Input Subsidy Programs and Commercial Market Development: Modeling Fertilizer Use Decisions in a Two-Channel Marketing System

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Fertilizer use in sub-Saharan Africa currently stands at 9kgs per cropped hectare -- by far the lowest of any developing region. There is widespread consensus that much greater use of fertilizer by African farmers will be required to generate the productivity growth needed to reduce poverty. However, there is considerable debate about exactly how to achieve sustainable increases in fertilizer use. Over the past 30 years, a number of different approaches have been attempted to promote fertilizer use in sub-Saharan Africa: state subsidized distribution programs, targeted input credit programs, free starter packs, interlinked credit-input-crop marketing outgrower arrangements, and "liberalization," whereby private traders are encouraged to develop commercial input marketing networks in rural areas, to name a few. A review of the literature reveals mixed evidence and considerable debate about the appropriate roles of government and the private sector in sustainably raising small farmers' use of fertilizer (for reviews, see Crawford, Jayne, and Kelly, 2006; Gladwin et al., 2002; and Minot, 2002).

One the one hand, there are major concerns about the private sector's ability to serve the needs of small farmers in remote areas and the ability of poor farm households to afford fertilizer, even where it is clearly profitable to use it. Dorward et al (2004) contend that state-led input and output marketing policies featured prominently in the "green revolutions" successes achieved in Asia in the 1970s and 1980s and that similar programs will be needed in Africa. The recent "Abuja Fertilizer Declaration" released by the African Union Member States in June 2006 contends that rapid productivity growth in Africa will require the return to large government subsidy programs.

On the other hand, there is great concern that sustainable increases in fertilizer use are blocked by a "catch-22" situation in which private traders' incentives are undermined by government fertilizer distribution programs, which may inhibit the development of commercial input markets, and then justify the rationale for continued government programs (Pletcher, 2000). In this way, stated policy objectives to encourage the development of commercial fertilizer markets may be continuously thwarted by programs designed to correct for temporary market failure.

The input marketing systems in many developing countries are characterized by parallel distribution channels, where commercial traders and government programs operate simultaneously. Realistic empirical analysis aimed at understanding the factors influencing farmer use of fertilizer and their implications for policy would presumably need to explicitly account for this parallel marketing structure, because effective demand in one channel may be affected by the behavior of agents in the other channel. The concept of "crowding out" is important in this regard. Crowding out in this paper refers to the extent to which government operations displace or depress the sales of commercial input suppliers. While concerns with crowding out have been important in debates over appropriate input marketing policies in low-income countries, there has been little or no attempt, as far as we are aware, to estimate this effect empirically.

Zambia, in southern Africa, provides an interesting case to examine the interactions between government and private input distribution channels and the measurement of crowding out. Government agricultural policy has for the past several decades focused on subsidized fertilizer distribution programs to alleviate poverty and enhance food security and aggregate economic growth. Although capacity in agriculture is under-utilized and the growth potential is considered large, agricultural production has been consistently low. Annual growth rates achieved between 1993 and 2003 was only 2.2% which hardly exceeded the population growth rate. Over 70% of the rural population lies below the poverty line. After legalizing private trade in fertilizer in the early 1990s, the Zambian government has resumed large-scale fertilizer subsidy programs since 1999 to kick-start productivity growth for small farmers (Jayne et al., 2003). Despite government's efforts, overall fertilizer consumption has expanded slowly and only 20% of smallholder farmers used fertilizer in the 2002/2003 crop season (Govereh et al., 2006).

The paper has three primary purposes. First, we develop a double hurdle modeling framework to identify the factors influencing the probability of maize farm households acquiring fertilizer from private and government distribution channels as well as the amount acquired from each channel. This modeling framework takes explicit account of how government programs affect households' purchase of fertilizer from private channels, and hence allows us to estimate the degree of crowding out. Second, we examine whether fertilizer use patterns among small farmers in Zambia are primarily a function of agroecological and market conditions or whether there are larger differences within particular zones that are driven by household-specific socioeconomic and demographic characteristics. Lastly we identify the potential to increase fertilizer use through public policy tools.

Previous Research

Econometric studies of fertilizer use in Sub-Saharan Africa are limited. Most studies analyzed factors influencing fertilizer adoption using either a probit or logit model (Falusi 1974, Green and Ng'ong'ola 1993, Negassa et al. 1997, Kaliba et al., 2000, Isham 2002, Chirwa 2005).

Falusi (1974) found that frequency of extension contact and access to credit have significant impact on fertilizer adoption in western Nigerian. Green and Ng'ong'ola (1993) indicated that the crops grown, farming system, access to credit, off-farm employment opportunities, and regular labor are the main factors influencing fertilizer adoption in Malawi. The study by Negassa et al. (1997) revealed that in the Bako area of Ethiopia, use of fertilizers is significantly related to provision of credit and the household head's level of education. Kaliba et al. (2000) presented empirical evidence that extension services, rainfall, on-farm field trials, and variety characteristics significantly influence fertilizer adoption in the intermediate and lowland zones of Tanzania. Isham's study (2002) found that the probability of adoption of fertilizer in the Central Plateau region of Tanzania is increasing in land under cultivation, cumulative adoption patterns, ethnic social affiliations, adoption of improved seeds, credit availability, extension services, and average years of residence in the village; whereas in the Plains region, the probability is increasing in land under cultivation, ethnic social affiliations and consultative norms. Chirwa (2005) found that fertilizer adoption by smallholder maize farmers in southern Malawi is associated with education level, plot size, non-farm income, gender of the household head, and the distance from input markets.

Croppenstedt and Demeke (1996) applied a Heckman model to Ethiopian data and found that farmer literacy, access to all-weather roads, oxen ownership, extension services, access to banking, and labor availability are important factors influencing whether farmers use fertilizer, whereas farm size, previous experience with fertilizer, fertilizer supply, liquidity, access to banking and credit, the number of oxen owned, and the price ratio of the main crop to the cost of fertilizer are important in explaining the quantity of fertilizer consumption.

Adugna (1997) analyzed factors affecting fertilizer adoption and the intensity of fertilizer use in central Ethiopia using a logit model and a simultaneous-equation regression model respectively. His study indicated that extension service, the number of oxen owned, access to hired labor, and the size of land holding are strong forces behind the farmers' decision to adopt fertilizer. The intensity of fertilizer use is significantly influenced by the number of oxen owned, access to credit, the use of hired labor, fertilizer-crop price ratio, crop-fertilizer response, farm size, off-farm income, and the distance from asphalted road.

Nkonya et al. (1997) applied a bootstrapped simultaneous equation Tobit model to data from Northern Tanzania and found that the number of hectares planted with improved maize seed and farm size are significantly related to the amount of nitrogen fertilizer applied per hectare.

Minot et al. (2000) used a Heckman model to identify the determinants of fertilizer use in Benin and Malawi. Their study revealed that fertilizer use in the two countries is closely related to crop mix and access to inputs on credit.

Knepper (2002) used a probit model and an ordinary least squares regression model respectively to analyze factors affecting adoption of fertilizer and the total quantity of fertilizer used by small and medium sized households in Zambia. His study indicated that ownership of transportation assets, level of district transportation infrastructure, total cropped area, ownership of farming assets, and proximity to a fertilizer depot are significantly related to household use of fertilizer; total cropped area, ecological zone variable, and provincial location variable have significant impacts on the quantity of fertilizer used.

Using a double-hurdle model, Croppenstedt et al. (2003) found that access to credit is a major supply-side constraint to fertilizer adoption in Ethiopia. Household size, value-to-cost ratio, and formal education of the farmer are the most significant demand-side factors influencing adoption and intensity of fertilizer use.

In Abdoulaye and Sanders (2005)'s study of stepwise decision of fertilization in Niger, probit and Tobit models were used to estimate demand functions for organic and inorganic fertilizers. They indicated that the price ratio of fertilizer to millet is always a highly significant determinant of fertilizer adoption; participation or visits in on-farm trials is a principal factor influencing the use of micro-dosage of inorganic fertilizer; the relative price of fertilizer to millet is the most important factor in the decision to use moderate levels of inorganic fertilizer.

While these studies have provided important insights into the factors influencing fertilizer use by small farmers, there are several notable problems. The first is the frequent use of explanatory variables that are arguably endogenous (e.g., crop mix, use of input credit, labor use). Failing to deal with the endogeneity problem can lead to biased parameter estimates and potentially misleading implications for policy. Another major limitation of prior studies is the difficulty of controlling for unobserved household heterogeneity. Relevant household variables are almost always missing, such as micro-variability in soil and agroecological conditions, farmer knowledge and risk attitude, which are difficult to measure or hard to obtain. Time-invariant unobserved effects can be controlled for through the use of panel data. We are unaware of previous longitudinal analysis using African data to econometrically study fertilizer use behavior.

Third, and particularly relevant for this study, while parallel input marketing channels featuring government subsidy programs and private commercial channels are a common feature of market structure in sub-Saharan Africa, to our knowledge, no previous research has attempted to discern how these channels interact to affect fertilizer purchase behavior or to distinguish between the attributes of households acquiring fertilizer from each channel. It is highly likely that household characteristics influencing fertilizer use will differ for commercial fertilizer retailers vs. government programs. Government programs often attempt to target poor households, while commercial fertilizer sales, being a function of effective demand, may be accounted for mainly by relatively wealthy and educated farmers. Moreover, a farmer's decision to purchase fertilizer commercially may greatly depend on whether subsidized fertilizer programs are operating in the area. Failure to account for parallel market structure precludes the detection of potential crowding out effects, which may lead to spurious conclusions about household-level and geographic factors influencing commercial fertilizer purchase decisions. This paper attempts to overcome these limitations.

Econometric Method

We use Cragg's double-hurdle model to analyze the probability of using fertilizer and the amount of fertilizer use from each fertilizer-marketing channel. The double-hurdle model is chosen because it nests the standard Tobit model and accommodates the possibility that the choice between adoption versus non-adoption and the level of adoption is determined by two processes, whereas in the Tobit model these decisions are determined as a single process. The Tobit model can be obtained as a special case of the double-hurdle model. The double-hurdle model has a binary adoption equation and a level of adoption equation:

Binary adoption equation: $d^* = X\beta + e$

$$d = \begin{cases} 1 & \text{if } d^* > 0 \\ 0 & \text{otherwise} \end{cases}$$

Level of adoption equation: $y^* = Z\gamma + u$

$$y = \begin{cases} y^* & \text{if } y^* > 0 \quad \text{and} \quad d = 1 \\ 0 & \text{otherwise} \end{cases}$$

where d^* is a latent variable, d is the corresponding binary variable with d=1 denoting the household used fertilizer, and 0 denoting the household did not use fertilizer; X and Z are vectors of explanatory variables; β and γ are vectors of parameters; y^* denotes a latent variable, y is the corresponding observed level of fertilizer consumption; e follows a standard normal distribution, and u has a zero mean homoskedastic normal distribution. Estimates of β and γ are obtained running a probit model and a truncated regression model respectively.

Crowding Out Effect

Whether there is crowding out effect of government distributing fertilizer on credit can be determined by the magnitude of $\frac{\Delta Total}{\Delta Gov} = \frac{\Delta(Gov + \Pr iv)}{\Delta Gov} = \frac{\Delta Gov}{\Delta Gov} + \frac{\Delta \Pr iv}{\Delta Gov} = 1 + \frac{\Delta \Pr iv}{\Delta Gov}$

where Δ denotes change in the quantity, *Total* is the total quantity of fertilizer adopted by farmers, *Gov* is the quantity distributed by government, and *Priv* is the quantity that farmers purchase from private traders.

We can categorize possible outcome into three groups based on the sign of $\frac{\Delta \Pr iv}{\Delta Gov}$:

(i) If $\frac{\Delta \Pr iv}{\Delta Gov} > 0$, then $\frac{\Delta Total}{\Delta Gov} > 1$

(ii) If $\frac{\Delta \Pr iv}{\Delta Gov} = 0$, then $\frac{\Delta Total}{\Delta Gov} = 1$

(iii) If $\frac{\Delta \Pr iv}{\Delta Gov} < 0$, then $\frac{\Delta Total}{\Delta Gov} < 1$

If (i) is found to exist, this means that government distribution is contributing positively to private sector sales, such that each additional ton of fertilizer distributed by the government generates a more-than-one ton increase in total fertilizer use. Condition (ii) implies that government programs have no effect on the quantity of fertilizer sold by private traders, i.e., the crowding out effect is zero. However, if condition (iii) is found to exist, this means that each additional ton of fertilizer distributed by government depresses sales by private traders and hence total fertilizer use rises by less than one ton. Condition (iii) is the mathematical expression of the crowding out effect.

Approach

To determine the extent of government crowding out of private fertilizer sales, we proceed as follows. Based on the estimates of the household-level probit model for the adoption of fertilizer from private channel and truncated regression model for the amount of fertilizer purchased from private channel, we examine whether the estimates of the coefficients – α and β in the probit model and truncated regression model respectively – on the government program variable, i.e., the amount of fertilizer distributed by government in a rural Standard Enumeration Area (SEA) where the household belongs divided by the total number of households in that area, are statistically significant or not. Statistically insignificant coefficient estimates of both α and β, while not necessarily indicating an absence of crowding out, are considered here to support condition (ii) above.

Except for the case that both α and β are statistically insignificant, we can divide the other possible outcomes of α and β into four categories: (a) both are statistically significant and negative; (b) both are statistically significant and positive; (c) both are statistically significant but have opposite signs; (d) only one of the two estimates is statistically significant. We discuss each below with a focus on the possible outcome (a).

Statistically significant and negative coefficient estimates is evidence of crowding out (condition iii) and we need to further quantify this effect. The coefficient estimates α and β from probit model and truncated regression model, if all negative, provide information on the ceteris paribus marginal effect of an increase in the quantity of fertilizer distributed by government in a rural SEA on decrease in the probability of a household purchasing fertilizer from private sector and reduction in the quantity of fertilizer purchased by a household from the private sector, respectively. To obtain the effect of an increase in quantity of fertilizer distributed by government on change in the total quantity of fertilizer procured from private sector in a particular rural area, we need to further obtain information about that area on the total number of farm households, the number of households purchasing fertilizer from private sector, and the average quantity purchased by a household from private sector. We can express this effect as

$$\left(\frac{\Delta \Pr iv}{\Delta Gov}\right)_i = \frac{\alpha n_i' q_i}{n_i} + \frac{(1+\alpha) n_i' \beta}{n_i} \tag{1}$$

where n_i is that total number of farm households in area i, n'_i is the number of households purchasing fertilizer from private sector in area i, q_i is the average quantity purchased from private sector by a household in area i, α is the coefficient estimate from probit model, and β is the coefficient estimate from truncated regression model. There are two sources of change in the total quantity of fertilizer purchased from private sector in a given area caused by government distributing additional amount of fertilizer in that area: one from change in the number of households purchasing from private sector and the other from change in the quantity purchased from private sector by those households who still purchase from private sector.

The right hand side of equation (1) which is comprised of two parts shows quantity change from these two sources. The first part gives estimate of the change in the quantity purchased from private sector due to some households no longer buying from private sector as α, being negative, is the estimate of decrease in the percentage of households buying from private sector associated with a marginal increase in the quantity distributed by government measured in terms of kilogram per farm household in the rural area where the household is located. The second part gives estimate of the change in the quantity procured from private sector caused by households still buying from private sector but buying less as β, being negative, is the estimate of decrease in the quantity purchased by a household from private sector associated with a marginal increase in the quantity distributed by government per household. Adding 1 to this estimate generates the area-specific crowding out effect

$$\left(\frac{\Delta Total}{\Delta Gov}\right)_i = 1 + \left(\frac{\Delta Priv}{\Delta Gov}\right)_i = 1 + \frac{\alpha n_i' q_i}{n_i} + \frac{(1+\alpha) n_i' \beta}{n_i} \tag{2}$$

Clearly area-specific crowding out effect will differ as n_i, n'_i and q_i vary across areas. If $n'_i=0$, we have $\left(\frac{\Delta Total}{\Delta Gov}\right)_i = 1$, i.e., there will be no crowding out in area *i* because no household purchase from private sector in that area.

We can further conduct simulation analysis and measure the aggregate quantity change of fertilizer procured from the private sector when government distributes additional amount of fertilizer in areas where the private sector operates. The formula for calculating this can be written as

$$\begin{aligned} \Delta Priv = \sum_{i=1}^{k}\left(\frac{\Delta Priv}{\Delta Gov}\right)_i (\Delta Gov)_i &= \sum_{i=1}^{k}\left(\frac{\alpha n_i' q_i}{n_i} + \frac{(1+\alpha) n_i' \beta}{n_i}\right)(\Delta Gov)_i \\ &= \alpha \sum_{i=1}^{k} \frac{n_i' q_i}{n_i}(\Delta Gov)_i + (1+\alpha)\beta \sum_{i=1}^{k} \frac{n_i'}{n_i}(\Delta Gov)_i \end{aligned} \tag{3}$$

where $\Delta Priv$ is the aggregate quantity change of fertilizer procured from private sector, $(\Delta Gov)_i$ is the quantity change of fertilizer distributed by government in area *i*, and *k* is the total number of areas that are targeted by the government program . The result depends on which and how many SEAs the government operates in and to what extent government increases the volumes of fertilizer it distributes in these areas.

If the coefficient estimates α and β are statistically significant and positive, condition (i) is satisfied and thus there is evidence that government input distribution programs enhances the quantity of fertilizer distributed by private sector and we can measure this effect using the same method as described above for estimating the crowding out effect by plugging the estimates in equations (1) ~ (3).

Equations (1) ~ (3) can also be used to determine whether there is crowding out or crowding in effect and the magnitude of the effect if both α and β are statistically significant but have opposite signs. Moreover, when only one of the two coefficient estimates, either α or β, is statistically significant, the corresponding calculation is simplified by plugging in zero for α or β in these equations.

Data

The source of the household-level panel data used in this study is the 1999/2000 Post Harvest Survey (PHS), the linked Supplementary Survey to the 1999/2000 PHS, and the 2003/04 Supplementary PHS Survey. These panel surveys tracking 6,922 households were conducted by the Central Statistical Office and Ministry of Agriculture, Food and Fisheries in Zambia.

The PHS is a nationally representative annual survey of small and medium scale agricultural households in Zambia. Sample weights were derived to scale-up results to the national level, and we use weighted regression techniques in our estimation. The PHS survey includes information on crop and livestock production and management as well as households' socioeconomic and demographic characteristics. Except two entirely urban districts (Lusaka Urban and Ndola Urban), all the other 70 districts are represented in the survey. A stratified three-stage sampling design was used for the survey, i.e., at the first stage, Census Supervisory Areas (CSAs) were selected with probability proportional to size (PPS) within each district, where size is measured according to the total number of households in the CSA; next, within each sample CSA, generally one Standard Enumeration Area (SEA) was selected with PPS; at the last stage, a sample of households were selected from a listing of households stratified by size within each sample SEA (Megill 2005).

The 1999/2000 PHS Supplemental Survey which was conducted in 2001 interviewed the same households in the 1999/2000 PHS and collected supplemental information based on the specific survey data needs of the Food Security Research Project for its various research activities. In 2004, the Second Supplemental Survey was conducted covering the same households in the first supplemental survey.

Information on the operation of government fertilizer programs was obtained by the Ministry of Agriculture. In the crop seasons covered by the two surveys, 1999/2000 and 2002/2003, the government was distributing fertilizer to farmers at roughly 50% of the full retail cost. Hence, if the government were distributing fertilizer in a particular area, a farmer who would have otherwise purchased fertilizer at full price from a private dealer may have perceived major advantage to trying to acquire her fertilizer needs from the government program instead.

Explanatory Variables

Economic theory indicates that farmers' decisions of whether to procure and how much to procure fertilizer from private suppliers are determined by the costs of procurement and the perceived benefits from fertilizer use. In the literature, factors identified to influence fertilizer demand by small-scale farmers in sub-Saharan Africa may be categorized into three groups: household socio-economic and demographic characteristics, market access variables, and agro-ecological variables. We discuss each below.

Household socio-economic and demographic characteristics: We examine the importance of a wide range of household-level variables in the models of fertilizer use from each channel – farm size, household wealth, the sex, age and education of the household head, the number of adult males, adult females, and children (proxies for household labor supply), whether the household head, spouse, or other adult has died during the past three years of each survey period (i.e., mortality shocks), and other household-specific variables that might influence the households' access to subsidized fertilizer through government programs (e.g., whether a household member is a civil servant or related to the local chief in the area).

Ceteris Paribus, we expect asset value, cropland size, education, number of male adults, and number of female adults to positively influence fertilizer purchase from private channel. Whether and how age and sex of the household head affect fertilizer demand is unclear due to the lack of straightforward theory and inconclusive findings in the literature. We would expect mortality shocks to adversely affect household purchasing power and therefore ability to purchase fertilizer commercially, although government distribution criteria may include targeting to AIDS-affected and other types of vulnerable households.

We also include these variables in the model of fertilizer use from government channel to investigate whether and how these variables, especially household economic status, affect the probability of a household receiving fertilizer from government and the amount received.

Whether a household acquires subsidized fertilizer from the government channel in Zambia is generally not determined by the household. Factors influencing fertilizer procurement from government channel are examined as an investigation of the criteria used by government to distribute fertilizer to targeted beneficiaries. We use the same set of household-level variables in the government fertilizer procurement models.

Market access variables: We include distance of the household to the main road and distance to the district town in the models of fertilizer use from each channel, and include another important variable, government fertilizer program variable measured by the quantity of fertilizer distributed by government divided by the total number of farm households in the area where the household is located as discussed in the Approach section, in the model of fertilizer use from private channel.[1] Households that are more distant to the main road or district town leads to higher transportation cost of fertilizer procurement and lower output prices, and therefore it is expected that these variables will be inversely related to a household's decision to purchase fertilizer from private channels. In Zambia, government fertilizer programs ostensibly aim to distribute fertilizer to households in remote areas where the private sector is assumed not to operate; if this is the case, we would expect the distance variables to be positively related to household's acquisition of government fertilizer.

Agro-ecological variables: Soil type and agro-zone variables are included in the models of fertilizer use from each channel. We expect the incentives for procuring fertilizer from private channel to be higher for certain soil types and agro-zones because of better maize yield response to fertilizer use. In other words, marginal product of fertilizer is expected to differ across soil types and agro-zones, thus we also expect fertilizer demand to differ accordingly. The significance of these agro-ecological factors in government targeting of fertilizer is also examined.

Table 1 shows the dependent and explanatory variables used in this paper and their definition.

Table 1. Definition of Variables

Variables	Definition
Dependent variables	
USEBSL_G	If the household used basal fertilizer from government channel or not (Yes=1)
USEBSL_P	If the household used basal fertilizer from private channel or not (Yes=1)
QBSL_G	Total basal fertilizer use amount in kilogram from government channel for the household
QBSL_P	Total basal fertilizer use amount in kilogram from private channel for the household
Explanatory variables	
Household socio-economic and demographic characteristics	
ASSET	Asset value including farm equipment, transportation equipment, and livestock value in Kwacha
CROPLAND	Size of cropland owned by the household in hectare
*CROPLAND*2	Square term of the variable cropland
AGE	Age of the household head
FEMALEHH	If the household head is a female or not (Yes=1)
EDUC	Education of the household head
N_MALE	Number of male adults
N_FEMALE	Number of female adults
N_KIDS	Number of kids (age less than 15)
HEAD_D	Indicates if the head of the household deceased within the last three years (Yes=1)
SPOUSE_D	Indicates if the spouse of the household head deceased within the last three years (Yes=1)
OTHER_D	Indicates if any other adult member deceased within the last three yeas (Yes=1)
CSERVANT	If the household has a member who is a civil servant or not (Yes=1)
HMANR_HH	If the household head is related to the village headman or not (Yes=1)
HMANR_SP	If the spouse of the household head is related to the Village headman or not (Yes=1)
Market access variables	
MAINROAD	Distance to the main road in km
DISTTOWN	Distance to the district town in km
BSL_GOV	Quantity in kilogram of basal fertilizer distributed by government divided by the number of farm households in the area where the household is located
Agro-ecological variables	
ZONEIIa	Indicates if the district belongs to agro-zone IIa (Yes=1)
ZONEIIb	Indicates if the district belongs to agro-zone IIb (Yes=1)
ZONEIII	Indicates if the district belongs to agro-zone III (Yes=1)
AF	Indicates if the soil type is acrisols or ferrasols (Yes=1)

AL	Indicates if the soil type is alisols or lixisols or luvisols (Yes=1)
HG	Indicates if the soil type is histosols or gleysols (Yes=1)
FV	Indicates if the soil type is fluvisols or vertisols (Yes=1)
LR	Indicates if the soil type is leptosols or regosols (Yes=1)

Findings

Before presenting the econometric results, we first provide some summary statistics for all variables in Table 1. Tables 2 and 3 show the percentages of households using basal fertilizer[2] and the average quantities acquired by fertilizer users from government and private channels. Less than 20% of households used fertilizer from either channel for each survey period although there is a slight increase over the survey interval in the percentage of households using fertilizer from each channel. The average amount of fertilizer used among adopters from government channel is lower in 2002/2003 than 1999/2000 while no significant differences were found for fertilizer users from private channel.

Table 2. Basal Fertilizer Use from Government Channel

	1999/2000	2002/2003
Households using fertilizer (%)	9.68	13.91
	(0.61)	(0.71)
Average quantity used among users (kilogram)	171.32	121.32
	(9.3)	(6.92)

Note: Standard errors are shown in parentheses.

Table 3. Basal Fertilizer Use from Private Channel

	1999/2000	2002/2003
Households using fertilizer (%)	13.61	15.26
	(0.66)	(0.7)
Average quantity used among users (kilogram)	121.67	120.56
	(6.87)	(6.36)

Note: Standard errors are shown in parentheses.

Table 4 gives weighted mean estimates of explanatory variables for users of basal fertilizer from alternative channels and non-users for each survey period.

Table 4. Users of Basal Fertilizer from Alternative Channels and Non-users

Explanatory Variables	1999/2000 Gov.	1999/2000 Private	1999/2000 Non-users	2002/2003 Gov.	2002/2003 Private	2002/2003 Non-users
ASSET	1,537,234	1,254,489	534,535	1,370,390	1,419,039	572,434
	(137,305)	(114,432)	(27,914)	(124,558)	(147,017)	(32,045)
CROPLAND	2.7	2.1	1.5	2.3	2.1	1.5
	(0.1)	(0.1)	(0.03)	(0.1)	(0.1)	(0.03)
AGE	45.5	44.2	43.5	47.6	44.7	47
	(1)	(0.8)	(0.4)	(0.8)	(0.7)	(0.4)
FEMALEHH (%)	7.9	15.1	22	16.7	13.7	22.7
	(1.6)	(1.9)	(1)	(2)	(1.7)	(1)
EDUC	6.6	5.8	4.7	5.8	6.1	4.4
	(0.3)	(0.2)	(0.1)	(0.2)	(0.2)	(0.1)
N_MALE	2	2	1	2	2	2
	(0.1)	(0.1)	(0.02)	(0.7)	(0.06)	(0.03)
N_FEMALE	2	2	1	2	2	2
	(0.1)	(0.1)	(0.02)	(0.1)	(0.1)	(0.02)
N_KIDS	4	4	3	3	2	2
	(0.2)	(0.1)	(0.1)	(0.1)	(0.1)	(0.04)
HEAD_D(%)	0	0.3	0.1	4.0	3.7	3.6
	(0)	(0.3)	(0.1)	(1)	(1)	(0.5)
SPOUSE_D(%)	1.2	2.1	1.4	2.7	1.3	1.8
	(0.6)	(0.8)	(0.3)	(1)	(0.5)	(0.3)
OTHER_D(%)	11.5	7.7	9.2	9.7	10.5	11.1
	(2.1)	(1.4)	(0.7)	(1.5)	(1.6)	(0.8)
CSERVANT(%)	3	3.6	1	3.3	3	1
	(0.9)	(1)	(0.2)	(0.8)	(0.9)	(0.2)
HMANR_HH(%)	28.2	26.6	35.5	28.7	20.6	37.4
	(3.1)	(2.4)	(1.1)	(2.5)	(2)	(1.2)
HMANR_SP(%)	8	5.5	7.7	7.9	6	7.7
	(2)	(1.1)	(0.6)	(1.6)	(1.1)	(0.7)
MAINROAD	20.5	26.4	25.6	20	24.8	26.3
	(1.9)	(2.1)	(0.9)	(1.5)	(1.9)	(0.9)
DISTTOWN	28.8	28.6	34.9	29.8	28.4	35.2
	(1)	(0.9)	(0.5)	(1)	(0.8)	(0.5)
ZONEIIa (%)	79	73.3	53.6	59.6	67.7	56.4
	(2.5)	(2.2)	(1.2)	(2.6)	(2.3)	(1.2)
ZONEIIb (%)	0.2	1.2	14.8	7.1	0.8	14.6
	(0.2)	(0.5)	(0.9)	(1.4)	(0.5)	(0.9)
ZONEIII (%)	16.6	23.8	23.2	29	27.4	20.6
	(2.2)	(2)	(0.9)	(2.3)	(2.1)	(0.9)
AF (%)	43.4	54.5	32.1	45.3	45.3	32.8
	(3.3)	(2.6)	(1.1)	(2.7)	(2.5)	(1.2)
AL (%)	17	13.5	11.7	12.9	13.3	12
	(2.5)	(1.7)	(0.8)	(2)	(1.6)	(0.9)

HG (%)	1.4	1.8	2.3	2.5	1.5	2.2
	(0.8)	(0.6)	(0.4)	(0.8)	(0.6)	(0.4)
FV (%)	4.6	2.9	4.2	3.2	5.2	4
	(1.4)	(0.8)	(0.4)	(0.9)	(1.1)	(0.5)
LR (%)	21.1	15.3	15	17	20	14.5
	(2.7)	(1.9)	(0.9)	(2.1)	(2.1)	(0.9)

Note: Gov. denotes government channel and Private denotes private channel. Standard errors are shown in parentheses.

Table 5 shows the 10th, 25th, 50th, 75th and 90th percentiles of *BSL_G_AREA* for SEAs in which government distributed fertilizer.

Table 5. Percentiles of *BSL_GOV* for SEAs in which Government Distributed Fertilizer (kilogram)

Percentiles	1999/2000	2002/2003
10%	3.7	3.4
25%	10.3	7.1
50%	21.4	16.7
75%	43.8	31.8
90%	87.5	58.7

Scatterplots of SEA-level total volume of fertilizer acquired from private retailers versus from government for each survey period are presented in Figures 1 and 2. These graphs show that government programs distributed fertilizer in many areas where private sector also operated although there was only one channel distributing fertilizer in some areas.

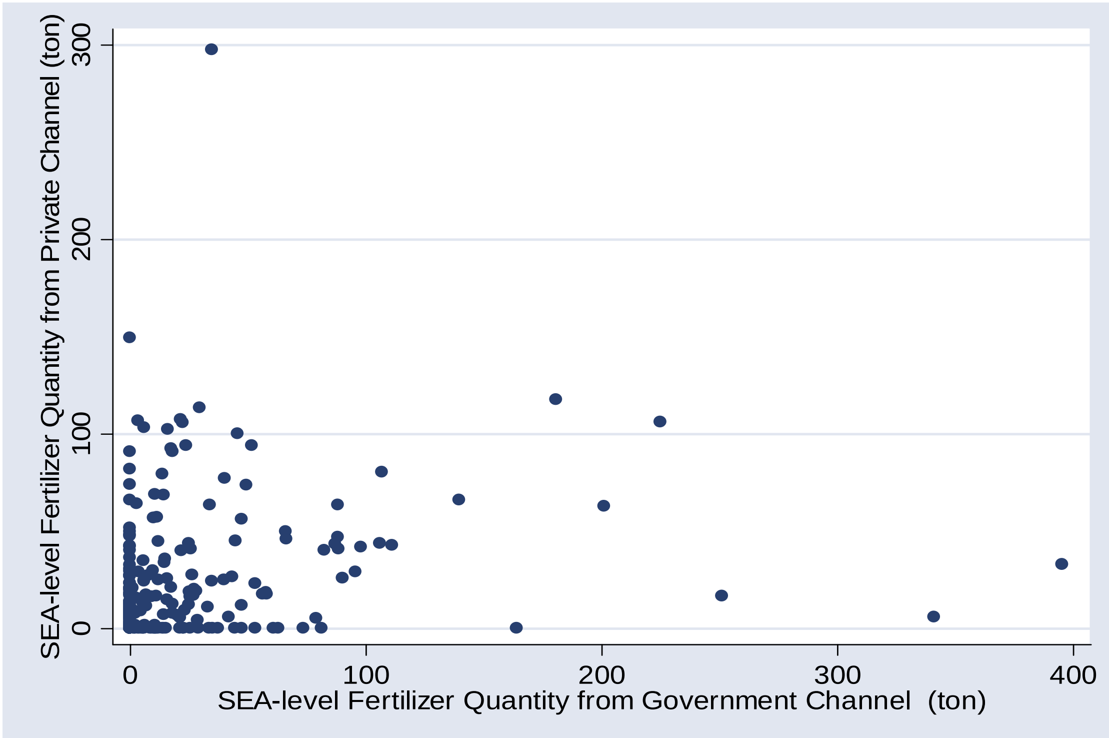

Figure 1. SEA-level total quantity of fertilizer acquired from private traders versus from the government, 1999/2000

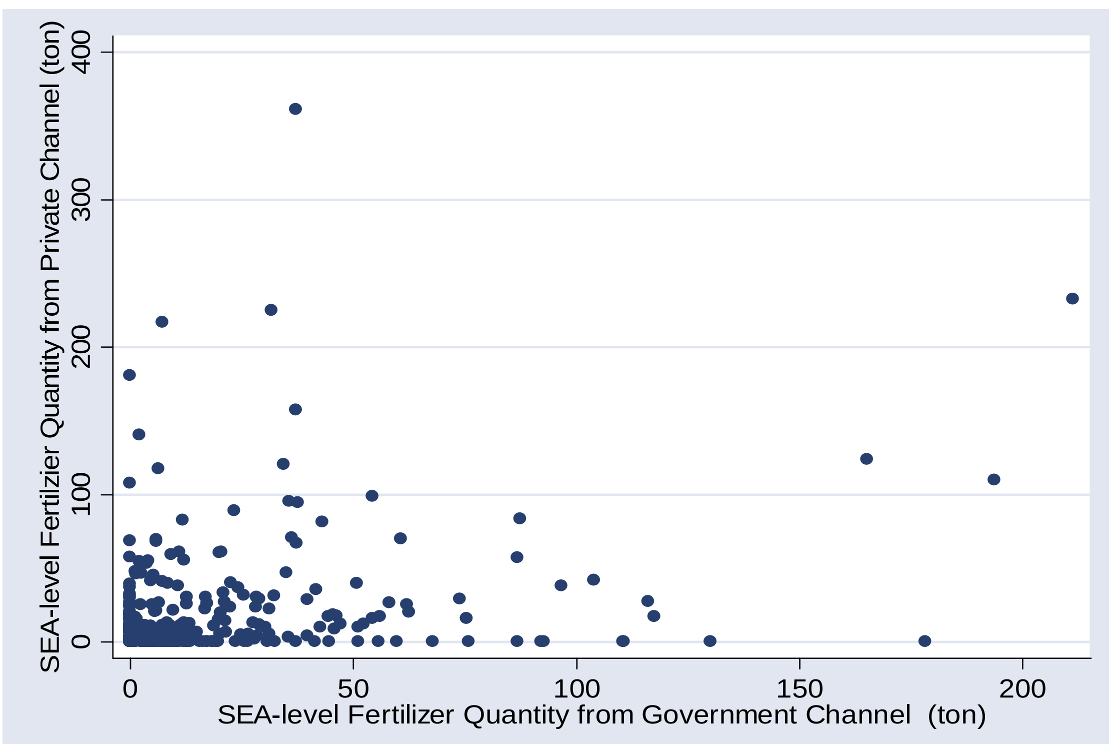

Figure 2. SEA-level total quantity of fertilizer acquired from private traders versus from the government, 2002/2003

Interestingly there are several notable differences between fertilizer users and non-users that are common to both channels for each period shown in Table 5. On average, households acquiring fertilizer from either private or government channels have larger farms, greater asset value, higher education levels of the household head, and are less likely to be female-headed, have a civil servant member, and closer to the district town, which are supported by adjusted Wald-test results.

For 1999/2000, test results suggest that on average, government fertilizer users have larger cropland holding size, fewer percentage of households being female-headed, household head with a higher level of education, fewer percentage of households in Zone IIb or 4, and fewer percentage having soil types acrisols and ferrasols (*AF*) than private channel fertilizer users. The other variables are not significantly different. For 2002/2003, except for the household head being older and more likely related to the village headman, fewer percentage of households in Zone IIa, and larger percentage in Zone IIb, no other significant differences were found between fertilizer adopters from government channel and from private channel.

The finding that government fertilizer recipients have significantly higher farm sizes and asset levels, and are also closer to main roads and district towns than non-users, indicate that government is not generally targeting poorer households that have relatively low purchasing power or those in remote areas. Results also suggest some potential for crowding out since the attributes of households purchasing fertilizer from private channel and government appear to be similar in many respects. However, these bivariate results do not control for other factors, and hence we move to the econometric findings.

Fertilizer Adoption from Government Channel

Probit estimates of the models for fertilizer adoption from government channel are presented in Table 6. To examine the robustness of the findings, we present probit estimates for the pooled 1999/2000 and 2002/2003 data, random effects, and fixed effects.

Table 6. Probit Estimates of Fertilizer Adoption from Government Channel Models

Variables	Pooled	Random effects	Fixed effects
ASSET	6.41×10^{-9}** *	6.51×10^{-9}***	8.05×10^{-9}*
	(2.01×10^{-9})	(9.07×10^{-10})	(4.59×10^{-9})
CROPLAND	0.017***	0.017***	_
	(0.002)	(0.0015)	
AGE	0.0008**	0.0008***	-0.001*
	(0.0003)	(0.0003)	(0.0006)
FEMALEHH	-0.013	-0.014	0.06
	(0.012)	(0.012)	(0.04)
EDUC	0.008***	0.008***	0.001
	(0.001)	(0.001)	(0.003)
N_MALE	0.007*	0.007**	-0.007
	(0.004)	(0.003)	(0.008)
N_FEMALE	0.007	0.007*	-0.001
	(0.005)	(0.004)	(0.008)
N_KIDS	0.004*	0.004**	-0.009***
	(0.002)	(0.0017)	(0.003)
HEAD_D	0.04	0.04	-0.013
	(0.04)	(0.03)	(0.04)
SPOUSE_D	0.02	0.01	-0.01
	(0.03)	(0.03)	(0.04)
OTHER_D	-0.01	-0.01	-0.002
	(0.01)	(0.01)	(0.02)
CSERVANT	0.04	0.04*	0.0002
	(0.03)	(0.02)	(0.05)
HMANR_HH	0.002	0.002	_
	(0.01)	(0.008)	
HMANR_SP	0.001	0.001	_
	(0.02)	(0.01)	
MAINROAD	-0.0004***	-0.0004***	_
	(0.0001)	(0.0001)	
DISTTOWN	-0.0007***	-0.0007***	_
	(0.0002)	(0.0002)	
ZONEIIa	0.05***	0.06***	_
	(0.02)	(0.02)	
ZONEIIb	0.001	0.001	_
	(0.03)	(0.02)	
ZONEIII	0.05**	0.05**	_
	(0.02)	(0.02)	
AF	0.05***	0.05***	_
	(0.01)	(0.01)	
AL	0.03*	0.03**	_
	(0.02)	(0.01)	
HG	0.03	0.03	_
	(0.04)	(0.03)	
FV	-0.005	-0.005	_
	(0.02)	(0.02)	

LR	0.07*** (0.02)	0.06*** (0.01)	_
YEAR2002	0.04*** (0.009)	0.04*** (0.009)	_

Note: Numbers in parentheses are robust standard errors. Estimated coefficients are marginal changes in probability taking into account sample weights.
Asterisks(*,**,***) significant at 10%, 5%, and 1%, respectively.

Among the variables describing household socio-economic and demographic characteristics, asset value, cropland holding size, age and education of the household head, number of male adults, and number of kids are statistically significant and all positively affect a household's probability to receive government fertilizer in the pooled and random effects models. In addition, number of female adults and the household having a civil servant are also significant factors and positively associated with the probability in the random effects model. In the fixed effects model, asset value positively affects the probability while age of the household head and number of kids have negative effects. Other time-invariant variables drop out from the fixed effects model. According to the estimates from the three models, the probability of receiving government fertilizer is approximately 6 to 8 percentage points higher for households with 10,000,000 Kwacha (roughly US$2000) increase in asset value. Each additional year of schooling of the household head is associated with a 0.8 percentage point higher chance of procuring government fertilizer according to the estimates from pooled and random effects models.

The two market access variables, distance to the main road and distance to the district town are both statistically significant and negative in the pooled and random effects models, indicating that government is more likely to distribute fertilizer to households closer to towns and main roads, and not in remote areas as is its official mandate. The distance variables are constant over time so coefficients cannot be estimated from fixed effects model. Holding other factors constant, 10 kilometers farther away from the main road or district town decreases the probability by 0.4 and 0.7 percentage points respectively.

The probability of households receiving fertilizer from government appears to be highly correlated with certain agro-ecological variables and soil types, as shown in the pooled and random effects estimates. These particular zones and soil types are relatively suitable for maize production in Zambia. All else equal, the probability of receiving government fertilizer is approximately 5% higher in Zone IIa or 4 than in Zone I or 3.

The trend variable *YEAR2002* is defined as equal to 1 for 2002/2003 and 0 for 1999/2000. It is statistically significant and positively influences the probability. Ceteris Paribus, a household is approximately 4 percentage points more likely to receive government fertilizer in 2002/2003 than in 1999/2000. This corresponds closely to the bivariate results in Table 2 showing that the percentage of household receiving fertilizer from the government rose from about 10 percent to 14 percent over the survey interval.

Fertilizer Adoption from Private Channel

Table 7 shows probit estimates of the models for fertilizer adoption from private sector.

Table 7. Probit Estimates of Fertilizer Adoption from Private Channel Models

Variables	Pooled	Random effects	Fixed effects
ASSET	1.18×10^{-8}***	1.2×10^{-8}***	3.72×10^{-9}
	(2.36×10^{-9})	(9.95×10^{-10})	(4.33×10^{-9})
CROPLAND	0.01***	0.01***	_
	(0.003)	(0.001)	
AGE	-0.0002	-0.0002	-0.001*
	(0.0004)	(0.0003)	(0.0006)
FEMALEHH	-0.018	-0.02*	0.08**
	(0.012)	(0.011)	(0.03)
EDUC	0.007***	0.007***	0.005*
	(0.001)	(0.001)	(0.003)
N_MALE	0.002	0.002	-0.009
	(0.005)	(0.003)	(0.008)
N_FEMALE	0.008	0.008**	0.003
	(0.005)	(0.004)	(0.008)
N_KIDS	0.0004	0.0004	-0.005*
	(0.002)	(0.002)	(0.003)
HEAD_D	0.04	0.03	-0.05
	(0.05)	(0.03)	(0.04)
SPOUSE_D	-0.003	-0.003	0.05
	(0.03)	(0.03)	(0.04)
OTHER_D	-0.01	-0.01	0.03
	(0.02)	(0.01)	(0.02)
CSERVANT	0.07*	0.06**	0.05
	(0.04)	(0.03)	(0.06)
HMANR_HH	-0.03**	-0.03***	_
	(0.01)	(0.01)	
HMANR_SP	-0.03**	-0.04**	_
	(0.01)	(0.015)	
MAINROAD	0.0001	0.0001	_
	(0.0001)	(0.0001)	
DISTTOWN	-0.001***	-0.001***	_
	(0.0002)	(0.0002)	
BSL_GOV	9.3×10^{-5}	9.4×10^{-5}	-0.0005**
	(0.0001)	(0.0001)	(0.0002)
ZONEIIa	0.09***	0.1***	_
	(0.02)	(0.02)	
ZONEIIb	-0.07**	-0.08**	_
	(0.025)	(0.034)	
ZONEIII	0.12***	0.1***	_
	(0.04)	(0.02)	
AF	0.07***	0.06***	_
	(0.01)	(0.01)	
AL	0.03*	0.03**	_
	(0.02)	(0.014)	
HG	-0.006	-0.006	_
	(0.03)	(0.025)	

FV	0.03	0.027	_
	(0.03)	(0.02)	
LR	0.07^{***}	0.06^{***}	_
	(0.02)	(0.01)	
YEAR2002	0.01	0.01	_
	(0.01)	(0.01)	

Note: Numbers in parentheses are robust standard errors. Estimated coefficients are marginal changes in probability taking into account sample weights.
Asterisks (*,**,***) significant at 10%, 5%, and 1%, respectively.

The probability of purchasing fertilizer from private retailers, in both the pooled and random effects models, is positively correlated with the following household characteristics: household wealth (assets), farm size (cropland), education of the household head, and households having a civil servant member. The number of female adults is also positively associated with this probability in the random effects model while the household head being a female is negatively associated with this probability. In contrast to the government fertilizer adoption model, the age of the household head and number of male adults and kids are no longer significant, but household head and spouse of household head being related to the headman of the village become significant and have negative effects in the pooled and random effects models. This result is not surprising because relatively large percentage of households among non-users of private channel fertilizer reported the household head and spouse being related to the headman. The effect of having a civil servant in the household is positive with the probability of purchasing fertilizer about 6 percentage points higher according to the pooled and random effects estimates. In the fixed effects model, age of the household head and number of kids are negatively associated with the probability of purchasing fertilizer, while household head being a female and educational attainment of the household head are positively associated with purchasing fertilizer from private retailers.

As in the government channel models, the distance to the district town is inversely and significantly related to the probability of purchasing fertilizer from a private dealer. Ceteris paribus an additional 10 kilometers farther away form the district town lowers the probability of purchasing fertilizer from private dealers by around 1 percentage point.

The coefficient estimate on *BSL_GOV* indicates the impact of government fertilizer programs on the probability of purchasing fertilizer from private retailers. In the fixed effects model the relationship is statistically significant. Fixed effects model is likely to give the most accurate estimate among the three models because it controls for unobserved time-invariant variables that may be correlated with the spatial pattern of government distribution programs while the other two estimation procedures do not. According to the fixed effects estimate, the probability of a household procuring fertilizer from a private retailer declines by approximately 5 percentage points if the quantity distributed by government in the area (SEA) is increased by 100 kilograms per farm household.

Among statistically significant agro-ecological variables, only Zone IIb has a negative effect; Zone IIa, Zone III, soil type *AF* (acrisols or ferrasols), *AL* (alisols or lixisols or luvisols) and *LR* (leptosols or regosols) have positive effects. The probability of purchasing private channel fertilizer is around 10% higher in Zone IIa and Zone III than in Zone I, and around 8% lower in Zone IIb than in Zone I.

Quantity Acquired from Government Channel

Estimation results of the truncated regression models for fertilizer use amount from government channel are presented in Table 8.

Table 8. Truncated Regression Estimates of Fertilizer Use Amount from Government Channel Models

Variables	Pooled	Random effects	Fixed effects
ASSET	$2.65\times10^{-6**}$	$3.67\times10^{-6***}$	2.71×10^{-6}
	(1.1×10^{-6})	(1.28×10^{-6})	(4.57×10^{-6})
CROPLAND	15.61^{***}	15.46^{***}	_
	(5.87)	(3.12)	
CROPLAND2	-0.59^{*}	-0.43^{**}	_
	(0.32)	(0.17)	
AGE	0.43	0.49	0.05
	(0.28)	(0.3)	(0.47)
FEMALEHH	-50.88^{**}	-29.22^{*}	-7.33
	(24.45)	(15.66)	(16.6)
EDUC	1.18	1.37	1.64
	(0.9)	(0.99)	(1.60)
N_MALE	-2.69	-3.62	8.49
	(3.24)	(3.36)	(6.41)
N_FEMALE	6.63^{*}	7.44^{**}	-5.21
	(3.49)	(3.49)	(7.16)
N_KIDS	2.93^{*}	4.03^{**}	-3.83^{*}
	(1.63)	(1.79)	(2.08)
HEAD_D	40.55	33.44	61.13^{**}
	(26.78)	(32.22)	(27.47)
SPOUSE_D	-1.13	-1.15	18.16
	(18.85)	(23.34)	(24.73)
OTHER_D	-27.38^{**}	-34.1^{**}	-30.16^{**}
	(13.55)	(14.24)	(14.78)
CSERVANT	12.8	13.57	3.35
	(12.4)	(21.11)	(20.38)
HMANR_HH	-0.11	-4.08	_
	(8.8)	(8.77)	
HMANR_SP	7.69	9.18	_
	(11.34)	(13.23)	
MAINROAD	-0.15	-0.18	_
	(0.13)	(0.15)	
DISTTOWN	-0.32	-0.34	_
	(0.23)	(0.23)	
ZONEIIa	102.62^{**}	-5.66	_
	(50.01)	(20.52)	
ZONEIIb	-27.31	-134.83^{***}	_
	(43.08)	(48.99)	
ZONEIII	93.65^{**}	-16.87	_
	(47.91)	(22.82)	
AF	1.1	2.62	_
	(11.32)	(11.99)	
AL	8.74	12.25	_
	(14.14)	(13.83)	
HG	-52.87	-59.23	_
	(36.51)	(40.88)	

FV	-39.59	-46.33**	_
	(25.3)	(23.6)	
LR	-10.82	-9.74	_
	(13.66)	(14.17)	
YEAR2002	-16.4*	-16.7*	_
	(9)	(8.56)	

Note: Numbers in parentheses are robust standard errors. Estimated coefficients are marginal effects taking into account sample weights.
Asterisks(*,**,***) significant at 10%, 5%, and 1%, respectively.

Table 8 shows that asset value, cropland holding size, household head being a female, number of female adults, number of kids, death of other adult member, and the trend variable are statistically significant in both pooled and random effects models. The positive sign on cropland and negative sign on the square term of cropland indicates that the amount of fertilizer acquired from the government increases with farm size, but at a decreasing rate. One additional female adult member is associated with about 7 kilograms (kgs) more fertilizer and one additional kid about 3 kgs to 4 kgs more fertilizer; female-headed household receive around 30 kgs to 50kgs less fertilizer than male-headed household and household obtain approximately 16 kgs less fertilizer in the second survey period than in the survey period according to the estimates from pooled and random fixed effects models. In the fixed effects model, death of household head has a positive effect while number of kids and death of other adult member have negative effects.

Quantity Acquired from Private Channel

Table 9 presents estimation results of the truncated regression models for fertilizer use amount from private channel.

Table 9. Truncated Regression Estimates of Fertilizer Use Amount from Private Channel Models

Variables	Pooled	Random effects	Fixed effects
ASSET	$1.76\times10^{-6***}$	$2.36\times10^{-6***}$	$3.76\times10^{-6**}$
	(4.61×10^{-7})	(6.97×10^{-7})	(1.9×10^{-6})
CROPLAND	22.33***	26.76***	_
	(7.67)	(3.74)	
CROPLAND2	-0.9**	-0.93***	_
	(0.36)	(0.23)	
AGE	-0.02	-0.001	0.31
	(0.17)	(0.23)	(0.44)
FEMALEHH	-8.45	-7.67	-3.82
	(9.15)	(10.12)	(23.72)
EDUC	0.57	0.65	-0.8
	(0.80)	(0.81)	(2.06)
N_MALE	-2.26	-2.84	1.18
	(2.39)	(2.69)	(5.38)
N_FEMALE	3.16	3.44	5.91
	(2.31)	(2.88)	(5.34)
N_KIDS	3.08**	3.55***	-1.94
	(1.21)	(1.32)	(2.13)
HEAD_D	-59.29*	19.33	-42.09
	(35.24)	(22.84)	(48.21)
SPOUSE_D	-24.63	-30.97	-7.88
	(18.85)	(26.95)	(17.5)
OTHER_D	-2.18	-4.08	9.23
	(7.91)	(10.84)	(14.56)
CSERVANT	19.46	19.92	17.45
	(13.07)	(15.85)	(27.19)
HMANR_HH	8.06	6.41	_
	(9.61)	(7.15)	
HMANR_SP	-10.34	-13.03	_
	(7.60)	(12.51)	
MAINROAD	-0.32**	-0.3***	_
	(0.15)	(0.09)	
DISTTOWN	-0.08	-0.09	_
	(0.12)	(0.17)	
BSL_GOV	-0.04	-0.01	-0.28*
	(0.08)	(0.08)	(0.17)
ZONEIIa	38.58	44.9*	_
	(23.6)	(23.55)	
ZONEIIb	-38.04	36.42	_
	(45.97)	(38.91)	
ZONEIII	20.01	27	_
	(21.49)	(23.96)	
AF	-4.53	-4.88	_
	(7.30)	(9.57)	
AL	-11.14	-13.23	_
	(9.89)	(11.41)	

HG	17.22	20.18	_
	(13.21)	(21.78)	
FV	-11.9	-12.21	_
	(12.25)	(16.28)	
LR	-19.79*	-18.48	_
	(11.51)	(11.69)	
YEAR2002	5.82	7.75	_
	(6.12)	(6.39)	

Note: Numbers in parentheses are robust standard errors. Estimated coefficients are marginal effects taking into account sample weights.
Asterisks(*,**,***) significant at 10%, 5%, and 1%, respectively.

Asset value has a positive effect in all three models. Estimation results from both pooled and random effects models indicate that cropland holding size has a positive effect but the effect decreases as the size increases, number of kids has a positive effect, and distance to main road has a negative effect. In contrast with the estimate from private channel fertilizer adoption models, number of kids becomes statistically significant in the level of adoption models according to the pooled and random effects estimates. One additional kid is associated with approximately 3 kgs more fertilizer purchased from the private sector. On the other hand, education and civil servant are longer significant as found in the adoption models. These findings justify our selection of double-hurdle model in analyzing fertilizer use behavior instead of Tobit model which can lead to inaccurate inferences due to the strong assumption.

Government fertilizer programs *BSL_GOV* is negatively associated with the level of adoption in the fixed effects model. In the pooled and random effects models, the inability to control for relevant time-invariant omitted variables which are correlated with the government fertilizer programs provides a greater likelihood of biased estimates than in the fixed effects model. Time-varying omitted variables may be a problem in all three models. Thus it may be most appropriate to say that crowding out effect may range from being insignificant to significant, as indicated by the fixed effects estimates from the adoption and level of adoption models. We estimate this effect and conduct simulations later in the paper to examine the magnitude of the crowding out effect, as a function of where government chooses to operate its distribution programs.

We can interpret -0.28 on *BSL_GOV* as the following: each one kilogram per farm household increase in government fertilizer program in a rural SEA is associated with 0.28 kilogram decrease in fertilizer purchased by a household from private retailers in that area, holding other factors constant.

Crowding Out Effect

We obtained estimates of the coefficient on the government program, *BSL_GOV*, using pooled, random effects and fixed effects models. Only estimates from fixed effects model are statistically significant and estimates from the other two models are not significantly different from zero. The fixed effects estimates are -0.0005 (α) and -0.28 (β) from probit and truncated regression respectively. Both are less than zero suggesting crowding out effect.

Among the total 356 SEAs in the sample, during 1999/2000 government operated in 135 SEAs and private traders in 173 SEAs, and during 2002/03 these numbers become 217 for government program and 195 for private retailers. In some areas both channels were found operating and the number of these areas is 100 for 1999/2000 and 139 for 2002/2003. That is, among 135 SEAs where government program operated in 1999/2000, 100 of them (74.1%) were areas where private retailers were also operating, and among 217 SEAs where government distributed fertilizer in 2002/03, 139 of them (64.1%) were areas where private retailers were also operating.

We obtain estimates of area-specific crowding out effect $\left(\frac{\Delta Total}{\Delta Gov}\right)_i$ using information on the total number of farm households n_i, number of households purchasing fertilizer from private sector n'_i, and the average amount purchased by a household from private sector q_i by equation (2) for those areas where both channels were operating for each period. Table 10 presents SEA-level minimum, median, maximum and average crowding out effect estimates for each of the two periods.

Table 10: Estimates of Area-Specific Crowding Out Effects

Period	minimum	median	maximum	average
1999/2000	0.996	0.906	0.689	0.894
2002/2003	0.993	0.921	0.654	0.899

Maximum area-specific crowding out effect is approximately 0.6 and average crowding out effect is about 0.9 over the two periods.

Next, we conduct simulation analyses to derive $\Delta Priv$, $\frac{\Delta Priv}{\Delta Gov}$, and $\frac{\Delta Total}{\Delta Gov}$ under three scenarios. In the first scenario, government operates exclusively in areas where the crowding out effects are in the upper 50%. Government increases the volume it distributes in each of these areas by 1 ton. We use equation (3) to obtain results shown in Table 11.

Table 11. Estimates of Crowding out Effect when Government Operates Exclusively in Areas (SEAs) in which the Crowding Out Effects are in the Upper 50%

Period	$(\Delta Gov)_i$	Number of SEAs (k)	ΔGov	$\Delta Priv$	$\frac{\Delta Priv}{\Delta Gov}$	$\frac{\Delta Total}{\Delta Gov}$
1999/2000	1 ton	87	87	-16.14	-0.19	0.81
2002/2003	1 ton	98	98	-17.64	-0.18	0.82

Results in Table 11 suggest that 1-ton increase in the volume of government fertilizer distributed in each of the SEAs where the crowding out effects are in the upper 50% is associated with over 16-ton decrease in the aggregate volume procured from private sector in these areas. In the second scenario, government exclusively operates in all the areas where private retailers also operate in the sample and in the third scenario government operates in all the areas in the sample. Results are shown in Table 12 and 13 respectively.

Table 12. Estimates of Crowding out Effect when Government Operates Exclusively in Areas (SEAs) in which the Private Sector Operates in the Sample

Period	$(\Delta Gov)_i$	Number of SEAs (k)	ΔGov	$\Delta Priv$	$\frac{\Delta Priv}{\Delta Gov}$	$\frac{\Delta Total}{\Delta Gov}$
1999/2000	1 ton	173	173	-20.24	-0.12	0.88
2002/2003	1 ton	195	195	-22.17	-0.11	0.89

Table 13. Estimates of Crowding out Effect when Government Operates in all the Areas (SEAs) in the Sample

Period	$(\Delta Gov)_i$	Number of SEAs (k)	ΔGov	$\Delta Priv$	$\frac{\Delta Priv}{\Delta Gov}$	$\frac{\Delta Total}{\Delta Gov}$
1999/2000	1 ton	356	356	-20.24	-0.06	0.94
2002/2003	1 ton	356	356	-22.17	-0.06	0.94

Magnitude of $\Delta Priv$ is larger in Scenario 2 than Scenario 1 because government program operates in more areas in which private retailers also operates in. However, the magnitude of crowding out effect is smaller in Scenario 2 than Scenario 1 due to the decline in the magnitude of the ratio $\frac{\Delta Priv}{\Delta Gov}$ caused by ΔGov being much larger in Scenario 2 than Scenario 1. Scenario 2 and 3 have the same $\Delta Priv$ because in Scenario 3 government operates in additional areas where private retailers do not operate thus $\Delta Priv$

in these areas are equal to zero. The magnitude of the ratio $\frac{\Delta \Pr iv}{\Delta Gov}$ is the smallest in Scenario 3 leading to the smallest magnitude of crowding out effect $\frac{\Delta Total}{\Delta Gov}$.

Conclusions

Parallel input marketing channels, featuring government and private distribution channels are very common in developing countries. There are concerns that government programs may undercut the development of commercial input distribution channels and thus cause unintended long-term consequences. However, the magnitude of this effect has, as far as we know, never been quantified, and most studies estimating input demand do not take into account the possible interactions between actors in the parallel marketing channels.

This paper constructed household fertilizer use models and investigated household socioeconomic, demographic, market access, and agro-ecological factors affecting fertilizer adoption, and the level of adoption from alternative fertilizer marketing channels using nationally representative household panel survey data in Zambia. We developed a method to measure the potential displacement, or crowding out, of private sector fertilizer sales resulting from government programs distributing subsidized fertilizer. This paper contributes to the literature by developing a modeling framework for explicitly taking into account the effect of government input marketing programs on households' fertilizer procurement from private sector and then provides empirical estimates of the crowding out effect and conducts simulation analyses under three alternative scenarios about government's selection of areas for its distribution programs.

According to the survey, less than 20% of households used fertilizer from either channel, although there is a slight increase in the percentage for each channel in the latter year. We found that the household attributes most important in explaining whether they buy from private retailers are, with few exceptions, the same variables correlated with acquisition of fertilizer from government programs. These attributes include the value of household assets, farm size, male-headed households, educational attainment of the household head, households containing a civil service employee, and relative proximity to district towns and road infrastructure. The correlation between these variables and households purchasing inputs on a commercial basis is not surprising – in poor areas, input purchase is likely to be highly correlated with household purchasing power. But the fact that these same variables are equally correlated with receipt of subsidized fertilizer from government is quite surprising, because it suggests that the treasury costs of subsidized fertilizer distribution are being captured disproportionally by relatively wealthy smallholder farmers in relatively accessible areas, in contrast to stated government objectives for the fertilizer subsidy program.

Econometric analyses of fertilizer adoption from each channel reveal positive effects of asset value and cropland holding size, indicating household economic status is an important factor influencing both government targeting of fertilizer and households' decision to purchase fertilizer from private channel. Education, which is a proxy for knowledge and skill is also found to be positively related to fertilizer acquisition from both government and private sector channels. Age and education of the household head, and number of male adults being significant and all having positive signs in the government channel fertilizer adoption model suggests that the more educated, the older, and a larger household size with more male adults is more likely to be targeted by the government probably because these households are politically more influential than others. Having a civil servant in the household is positively related to the probability of procuring fertilizer from private suppliers and government program distributing fertilizer in the area is negatively associated with this probability. The results also indicate that government tends to target fertilizer distribution disproportionately in areas with relatively productive soil types and agro-ecological potential

A different set of factors are found significant in the level of adoption models for both channels than in the corresponding adoption models, which suggests use of double-hurdle models is more appropriate than Tobit models in analyzing fertilizer use. Econometric analysis of the extent of fertilizer adoption from government channel indicates positive association with household asset value, farm size, number of female adults and kids, and negative effects of the square term of cropland size, female-headed household and death of other adult member. Household asset value, cropland holding size and number of kids are also significant factors positively influencing the quantity of fertilizer purchased from private channel. Square term of cropland holding size is significant and has a negative sign suggesting quantity of fertilizer procured increases with the cropland size but at a decreasing rate. Farther distance to the main road and government targeting more fertilizer in the area both reduce the quantity purchased from private traders.

Coefficient estimates on the government fertilizer program are statistically significant and negative from the fixed effects models suggesting crowding out effect. Based on such estimates we derived average crowding out effect to be approximately 0.9.

Simulation study shows that crowding out effect due to increase in the volume of fertilizer distributed by government in SEAs critically depends on which SEAs and the number of SEAs included in the government program.

Empirical results from this study suggest that government programs distributing subsidized fertilizer may significantly reduce the probability and quantity of fertilizer procured from private suppliers. In addition, households that received government program fertilizer are more likely to purchase fertilizer from private sector than non-users in the absence of government programs. Thus in order to enhance small farmer income through increased fertilizer use and thereby productivity, households that have less capability to bear risks should be emphasized by government programs. Furthermore, government programs may be more effective if they target areas where the private sector is not already active, and where lack of knowledge and extension problems may provide opportunities for subsidized distribution to facilitate learning so as to expand the commercial demand for fertilizer over time. This may require appropriate management extension, small-pack distribution, and complementary investments in physical infrastructure and transport logistics so that fertilizer use can be made to be more profitable for farmers, introduce fertilizer in areas where fertilizer use is most likely to be profitable. To increase the incentives of private traders in participating in the fertilizer market, the quantity of fertilizer distributed by government should be reduced and reallocate scarce resources to improve both the quantity and quality of extension service to farmers.

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Endnotes

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[1] The geographic unit of analysis is the Standard Enumeration Area (SEA), which is the most disaggregated geographic unit in the data. In Zambia, an SEA many include 2-4 villages of several thousand people.

[2] This paper only reports estimation results for basal fertilizer use. Results for top dressing are very similar to those for basal fertilizer because households tend to use them at the predominant ratio 1:1.