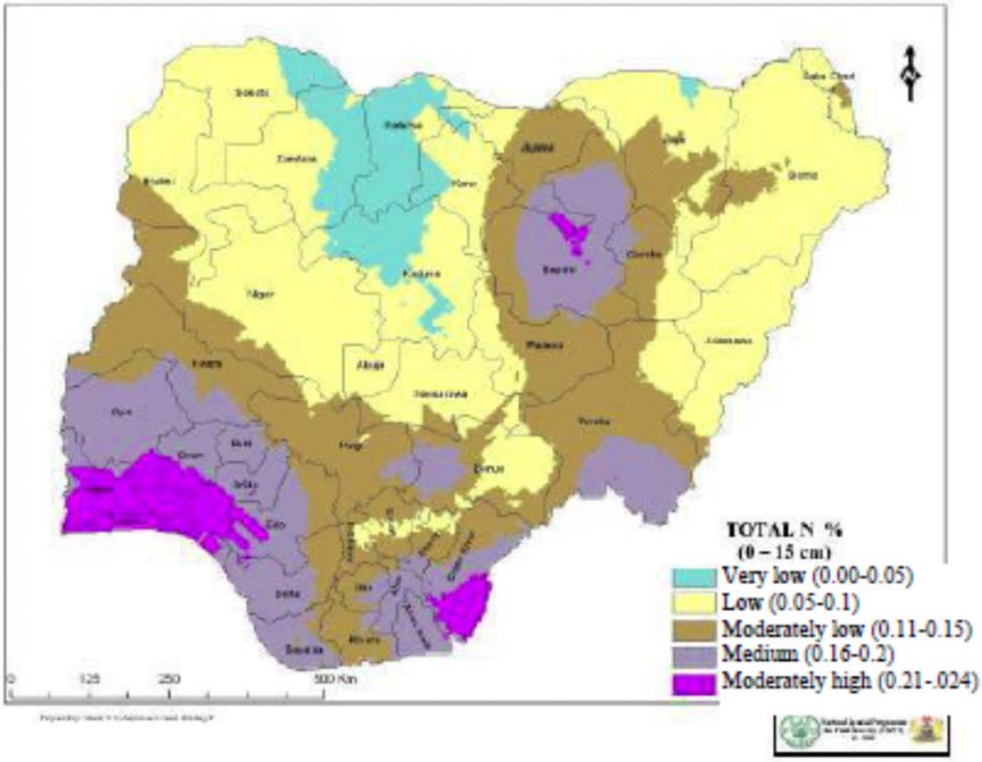
Figure 3: Subsidy rates and fertilizer application rate per household



Sources: Banful et al 2010 (fertilizer subsidy rate), LSMS household survey 2010 (rate of fertilizer use).

The effect of fertilizer subsidies on the private fertilizer sector can be first assessed by comparing the theoretical open-market price (or import parity price), the actual open-market price, and the subsidized price of fertilizer in each region. The import parity price reflects the actual price that would prevail in the absence of market distortions due to the subsidy. The subsidized price should be the import parity price minus the federal and state government subsidies, while the actual open-market price is the price that is influenced by market distortions due to fertilizer subsidies and other market interventions. If subsidies depress the open market price of fertilizer, we expect to find that the actual open-market price will be lower than the import parity price, and such reduction may be greater in regions with higher effective subsidy rates. The theoretical open market price is expected to vary across regions due to transaction costs, which include transportation, storage charges, and taxes. Determination of the theoretical price could be used to change the current federal level pan-territorial subsidy rate (25 percent) to a rate that reflects actual transaction costs. Such a comparison may help the government determine appropriate subsidy rates by considering the influence of those subsidies on the market price of fertilizer. Of particular concern is the transportation cost, which many studies show to be the driver of high fertilizer prices in Africa (Otsuka and Kalirajan 2006; Pinstrup-Andersen 1993).

Figure 4: Topsoil soil fertility in Nigeria (% of total N in 0-15cm depth)



Source: FGN and FAO.

We estimate the import parity price of NPK assuming that fertilizer is imported through Lagos and transported by road by 30-ton trailers to one of the central cities in each of the six geopolitical zones.[6] We use the CIF price, fees at Lagos port (obtained from the Department of Fertilizer, Federal Ministry of Agriculture & Rural Development), and transportation costs from Lagos to various major cities obtained from major fertilizer manufacturers in Nigeria (Table 5). Given the CIF prices and other handling costs at the Lagos port, the ex-Lagos prices per ton in 2010 were $517, $582, and $382 for Urea, NPK, and SSP, respectively. Transport costs per ton range from $46 in the South-West to $98 in the North-East. Variations in transport costs within each geopolitical zone are relatively small (Table 6),[7] except in the North Central zone, where the cost can vary from $46 (Lagos-Ilorin) to $71 (Lagos-Abuja). The costs are similar to earlier estimates of $50 for Lagos-Abuja in 2005 by Gregory and Bumb (2006). It is interesting to note that transportation cost accounts for only 14 percent of the parity price in North-East and 7 percent in South-West (Figure 7). This is comparable to a 12 percent transportation cost observed by Wanzala et al (2002) in Kenya,[8] but smaller compared to other studies, which have shown the transportation cost to account for up to 50 percent of the price of fertilizer (e.g. Jayne et al. 2003).[9]

[6] We only estimate the NPK price since NPK is the most commonly used fertilizer in Nigeria and its price should largely determine the fertilizer market price in each region. The flow of other types such as Urea in Nigeria is less straightforward. Some companies obtain raw materials for Urea domestically instead of internationally and blend them in Port Harcourt instead of Lagos, which can affect the theoretical price in South South and South East regions.

[7] Interestingly, the transportation cost from Lagos-Maiduguri ($98/ton) is the same as Lagos-Jalingo or Lagos-Yola. This is possibly because most fertilizer transported to Maiduguri goes through the Lagos-Kano route, which is relatively in better conditions than other trunk roads (Figure 5). The theoretical price in South-South is not too different from North East, and higher than North West, due to the fact that most fertilizer bound for South-South is still imported from Lagos, instead of other major cities in the region such as Port-Harcourt (informal communication with the fertilizer companies).

[8] Wholesaler sale price was Kenyan Shilling 1450 while transportation cost from Mombasa-Eldoret was KES185 (Wanzala et al. 2002).

[9] Jayne et al (2003) observed a 93% increase in the wholesale price of DAP in Kenya from US$169/ton CIF Mombasa to $309/ton in Nakuru.

Table 5. Estimated import parity price of Urea, NPK, SSP in major cities in each geopolitical zone (2010)[a]

	Urea			NPK			SSP		
CIF price ($/MT)		370			425			255	
Ex-Lagos ($/MT)		517			582			382	
Import parity price	**Geopolitical zone**								
		NW			**NC**			**NE**	
	Urea	NPK	SSP	Urea	NPK	SSP	Urea	NPK	SSP
Local transportation ($/MT)		82			59			98	
Goods-in-transit insurance @ 0.65%	3.9	4.3	3.0	3.7	4.2	2.9	4.0	4.4	3.1
5% withholding tax[b]	18.5	21.25	12.75	18.5	21.25	12.75	18.5	21.25	12.75
Total ($/MT)	622	689	479	598	666	456	638	706	496
Total (NAIRA) @ 153.8/$	95590	106044	73732	92030	102484	70172	98067	108521	76209
		SW			**SS**			**SE**	
	Urea	NPK	SSP	Urea	NPK	SSP	Urea	NPK	SSP
Local transportation ($/MT)		46			87			61	
Goods-in-transit insurance @ 0.65%	3.7	4.1	2.8	3.9	4.3	3.1	3.8	4.2	2.9
5% withholding tax	18.5	21.25	12.75	18.5	21.25	12.75	18.5	21.25	12.75
Total ($/MT)	585	653	443	627	695	484	600	668	458
Total (NAIRA) @ 153.8/$	90018	100472	68159	96364	106818	74506	92340	102794	70481

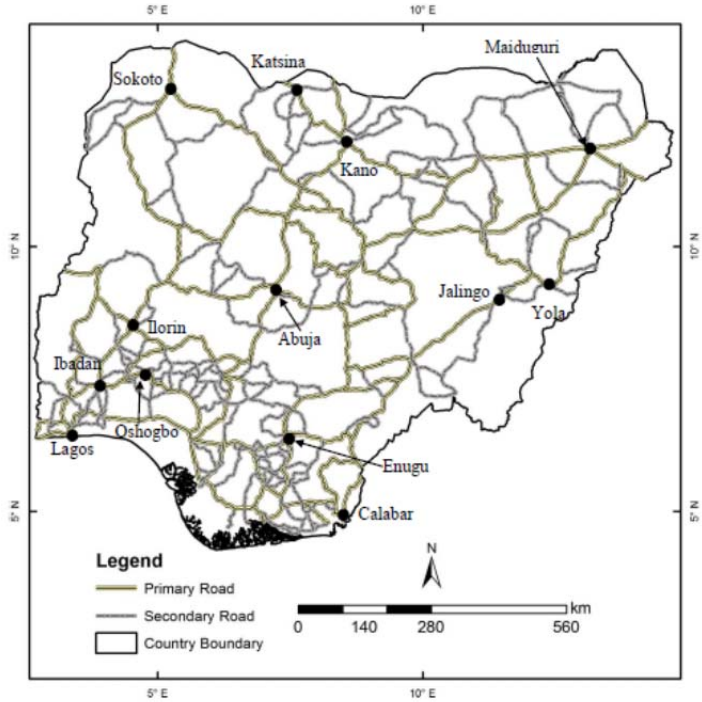
Source: Authors' calculations based on the Department of Fertilizer (2011) and transport costs assessed through informal communications with major fertilizer manufacturers in Nigeria (Notore and Tak International).
[a]NW = North West; NC = North Central; NE = North East; SW = South West; SS = South South; SE = South East
[b]Tax is applied to the CIF price.

Table 6. Transportation costs from Lagos to major fertilizer destinations[a]

Destination	Geopolitical zone	Transportation costs for 30 ton trailer (USD)
Sokoto	NW	82
Kaduna	NW	82
Katsina	NW	82
Maiduguri	NE	98
Yola	NE	98
Jalingo	NE	98
Abuja	NC	71
Ilorin	NC	46
Oyo	SW	44
Oshogbo	SW	49
Calabar	SS	87
Enugu	SE	61

Source: Informal communication with major fertilizer manufacturers in Nigeria.
[a]NW = North West; NC = North Central; NE = North East; SW = South West; SS = South South; SE = South East

Figure 5. Major roads, fertilizer destinations in Nigeria and cost from Lagos



Source: Generated by Renato Folledo using ESRI World Street Map (http://www.arcgis.com/home/item.html?id=3b93337983e9436f8db950e38a8629af).

We then compare the import parity price at the major regional cities with the open market price and subsidized price obtained from the LSMS data. The open market and subsidized prices are calculated for commercial and public sources as defined in Table 3 for each household, respectively. The import parity prices of the urban center in each zone are expected to be directly correlated with the rural prices. The implications of the subsequent discussions are expected to hold even if we use import parity prices for rural areas. A comparison of the three prices reveals interesting patterns (Figure 7). Consistent with Banful et al. (2010), the subsidized price is much lower than the open market price in the North compared to the South, underscoring the heavy influence of the generous subsidies in the northern zones. Secondly, the open market price is lower than the theoretical price in all zones, indicating that fertilizer subsidies depressed the open market prices through leakages of subsidized fertilizer into the open market. We also compared the LGA median prices of commercial and subsidized sources using both the NSAEC and the LSMS data. We found statistically significant positive correlations between commercial and subsidized fertilizer prices in all years for NSAEC data, and for a sub-sample of LGAs in the LSMS data that excluded extremely high fertilizer prices (Table 7). This suggests that fertilizer subsidies have generally depressed open market prices.[10] Such effects on open market price can lead to crowding-out of the private sector, unless private agro-dealers can somehow reduce fertilizer procurement costs per unit and make a profit selling at lower prices. This is generally unlikely, since not many private dealers have easy access to leaked subsidized fertilizer. These descriptive results motivate us to further analyze crowding-out effects using household level data.

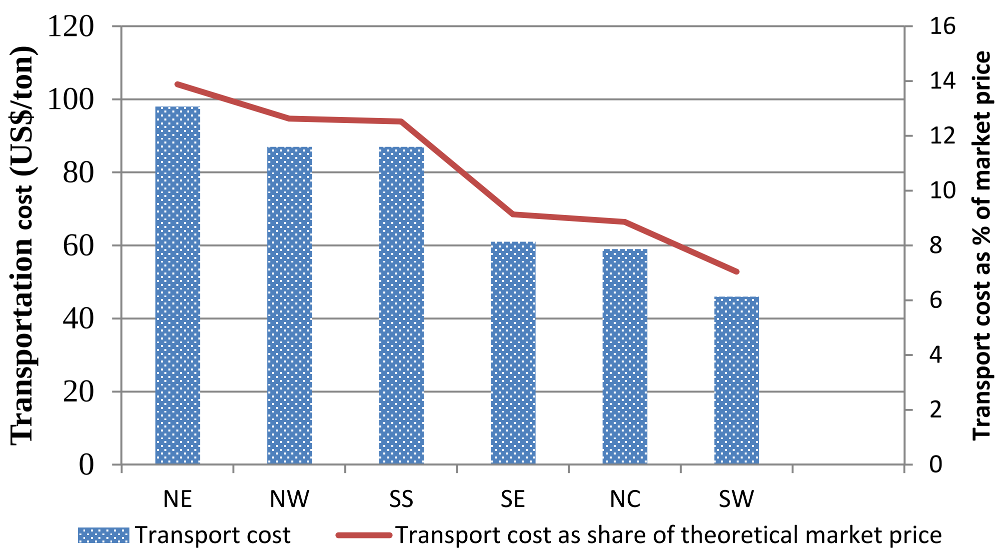
Table 7. Correlation between open market and subsidized price

	NSAEC data			LSMS data	
	2003	2006	2007	All LGA	Sub-sample[a]
Correlation coefficient	.391	.163	.565	.014	.261
Sample size	135	114	83	70	68
p-value (H0: correlation coefficient = 0)	.000	.083	.000	.907	.031

Source: Authors' calculations.
[a]Sub-sample consists of 68 LGAs out of 70 LGAs with data for subsidized fertilizer prices, where the calculated fertilizer price is less than US$2000 / ton.

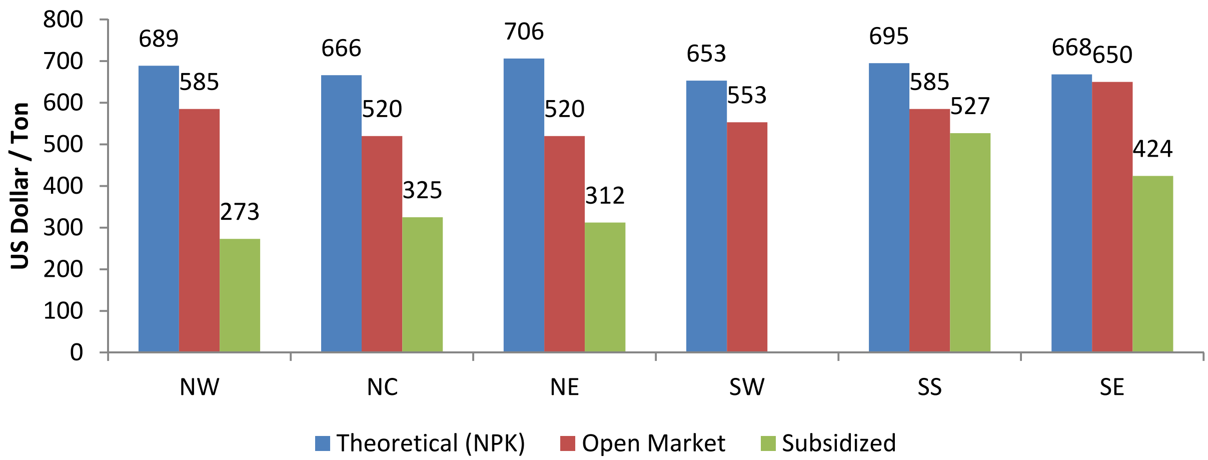
[10] We did not use LGA level information for similar panel data analysis on household level data since there are potential problems on the LGA level information due to varying sample size in each LGA, and uncertainty in the suitability of LGA as a cohort in the pseudo-panel.

Figure 6: Transportation cost as share of NPK parity price



Source: Calculated from Table 7.

Figure 7. Fertilizer Price (US$ / ton) in 2010 – theoretical import parity, open market, subsidized[abc]



Source: Authors' calculations.
[a] NW = North West; NC = North Central; NE = North East; SW = South West; SS = South South; SE = South East
[b]Open market and subsidized prices are medians of each region in LSMS data. No subsidized price was obtained for the South West region.
[c]Most farmers in LSMS data bought NPK, so we use the theoretical price of NPK.

Empirical methods to estimate crowding-in or crowding-out

Following Xu et al. (2009) and Ricker-Gilbert et al. (2011), crowding-in and crowding-out effects can be estimated in the following framework. Let $T = G + C$ where

- T = Total fertilizer consumption
- G = Quantity purchased through government subsidy
- C = Quantity purchased through commercial sources.

A change in subsidized fertilizer quantity G changes the total fertilizer consumption T through two pathways, through direct contribution of change in G, and indirect contribution through its effect on commercial fertilizer quantity C so that,

$$\frac{\partial T}{\partial G} = \frac{\partial G}{\partial G} + \frac{\partial C}{\partial G} = 1 + \frac{\partial C}{\partial G} \qquad (1)$$

where $\frac{\partial C}{\partial G} > 0$ indicates crowding-in, and $\frac{\partial C}{\partial G} < 0$ indicates crowding-out. If $\frac{\partial C}{\partial G} = 0$, a fertilizer subsidy has no effect on commercial sales.

A double-hurdle model (Cragg 1971) has been commonly applied to the consistent estimation of $\frac{\partial C}{\partial G}$ (Xu et al. 2009; Ricker-Gilbert et al. 2011). Double-hurdle models assume two decisions, one for participation (purchase of subsidized or commercial fertilizer) and one for the quantity of fertilizer purchased. We, however, modify the estimation approach due to the unique structure of our data, particularly the NSAEC data. One notable characteristic of our data is that most farmers only use either a public or a commercial source, and not both sources. Table 8 summarizes the proportion of farmers who used fertilizer from specific sources for both export crop growers (NSAEC) and for all farmers (LSMS data). Only 20 to 30 percent of farmers, or approximately 4 to 6 million farmers in Nigeria, use fertilizer. A majority of fertilizer users in the NSAEC data used commercial sources only (89 percent in 2003 and 88 percent in 2006) or public source only (8 percent in 2003 and 9 percent in 2006), while only about 3 percent of them used both commercial and public sources. Such dominance of single-sourcing is also observed in the 2010 LSMS survey and suggests that estimating crowding-in and crowding-out effects among single-source users can provide a good approximation of the overall effects for the entire fertilizer market. Using single-source users also helps overcome one of the limitations, which is that those sample farmers who obtained fertilizer from both commercial and public sources did not report the quantity obtained from each source. Estimating the crowding-out effect is impossible for those observations, so we need to limit our analysis to those who obtained fertilizer from only one source (commercial or public). Therefore we estimate the crowding-in and crowding-out effects using only single-source users. However, since farmers can self-select whether to use only one source or both sources, limiting the analysis to single-source user can lead to biased estimation. We therefore employ sample selection methods, as described below.

Table 8. Percentage of households by source of fertilizer obtained[a]

	Among export crop growers (NSAEC)			LSMS
	2003	2006	2007	2010
No fertilizer	79.6	78.5	69.7	75.3
Use fertilizer	20.4	21.5	30.3	24.7
Use commercial sources only	88.9	87.7	82.6	82.7
Use subsidized sources only	8.2	8.9	6.9	13.4
Use both sources	2.8	3.4	10.5	3.9

Source: Authors' calculation.
[a]In LSMS, the sample is all farmers who cultivated at least one plot in 2010.

Table 9 summarizes the median fertilizer quantity used for each type of farmer based on the source and whether the quantity varies significantly across these types. In 2003, those using fertilizer from commercial sources only, used 50 kg at the median, while those using subsidized fertilizer used only 10 kg, with the difference being statistically significant at p=0.01. Likewise, the quantity of subsidized fertilizer used by single source farmers was smaller than the quantities used by farmers obtaining fertilizer from commercial sources only for the NSAEC data in 2007. In the NSAEC data in 2006 and the LSMS data, however, the pattern of fertilizer use for the three groups is as expected. Farmers using both sources typically applied the greatest fertilizer quantities of 150 kg per household, while single source users applied 100 kg per household, which is statistically significantly less.

Table 9. Quantity of fertilizer used by sources (median among actual users, kg / household)

Data	NSAEC			LSMS
Year	2003	2006	2007	2010
Commercial source only	50	100	100	100
Subsidized source only	10	100	50	100
Both	28	150	50	151
p-value (H_0: commercial = both)[a]	.830	.000	.000	.000
p-value (H_0: public = both)[a]	.045	.000	.650	.000
p-value (H_0: commercial = public)[a]	.000	.008	.000	.796

Source: Authors' calculation.
[a]Test is based on Wilcoxon-Mann-Whitney (WMW) test (Mann & Whitney 1947).

We estimate the crowding-out effect $\frac{\partial C}{\partial G}$ in (1) using an endogenous Tobit model for both NSAEC and LSMS data, incorporating the fact that both *G* and *C* are censored at zero, and *C* may be endogenously determined with *G* by common socio economic factors. In addition, unlike in other countries where large-scale voucher distributions were implemented, subsidies in Nigeria involved direct distribution of fertilizer by the government and the actual quantity of fertilizer considered "subsidized" may be measured with errors. Using an endogenous Tobit model can reduce the bias caused by such measurement error. Furthermore, for the NSAEC data, we combine the endogenous Tobit model with a bivariate probit sample selection process in order to address the aforementioned sample selection bias. We also apply a modification of correlated random effects model in a context of pooled cross-section data in order to exploit its pseudo-panel data structure.

More specifically, the estimation proceeds in the following way. For the LSMS data, we estimate endogenous Tobit models using a control function approach (Papke and Wooldridge 2008) where,

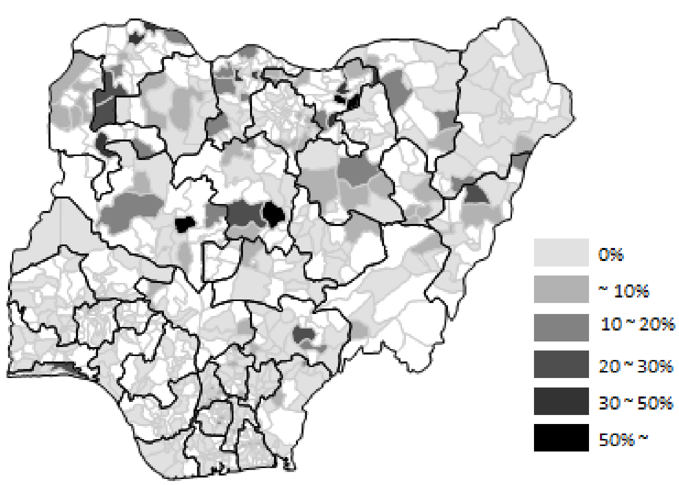
$$p = f(p', \text{distance to major cities}) \quad (2)$$

$$sub^* = f(x, p, \eta^*, \text{state dummy}) \quad (3)$$

$$com^* = f(sub, \varepsilon^*, p, \eta^*, x, \text{agroecological zone}) \quad (4)$$

in which η^* and ε^* are the residuals from the OLS equation (2) and Tobit equation (3), *p* is the observed commercial fertilizer price and p' is the import parity price of corresponding geopolitical zones in Figure 7. Distance to major cities represents the distance to major regional centers and is proxied by the LGA average hours required to travel to the nearest town with a population of more than 100,000 in 2000.[11] In regions with higher p', farmers may have more demand for subsidized fertilizer, which can affect their state government's subsidy rates. As a result of subsidized fertilizer allocation and leakage into commercial market, the observed open-market fertilizer price *p* is determined. Therefore, the observed open-market price *p* may be endogenous to both demand for subsidized fertilizer and commercial fertilizer. In (2), we instrument *p* with p', as well as the distance from each LGA to the regional center. We then correct the endogeneity biases due to *p* in (3) and (4) through a control function approach by inserting η^* as an additional explanatory variable. Similarly, the endogeneity biases due to the subsidized fertilizer quantity (*sub*) and price (*p*) are corrected with inclusions of η^* and ε^* in equation (4). We use state dummy variables in (3), which are not included in equation (4). This is because the supply of subsidized fertilizer is often influenced by the political factors and the share of farmers who receive subsidized or free fertilizer can vary across the local government areas or states within the same geo-political zones (Figure 8 and Figure 9).[12] The estimated coefficient for *sub* in (4) is used to calculate the crowding-in/out effects.

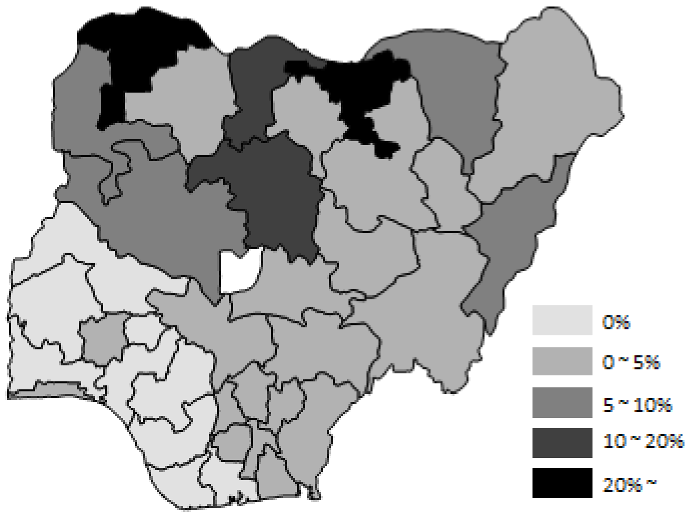
Figure 8. Share (LGA level) of farmers buying fertilizer from public source (among all farmers including non-users)



Source: Authors' calculation from LSMS data.

[11] Pixel level data were obtained from the Harvest Choice website and LGA average was calculated using GIS.
[12] Informal communications with local experts also suggest that the origin LGAs of the state government officials may sometimes receive more subsidized fertilizer.

Figure 9. Share (state-level) of farmers buying fertilizer from public source (among all farmers including non-users)



Source: Authors' calculation from LSMS data

Variables *x* are key household characteristics, including household size, age and gender of household head, level of education attained (primary, secondary, post-secondary), area of land owned and distributed under customary tenure, and whether the household has access to credit. Variables *x* also include historical average and standard deviation of annual rainfall for each LGA calculated based on the rainfall data from the University of East Anglia. The LGA average distance is measured in hours to the nearest town with population of at least 20,000, which is the proxy for farmers' market access[13] and LGA average maize price.[14]

Specifications for the NSAEC data are similar to (2) through (4). We, however, first use a bivariate probit to estimate the probability that the farmer *i* purchases fertilizer from commercial source (Π_c) and subsidized source (Π_s) each where,

$$(\Pi_c, \Pi_s) = f(x, \text{distance to major cities, geopolitical zone}), \tag{5}$$

and obtain the inverse Mills ratio (λ) using the formula in Cao et al. (1996) for each observation. Note that in (5), the effect of the import parity price is captured by the inclusion of geopolitical zone dummies. We then estimate endogenous Tobit models following Lee (1981),

$$p = f(p', \text{distance to major cities}) \tag{6}$$

$$sub^* = f(x, p, \eta^*, \text{geopolitical zone}, \hat{\lambda}) \tag{7}$$

$$com^* = f(sub^*, p, \eta^*, x, \text{agroecological zone}, \hat{\lambda}) \tag{8}$$

in which *com** and *sub** are latent variables for fertilizer quantity from commercial source and public subsidized source, respectively, and $\hat{\lambda}$ is the predicted inverse Mills ratio inserted to reduce the sample selection bias from excluding dual-source users from the sample. We used Lee (1981) instead of the control function approach for (8).[15] Standard errors in (4), (6), and (8) are estimated through 100 paired bootstrap simulations.

A correlated random effects (CRE) model proposed by Chamberlain (1984) has been applied to a non-linear panel model (Papke and Wooldridge 2008; Ricker-Gilbert et al. 2011; Xu et al. 2009), to improve on the single cross section. Its advantage is to reduce the bias due to unobserved heterogeneity potentially correlated with observed explanatory variables.

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[13] Similar to the distance to the nearest major city, pixel level data were obtained from the Harvest Choice website, and LGA average was calculated using GIS.

[14] Maize price was not available in NSAEC data and therefore not included for the analysis in NSAEC data.

[15] Coefficient on *sub* is not estimable using the Tobit specification (4) for NSAEC data. This is because, among single source users in NSAEC data, *com* = 0 whenever *sub* > 0 and *com* > 0 only when *sub* = 0, so that *sub* perfectly predicts whether *com* is censored or not.

We use a modified version of the CRE model applicable to pooled cross section data like the NSAEC dataset. Using the expression in Moffitt (1993), our model is similar to

$$y_{i(t)t} = \beta_0 + \beta_1 x_{i(t)t} + f_{i(t)} + \varepsilon_{i(t)t}, \text{i(t) = 1, ..., N, t = 1,..., T.} \quad (9)$$

in which $x_{i(t)t}$ is potentially correlated with unobserved heterogeneity $f_{i(t)}$, and can be endogenous. We interacted $x_{i(t)t}$ with year dummies d_t, assuming that

$$f_{i(t)} \approx \sum_t \sum_x \beta_{xt} \cdot (x_{i(t)t} \cdot d_t) \quad (10)$$

in which d_t = 1 if year = t and 0 otherwise. We interact most of the variables with year dummies, except some time-consistent variables like rainfall. This is similar to the idea in Chamberlain (1984)'s CRE model, which uses an average of x over time ($\overline{x_i}$) instead of $x_{i(t)t} \cdot t$ in panel data from which $\overline{x_i}$ is obtainable for each i. Assumption (10) is appropriate since it at least captures the variations in $x_{i(t)t}$ over year t and thus minimizes the bias caused by the yearly changes in samples.[16]

Descriptive statistics are shown in Table 10 (NSAEC data across years) and Table 12 (LSMS data), while the significance in the difference across different types of farmers is shown in Table 11 (NSAEC data) and Table 13 (LSMS data).[17] We reject the null hypotheses that the distribution of variables do not differ across years in the NSAEC data. Such variations across years also support our methodologies. In the LSMS data, significant variations are also observed across the type of farmers. Generally, fertilizer users have larger household size, are male headed, own a larger area of land, reside in drier areas, and face lower commercial fertilizer prices, albeit with variations. In both data sets (NSAEC and LSMS), households headed by those with no education were the least likely to obtain subsidized fertilizer among the three groups for farmers, suggesting that more educated farmers were more likely to have access to subsidized fertilizer. Likewise, LSMS data show that farmers closer to urban areas were more likely to acquire subsidized fertilizer. Female-headed households were less likely to use fertilizer compared to male-headed households. They were also less likely to acquire fertilizer from commercial sources. These results suggest that the fertilizer subsidy program in Nigeria did not target the poor and that male-headed households, the better educated, and those closer to urban areas were more likely to acquire subsidized fertilizer.

[16] In the context of pooled cross section, Moffitt (1993) alternatively suggests instrumenting such endogenous variables with appropriate instrumental variables (IVs). However, it is difficult in our estimation due to the lack of such IVs, and also the complexity of the endogenous Tobit model.

[17] We dropped the prices greater than 200Naira/kg, as that is not realistic. LGA average price is based on the remaining prices.

Table 10. Descriptive statistics (Export Grower Data)[a]

	2003				2006				2007			
	Non-user	Com	Sub	Both	Non-user	Com	Sub	Both	Non-user	Com	Sub	Both
Sample	10984	2505	232	80	12556	3010	306	117	10191	3668	309	463
Household size	4.5	5.3	6.2	6.6	5.4	7.6	7.1	7.5	4.6	6.7	5.8	6.7
Age	48	44	48	45	50	46	49	47	50	48	49	48
Female	9	2	4	0	12	2	4	1	15	7	10	7
Primary education or less (%)	85	89	77	86	53	64	51	69	53	64	44	60
Secondary education (%)	11	8	18	13	29	23	23	15	29	21	29	23
Post-secondary education (%)	3	3	6	3	18	14	26	17	15	10	17	11
Land owned	1.2	1.5	0.7	1.7	4.9	4.0	7.7	7.0	0.9	0.8	1.7	1.2
Customary (%)	31	17	27	25	14	7	7	9	13	13	12	12
Use credit (%)	7	4	13	9	7	3	8	3	6	6	6	6
Fertilizer price (commercial)(N/kg)	49	42	35	36	58	55	52	54	61	54	60	52
Fertilizer price (subsidized) (N/kg)	44	28	59	23	59	51	51	54	42	39	44	37
Travel time to the nearest 20k town (hours)	2.3	2.2	2.3	1.7	2.2	2.1	2.2	2.3	2.2	2.0	1.8	1.9
Average annual rainfall (mm)	1506	1020	1322	990	1528	995	1426	926	1559	1246	1579	1265
Standard deviation of annual rainfall (mm)	213	172	187	170	216	170	205	161	222	198	226	199

Source: Authors' calculation.

[a]Note: com = commercial, sub=subsidized, both=dual sources.

Table 11. Significance in the difference across types of farmers based on paired-test (Export Grower Data)[ab]

	2003						2006						2007					
Household size	Non vs. com	Non vs. sub	Non vs. Both	Com vs. Sub	Com vs. Both	Sub vs. Both	Non vs. com	Non vs. sub	Non vs. Both	Com vs. Sub	Com vs. Both	Sub vs. Both	Non vs. com	Non vs. sub	Non vs. Both	Com vs. Sub	Com vs. Both	Sub vs. Both
Household size	–**	–**	–**	–**	–**		–**	–**	–**	+†			–**	–**	–**	+**		–**
Age	+**		+*			+*	+**		+**	–**		+†	+**	+†	+**			
Female	+**	+**	+**	–†		+†	+**	+**	+**	–†			+**	+**	+**	–†		
Primary education or less (%)	+**	+**	+**	+†	+†			–**		–*		+†	–**	+**	–**	+**		–**
Secondary education (%)	+**	–**		–**			+**	+*	+**		+*	+†	+**		+**	–**		+*
Post-secondary education (%)		–*		–†			+**	–**		–**		+*	+**		+**	–**		+**
Land owned	+**	+†	–*	+**		–**	+**	–**	–**	–**	–**	+*						
Customary (%)	+**			–**	–†		+**	+**	+†									
Use credit (%)		–**		–**	–*		+**		+†	–**		+†						
Fertilizer price (commercial)(N/kg)	+**	+**	+**	+**	+**	–**	+**	+**		+**		–*	+**		+**		+**	+**
Fertilizer price (subsidized) (N/kg)	+**	+**	+**	–**	+*	+**	+**	+**			–*	–**	+**		+**	–**	+**	+**
Travel time to the nearest 20k town (minutes)	+†		+*	–*	+**		+*			–†	–*		+**	+**	+**	+**		–†
Average annual rainfall (mm)	+**	+**	+**	–**		+**	+**	+**	+**	–**	+*	+**	+**		+**	–**		+**
Standard deviation of annual rainfall (mm)	+**	+**	+**	–*			+**	+**	+**	–**	+**	+**	+**		+**	–**		+**

Source: Authors' calculations.

[a]Kruskal-Wallis test for the equality of population is used for continuous variables, while chi-square test is used for discrete variables.

[b]Levels of significance are indicated with ** as 1%, * as 5% and † as 10%, respectively.

Table 12. Descriptive statistics (LSMS Data)[a]

	Types of farmers			
	Non-user	Commercial source only user	Subsidized source only users	Dual-source users
Sample	1744	1019	165	48
Household size	5.5	6.6	6.8	7.5
Age	52	49	50	47
Female	16	6	4	4
Primary education (%)	31	26	25	23
Secondary education (%)	15	15	16	25
Post-secondary education (%)	6	9	8	13
Household asset value (1000 Naira)	93	150	140	100
Total plots cultivated (ha)	1.2	1.3	0.9	3.3
Area of plots owned (ha)	0.2	0.4	0.2	0.2
Share of land from outright purchase (%)	4	10	9	16
Share of land distributed by community or family (%)	67	70	72	66
Use credit (%)	3.1	2.9	1.2	0.0
Travel time to the nearest 20k town (minutes)	152	151	142	153
Average annual rainfall (mm)	1745	1343	1196	1012
Standard deviation of annual rainfall (mm)	217	189	176	158
Fertilizer price (commercial)(Naira/kg)	123	97	111	122

Source: Authors' calculation.
[a]p-value: H_0: no difference in mean across groups based on Kruskal-Wallis test for the equality of population.

Table 13. Significance in the difference across types of farmers based on paired-test (Export Grower Data)[ab]

	Non vs. com	Non vs. sub	Non vs. Both	Com vs. Sub	Com vs. Both	Sub vs. Both
Household size	–**	–**	–**		–*	–†
Age						
Female	+**	+**	+*			
Primary education (%)						
Secondary education (%)	+**	+†			–†	
Post-secondary education (%)	+**	+*				
Household asset value (1000 Naira)	–**					
Total plots cultivated (ha)	–**	+*	–**		–†	–†
Area of plots owned (ha)	–**					
Share of land from outright purchase (%)	–**					
Share of land distributed by community or family (%)	–**	–*				
Use credit (%)	–**	–*			+*	+†
Travel time to the nearest 20k town (minutes)	+**	+**	–*			
Average annual rainfall (mm)	+**	+**	+**	+**	+**	
Standard deviation of annual rainfall (mm)	+**	+**	+**	+**	+**	
Fertilizer price (commercial)(Naira/kg)						

Source: Authors' calculations.
[a]Kruskal-Wallis test for the equality of population is used for continuous variables, while chi-square test is used for discrete variables.
[b]Levels of significance are indicated with ** as 1%, * as 5% and † as 10%, respectively.

RESULTS

Tables 14 through 16 present the unconditional average partial effects (APE) across all samples used in the analysis. In Tobit, unconditional APEs are estimated using the method by McDonald and Moffitt (1980). APEs for variables interacted with year dummies are estimated using the year-specific mean values of each variable. The *Z*-values correspond to the estimated coefficients instead of estimated APEs, since the statistical significance of the APEs depends on the statistical significance of the estimated coefficients.

Decisions to purchase fertilizer from each source

Table 14 presents the APE of each variable on the probability of purchasing fertilizer from commercial source and public source, based on NSAEC data. Farmers who are more likely to purchase from commercial source are those living in areas with lower and less predictable rainfall, with larger male-headed household, and having completed at least primary education. Farmers who are more likely to purchase fertilizer from a public source are those living in areas with more and stable rain and who have larger households. Some of the characteristics of farmers who are likely to purchase fertilizer from commercial sources are somewhat similar to the characteristics of those who are likely to purchase fertilizer from public sources, in particular the proximity to the major cities, household size, gender of household head, whether the household head has post-secondary education, and access to credit. Such similarity in characteristics weakly indicates that they may be more likely to substitute fertilizer from one source for the other, thus potentially leading to crowding-out by subsidized fertilizer.

Crowding-out

Table 15 presents the determinants of the quantity of subsidized fertilizer and commercial fertilizer obtained by single-source users based on equations (6) and (8). Results from the LSMS data are presented in Table 16. The estimated APE of subsidized fertilizer on commercial fertilizer measures the average crowding-in or crowding-out effect for the sample. The estimated APEs are statistically significantly negative, suggesting the crowding-out of commercial fertilizer by subsidized fertilizer. Estimated APEs are -0.193 from the NSAEC data and -0.345 from the LSMS data. We can interpret this for collections of farmers, whereby "collection" simply means multiple farmers.[18] The results indicate that if a collection of farmers is using one ton more subsidized fertilizer in total, that same group will be using between 0.19 and 0.35 ton less fertilizer in total from commercial sources. While we would expect to find evidence suggesting crowding-out among single-source users (NSAEC data), results from the LSMS data suggests that the crowding-out also may be present for larger groups of farmers, including dual-source users and non-export crop growers, and possibly in a greater magnitude relative to the NSAEC results.

Results of the effects of other determinants are also similar between Table 15 and Table 16, except for some differences in statistical significance possibly due to the presence of non-export crop growers in the former. Generally, farmers using more subsidized fertilizer are those living in areas with higher rainfall, who reside near towns, who have larger households, and are older males who have completed secondary or post-secondary education. This suggests access to and use of subsidized fertilizer was higher in places closer to markets than in remote areas. Similarly, farmers who use more commercial fertilizer are male farmers living near towns, with larger households, and reasonable access to credit. A larger household size may induce greater demand for fertilizer possibly because using more fertilizer may make sense when there are enough family members who can be mobilized for more intensive weeding or harvesting activities. The commercial fertilizer price was found not to affect fertilizer demand in a statistically significant manner. This is consistent with Banful et al. (2010) who observed that farmers perceived that the physical availability of fertilizer was a more serious problem than was a higher price. A statistically significantly positive coefficient on the inverse Mills ratio λ indicates that idiosyncratic factors raising the likelihood of farmers using public sources of fertilizer only positively affects the quantity purchased. Similarly, a statistically significant coefficient on the residual of the price equation indicates that the fertilizer price may be endogenous, as discussed above and corrected in our specifications.

[18] Similar interpretations are, however, difficult for an individual farmer because our model assumes that an individual farmer obtains fertilizer from only one source. Once he/she decides to use subsidized fertilizer, the quantity of subsidized fertilizer does not affect how much he/she obtains commercial fertilizer. Therefore, the estimated crowding-out effect is more meaningful at the aggregated level, such as groups of farmers.

Table 14. Bivariate probit model on whether to purchase fertilizer from commercial and public source (estimated average partial effect on the marginal probability at the mean of variables)[a]

Dependent variable = Marginal probability	Public subsidized source						Commercial source					
			APE	*z*					APE	*z*		
Rainfall – average (1000mm)			.291**	4.32					-.240†	-1.89		
Rainfall – standard deviation (100mm)			-.143*	-2.27					.667**	5.86		
Distance to nearest town (hour)			-.003	-1.30					-.003	-.77		
	2003		2006		2007		2003		2006		2007	
	APE	*z*	APE	*z*	APE	*z*	APE	*z*	APE	*z*	APE	*z*
Distance to major cities (hour)	-.003†	-1.88	-.003†	-1.77	-.003	-1.25	-.000	-.11	-.010**	-2.95	.000	.10
Land owned (ha)	-.001†	-1.94	.000	1.01	-.000*	-2.11	.002*	2.12	.000	.99	.000	1.63
Customary tenure (yes = 1)	-.002	-.64	-.010*	-2.48	.000	-0.00	.001	.13	-.014	-1.48	.015	.95
Household size	.003**	6.78	.001**	3.42	.002**	3.97	.008**	7.94	.007**	10.62	.015**	14.67
Age	.002	1.26	.000	1.39	.000	-.54	.000	-1.47	-.001**	-5.01	.000	-.71
Female	-.008	-1.12	-.016*	-2.14	-.012	-1.46	-.045**	-3.51	-.038**	-2.67	-.036**	-2.71
Primary education	-.016**	-4.25	.013*	2.12	.007	.49	-.003	-.40	.056**	3.27	.055*	2.44
Secondary education	.008†	1.90	-.003	-.79	.022	1.43	.015	1.36	.027**	4.16	.060*	2.52
Post-secondary education	.008	1.34	.013**	4.36			.049**	3.11	.039**	5.90		
Access to credit (yes = 1)	.022**	4.77	.009	1.63	-.011	-1.24	.075**	5.21	.016	1.28	.002	.12
Geopolitical dummy	yes		yes		yes		yes		yes		yes	
ρ						.118**						
Number of observations						45752						

Source: Authors' calculations.

[a]Levels of significance are indicated with ** as 1%, * as 5% and † as 10%, respectively.

Table 15. Determinants of fertilizer quantity (unconditional APE) – NSAEC data[ab]

Dependent variable = quantity (kg) of subsidized fertilizer used	Subsidized quantity						Commercial quantity					
			APE	*z*					APE	*z*		
Subsidized fertilizer quantity (kg)									**-.193****	-3.17		
Rainfall – average (mm)			.322**	2.73					.292	.75		
Rainfall – standard deviation (mm)			-.101	-1.22					-.929*	-2.39		
Distance to nearest town (hour)			-5.587**	-2.84					-.018**	-2.63		
λ			.093**	5.29					-.002	-.06		
Residual of price equation			-.001	-1.29					-.002†	-1.83		
	2003		2006		2007		2003		2006		2007	
	APE	*Z*	APE	*z*	APE	*z*	APE	*z*	APE	*z*	APE	*z*
Commercial fertilizer price (Naira)	.117	1.17	.158	1.17	.131	1.25	.470	.36	-1.094	-.76	-1.425	-1.05
Land owned (ha)	-2.121	-1.64	.056	1.51	-.097	-1.41	1.177	.15	.362*	2.13	-.475	-1.42
Household size[c]	.003**	4.49	.002*	3.63	.002**	3.86	.010**	3.30	.001	.41	.006*	2.04
Age[c]	.000†	1.80	.000	.98	.000	-.63	.002†	1.90	.002**	2.57	.001	1.18
Female[c]	-.010	-1.40	-.026†	-1.86	-.013*	-1.99	-.020	-.54	.038	.68	-.026	-.95
Primary education [c]	-.015*	-2.55	.021*	2.35	.003	.16	-.052*	-2.12	-.024	-.63	.011	-.08
Secondary education [c]	.015*	2.23	-.001	-.19	.014	.67	.056	1.56	-.056**	-2.92	.041	.31
Post-secondary education [c]	.012	1.54	.031**	3.47			.065	1.24	.074*	2.23		
Customary[c]	-.003	-.76	-.022*	-2.41	-.002	-.63	.036	1.37	-.050	-1.31	-.036	-1.61
Use credit[c]	.031**	3.31	-.009	1.21	-.010	-1.62	.107*	2.24	.077*	2.50	-.009	-.22
Agroecological zone dummy							yes		yes		yes	
Geopolitical zone dummy	yes		yes		yes							
σ_1			.302**						.462**			
Number of observations						8400						

Source: Authors' calculations.
[a]Levels of significance are indicated with ** as 1%, * as 5% and † as 10%, respectively.
[b]Z-values are based on standard errors obtained through 100 bootstrap simulations.
[c]Coefficients for these variables are measured in tons.

Table 16. Results from 2010 LSMS data (estimated average partial effect at the mean of variables)[ab]

Dependent variable = quantity (kg) of fertilizer used	Subsidized fertilizer (1)		Commercial fertilizer (2)	
	APE	z	APE	z
Subsidized fertilizer quantity (kg)			**-.346***	-2.12
Residual from equation (1)			.025†	1.71
Rainfall – average (mm)	.026†	1.77	-.046**	-2.68
Rainfall – standard deviation (mm)	-.320*	-2.13	.232	1.29
Distance to nearest town (hour)	-.105*	-2.19	-.209**	-3.01
Commercial fertilizer price (Naira / kg)	.930	.24	.001	1.21
Residuals from price equation	-.952	-.25	-1.584	-1.43
LGA average maize price	-.009	-1.12	-.008	-1.19
Household size	1.169*	1.99	7.477**	5.43
Age	.366*	2.18	-.267	-.81
Female (yes = 1)	-4.992	-.57	-28.110†	-1.89
Household asset (1000 US$)	-1.555	-1.05	-.050	-.01
Education (primary)	13.650**	3.10	-3.958	-.36
Education (secondary)	20.091**	3.63	6.357	.57
Education (post)	18.283*	2.06	15.206	.93
Education (Koranic and other)	13.300†	1.71	4.568	.37
Education (other)	10.749†	.16	10.952	.57
Land owned (ha)	-.308	-.11	1.587	.64
Land distributed (ha)	.903*	2.26	5.342	.73
Accessed credit	-6.811	-1.51	7.236	.87
AEZ 1			8.098	.55
AEZ 2			67.644**	7.85
AEZ 3			62.977**	3.85
State dummy	Yes**			
σ_1	.409**		.287**	
Number of observations	1530		1530	

Source: Authors' calculations.
[a]Levels of significance are indicated with ** as 1%, * as 5% and † as 10%, respectively.
[b]Standard errors are obtained through 100 bootstrap simulations.

Another important result is that crowding-out may be more likely because farmers using more subsidized fertilizer have somewhat similar characteristics to those who are expected to use commercial fertilizer, in particular the proximity to town and large household size. To see this, we derive the partial effect (PE),

$$\frac{\partial E[com|X_i]}{\partial sub^*} = \beta_{sub}\Phi\left(\frac{X_i\beta}{\sigma}\right) \qquad (11)$$

in which $\Phi(\cdot)$ is the normal distribution function, X_i is the set of all covariates in (4) and (8), β is the estimated coefficients, and σ is the estimated standard deviations of the error term in (4) and (8). The value of (11) varies across farmers since the term $\Phi\left(\frac{X_i\beta}{\sigma}\right)$ is individual specific. Crowding-out will be greater if a subsidy is provided for farmers with characteristics X_i that lead to greater $\Phi\left(\frac{X_i\beta}{\sigma}\right)$. In our results, both proximity to the nearest town and large household size lead to greater $\Phi\left(\frac{X_i\beta}{\sigma}\right)$, indicating that crowding-out might have been greater particularly for farmers with larger households residing closer to town. At the same time, our results above indicate that these farmers are also likely to use more commercial fertilizer even in the absence of subsidy. Providing them with subsidized fertilizer may displace much of their fertilizer purchases from commercial sector sources.

Supplementary analysis

Using the NSAEC data, we also assess if there is a significant crowding-in among dual-source users. As mentioned above, dual-source users in the NSAEC data only report the total fertilizer purchased from two sources and not individual sources. We therefore investigate whether using both sources led to a substantial increase in total fertilizer quantity obtained compared to using only one source. Moreover, we estimate the following reduced form ordinary least square (OLS) among all fertilizer users,

$$total^{*} = f(x, p, \eta^{*}, \text{agroecological zone}, \text{geopolitical zone}, \delta^{*}) \tag{12}$$

in which *total** is the total fertilizer quantity, and δ^{*} is the probability estimated from (5) that the farmers purchase fertilizer from both sources using the formula by Cao et al. (1996). The specification (12) is an extension of a method suggested by Wooldridge (2002, 625), which provides consistent estimates of the average treatment effect of using both sources on the total quantity of fertilizer used, under the general assumptions including the assumption that (5) is a correct specification of farmers' decision-making on the choice of fertilizer sources. We find that the result rejects the hypothesis that using both sources statistically significantly increases the total fertilizer used. Using both sources therefore does not lead to crowding-in, but may lead to crowding-out, as farmers are likely to substitute fertilizer obtained from one source for fertilizer obtained from the other source. Combined with the fact that most farmers only use one type of source, the comparison of single- and dual-source users indicates crowding-out.

Policy issues for reducing leakages

The analyses above indicate that the leakage of subsidized fertilizer into the open market seems an important hindrance to the development of the private fertilizer sector in Nigeria. If a vibrant private fertilizer sector is to be established, minimizing such leakages is crucial. Key policy issues for reducing leakages in fertilizer subsidy programs include the support for more ex-ante assessments of fertilizer demand, effective targeting or monitoring, and the setting of appropriate fertilizer subsidy levels.

An ex-ante assessment is important in assessing the strength of demand for fertilizer of the intended beneficiaries. This assessment should also take into account the suitability of their agroecological environment for fertilizer responsive crops, their access to output markets and to other complementary inputs, their knowledge about the benefits of fertilizer and, thus, the potential for their sensitization through the fertilizer subsidy to significantly increase their demand for fertilizer. Though our study shows the evidence of crowding-out and leakage at the national level, more ex-ante studies are needed for different types of farmers. While the political will behind the new subsidy scheme under the ATA to target 20 million farmers is welcome, and demand for fertilizer is expected to be large for some farmers, there is still a paucity of evidence in Nigeria that a majority of these farmers have sufficient demand for fertilizer. The limited demand for fertilizer of Nigerian farmers is due, in part, to their access to certain traditional varieties that grow well with relatively little fertilizer, their lack of access to the other complementary inputs needed to exploit the full potential of fertilizer, abundant land in some areas that allows recovery of soil fertility through fallowing, obviating the need for fertilizer, and low farm gate crop prices.

Once the intended beneficiaries are identified, appropriate targeting mechanisms should be implemented. Although challenging, targeting can be implemented through geographical targeting (subsidized inputs are provided to all farmers in defined geographical areas), community-based targeting, and indicator-based targeting. Geographical targeting is less costly but often associated with high leakage (Houssou and Zeller 2011). Community-based targeting, which relies on local authorities or community representatives to select beneficiaries, has generally been ineffective in Sub-Saharan Africa due to political favoritism or misunderstanding by community leaders of the criteria for selection (Chinsinga 2005; Conning and Kevanne 2002), although in certain cases community-based targeting can make use of local information about the beneficiaries, which is often unobservable from outsiders, when selecting beneficiaries (Alatas et al. 2012). In a community-based targeting process used in Tanzania for an input subsidy voucher program, elite capture of vouchers was prevalent, particularly in remote areas with high inequality in access to land within the community (Pan and Christiaensen 2012). Indicator-based targeting, in which subsidized fertilizer would be provided to beneficiaries based on their household characteristics, though costlier than the aforementioned targeting methods, can be a more effective means of targeting. A study in Malawi suggests that, if indicator-based targeting had been used in its subsidy program, overall cost-effectiveness would have been better due to reduced leakage (Houssou and Zeller 2011). However, under all targeting schemes, continuous scrutiny and monitoring is needed so that leakage is minimized.

Using electronic vouchers, as in the new fertilizer subsidy scheme for Nigeria, may reduce but not entirely eliminate leakage of the subsidized fertilizer. Sufficient demand for fertilizer by beneficiaries is still crucial. While the quota is set at 100 kg of fertilizer per beneficiary under the new subsidy scheme, beneficiaries needing less than 100 kg of fertilizer always have incentives to re-sell some of the subsidized fertilizer they received in the open market, causing leakages. Ex-ante assessment is therefore again important in ensuring that the intended beneficiaries indeed need more than the quota of 100 kg of fertilizer, because this 100 kg of fertilizer provides more returns to the household receiving it if used for crop production than if it is resold in the open market at higher prices. For this reason, setting a too generous subsidy rate also involves risks of causing greater leakages, particularly if the demand for fertilizer is inelastic and the higher subsidy rate leads to a greater reduction in the subsidized fertilizer price, potentially inducing more rent-seeking activities by non-beneficiaries. If an accurate ex-ante assessment of the demand for fertilizer by the intended beneficiaries is costly, reducing the subsidy rate would be a safer option, not only reducing the budget requirement for the subsidy program, but also the risk of leakage.

CONCLUSIONS

Governments in countries in Sub-Saharan Africa often use subsidies with the aim of building and strengthening private-sector led agricultural input sectors. For a country like Nigeria undergoing subsidy reform, the information provided through this analysis of the effectiveness of previous subsidy schemes provides an important base by which to compare the likely impact of the new fertilizer subsidy scheme being planned. We examined the effect of subsidized fertilizer on private-sector fertilizer supply in Nigeria, taking into account its complicated structure where the private-sector fertilizer price can be influenced by fertilizer subsidies. More specifically we examined deviations in the private-sector fertilizer price from the theoretical import parity price and estimated how subsidized fertilizer supply by the public sector may crowd-in or crowd-out commercial fertilizer supply. We find several patterns suggesting that previous fertilizer subsidy schemes crowded-out private-sector supply of fertilizer;

- Greater subsidy rates are associated with lower open market fertilizer prices, indicating a price depressing effect of the fertilizer subsidy, which generally lowers the profitability for private fertilizer marketing sector.
- A majority of farmers using fertilizer may use only a single-source to obtain their fertilizer – from either commercial or public sources, but not both, weakly suggesting a potential crowding-out effect.
- For single-source users, the supply of subsidized fertilizer from public source crowds out approximately 19 to 35 percent of the fertilizer supplied from commercial sources, with a potentially larger crowding-out effect among dual source users who obtain fertilizer from both commercial and subsidized sources.
- The characteristics of subsidy beneficiaries and those with greater demand for commercial fertilizer indicate that many subsidy beneficiaries under previous subsidy schemes would have otherwise purchased fertilizer from commercial sources in the absence of a subsidy. This likely is one of the reasons for the subsidy crowding-out the commercial fertilizer sector. We also observe that previous subsidy programs were favorable to farmers closer to urban areas and those that were male-headed with larger households.

The results suggest key lessons for the Nigerian government in its fertilizer subsidy reform. It is important to effectively target fertilizer subsidies to farmers whose subsidized fertilizer use is less likely to affect their commercial fertilizer use. A recent study in Kano State, suggests that subsidies provided through vouchers may stimulate farmers' demand for non-subsidized fertilizer, potentially crowding-in the private fertilizer sector (Liverpool-Tasie 2012). This indicates that a voucher-based system, like that planned under the ATA, could improve the targeting of subsidy beneficiaries and reduce crowding-out of the private fertilizer sector. Even if the subsidy is well targeted, however, providing excess quantity of subsidized fertilizer can still crowd-out the private sector since the subsidy may create an environment for resale of subsidized fertilizer, depressing the private-sector fertilizer price. It is crucial for the Nigerian government to provide an environment in which returns to fertilizer are high enough, in order for the new fertilizer subsidy scheme to have greater impact than the previous fertilizer subsidy scheme that we studied.

REFERENCES

Adesina A. 2011. Agricultural Transformation Agenda. Presentation made by the Honorable Minister of Agriculture to the Economic Management Team Abuja, September 9, 2011**.**

Alatas V, A Banerjee, R Hanna, BA Olken, and J Tobias. 2012. Targeting the Poor: Evidence from a Field Experiment in Indonesia. *American Economic Review* 102 (4): 1206–1240.

Alene A.D., V.M. Manyong, G. Omanya, H.D. Mignouna, M. Bokanga, and G. Odhiambo. 2008. Smallholder market participation under transactions costs: Maize supply and fertilizer demand in Kenya. *Food Policy* 33 (4): 318–328.

Banful A.B., E Nkonya, and V Oboh. 2010. *Constraints to fertilizer use in Nigeria: Insights from agricultural extension service*. IFPRI Discussion Paper 01010. Washington, DC: IFPRI.

Banful A.B. and O. Olayide. 2010. Perspectives of Selected Stakeholder Groups in Nigeria on the Federal and State Fertilizer Subsidy Programs. *IFPRI NSSP Report 08.* Abuja: IFPRI-Abuja.

Cao J., E.W. Stromsdorfer, and G. Weeks. 1996. The Human Capital Effect of General Education Development Certificates on Low Income Women. *J. Human Res.* 31 (1): 206–228.

Chamberlain G. 1984. *Panel Data.* In "Handbook of Econometrics*."* Vol. 2, edited by Z. Grilliches and M.D. Intriligator, 1247–1318. Amsterdam: North-Holland.

Chinsinga B. 2005. The clash of voices: community-based targeting of safety-net interventions in Malawi. *Social Policy and Administration* 39 (3): 284–301.

Coady D, M Grosh & J Hoddinott. 2004. Targeting outcomes redux. *The World Bank Research Observer* 19 (1): 61–85.

Conning J. and M. Kevanne. 2002. Community-based targeting mechanisms for social safety nets: a critical review. *World Development* 30 (3): 375–394.

Cragg J.G. 1971. Some Statistical Models for Limited Dependent Variables with Application to the Demand for Durable Goods. *Econometrica* 39 (5): 829–844.

FAO. 2012. FAOSTAT 2012. Rome, Italy.

FGN (Federal Government of Nigeria). 2011. *The Transformation Agenda, 2011-2015.* National Planning Commission, Abuja Nigeria. Computer Disk, Washington DC.

Federal Ministry of Agricultural & Rural Development (FMARD). 2011. *Agricultural Transformation Agenda: We Will Grow Nigeria's Agricultural Sector.* Draft. Abuja, Nigeria. Computer Disk, Washington DC.

Federal Ministry of Agricultural & Rural Development (FMARD). 2012a. *Technology Enabled Fertilizer Market Stabilization Scheme*. Unpublished report prepared by the FMARD, Cellulant Corporation, International Fertilizer Development Center. Computer Disk.

Federal Ministry of Agricultural & Rural Development (FMARD). 2012b. *Ministerial platform for the 2012 national democracy day celebration and first anniversary of president Goodluck Jonathan's administration: input from the Federal Ministry of Agricultural & Rural Development*. Unpublished report prepared by the FMARD. Computer Disk. Abuja: FMARD.

Greene W. 2003. *Econometric Analysis*. 5th Edition. New York: Prentice Hall.

Gregory I. and B.L. Bumb. 2006. *Factors Affecting Supply of Fertilizer in Sub-Saharan Africa*. Washington, DC: World Bank, Agriculture and Rural Development Discussion Paper 24. Washington, DC: World Bank.

Gregory I. 2008. *Report on 2008 and 2009 fertilizer voucher program in conjunction with NPFS and Ministry of Agriculture and Water Resources and State Ministries of Agriculture.* Submitted to USAID MARKETS Project, Nigeria.

Headey D., D. Bezemer, and P. Hazell. 2010. Agricultural Employment Trends in Asia and Africa: Too Fast or Too Slow? *The World Bank Research Observer* 25 (1): 57–89.

Holden, S. and R. Lunduka. 2012. Do fertilizer subsidies crowd-out organic manures? The case of Malawi. *Agricultural Economics.* 43: 303–314.

Houssou, N. and M. Zeller. 2011. To target or not to target? The costs, benefits, and impacts of indicator-based targeting. *Food Policy* 36 (5): 627–637.

Jayne, T.S., J. Govereh, M. Wanzala, and M. Demeke. 2003. Fertilizer market development: a comparative analysis of Ethiopia, Kenya, and Zambia. *Food Policy* 28 (4): 239–316.

Lee, L.F. 1981. *Simultaneous Equations Models with Discrete and Censored Dependent Variables.* In *Structural Analysis of Discrete Data with Econometric Applications*, edited by C.F. Manski and D. McFadden, 346–64. Cambridge: The MIT Press.

Liverpool-Tasie, S., B. Olaniyan, S. Salau, and J. Sackey. 2010a. *A Review of Fertilizer Policy Issues in Nigeria*. IFPRI NSSP Working Paper 0019. Abuja: IFPRI-Abuja.

Liverpool-Tasie, S. A.B. Banful, and B. Olaniyan. 2010b. *Assessment of the 2009 fertilizer voucher program in Kano and Taraba, Nigeria*. IFPRI NSSP Working Paper 17. Abuja: IFPRI-Abuja.

Liverpool-Tasie, S. 2012. *Targeted subsidies and private market participation: An assessment of fertilizer demand in Nigeria* IFPRI Discussion Paper 01194. Washington DC: IFPRI.

Mann, H.B. and D.R. Whitney. 1947. "On a test whether one of two random variables is stochastically larger than the other." *Annals of Mathematical Statistics* 18: 50–60.

McDonald, J.F. and R. Moffitt. 1980. "The use of Tobit Analysis." *Review of Economics and Statistics.* 62: 318–321.

Moffitt, R. 1993. "Identification and estimation of dynamic models with a time series of repeated cross-sections." *J. Econometrics* 59: 99–123.

Nagy, J. G. and O. Edun. 2002. *Assessment of Nigerian government of policy and suggested alternative market friendly policies.* Muscle Shoals, AL, USA: International Fertilizer Development Center.

Otsuka, K. and K. Kalirajan. 2006. "Rice green revolution in Asia and its transferability to Africa: An introduction." *The Developing Economies* 44 (2):107 –122.

Pan, L. and L. Christiaensen. 2012. Who is Vouching for the Input Voucher? Decentralized Targeting and Elite Capture in Tanzania. *World Development* 40 (8): 1619–1633.

Papke, L.E. and J.M. Wooldridge. 2008. "Panel Data Methods for Fractional Response Variables with an Application to Test Pass Rates." *Journal of Econometrics* 145: 121–133.

Pinstrup-Andersen, P. 1993. "Fertilizer Subsidies: Balancing Short-Term Responses with Long-Term Imperatives." In *Policy Options for Agricultural Development in sub-Saharan Africa*, edited by Nathan C. Russell and Christopher R. Dowswell. Mexico City: CASIN/SAA/Global 2000.

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.

Stiglitz J. 1987. "Some theoretical aspects of agricultural policies." *The World Bank Research Observers* 2 (1), 43–60.

Wanzala, M., T.S. Jayne, J.M. Staatz, A. Mugera, J. Kirimi, and J. Owuor. 2002. Fertilizer markets and agricultural production incentives: Insights from Kenya, Tegemeo Institute, Egerton University Kenya, Working Paper #3.

Wooldridge J. 2002. *Econometric analysis of cross section and panel data*. Cambridge, Massachusetts and London, England: MIT Press.

World Bank. 2007. *World Development Report 2008: Agriculture for Development*. Washington, DC: World Bank. 2012. Country development indicators. World Bank. Online http://api.worldbank.org/datafiles/NGA_Country_MetaData_en_EXCEL.xls.

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 Use Decisions in a Two-Channel Marketing System. *Agricultural Economics.* 40 (1): 79–94.

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This Working Paper has been prepared as an output for the Nigeria Strategy Support Program, funded by USAID, and has not been peer reviewed. Any opinions stated herein are those of the author(s) and do not necessarily reflect the policies or opinions of IFPRI.