Does Subsidizing Fertilizer Increase Yields? Evidence from Malawi

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Abstract

Despite their strain on government and donor budgets, fertilizer subsidies have once again become popular policy tools in several Sub-Saharan Africa countries as a potential way to increase yields in staple crops like maize. Policy makers often assume that farmers who receive the subsidy will achieve yield responses that are similar to those obtained by farmers who pay commercial prices for the input. This notion has not been verified empirically. Our study uses panel data from Malawi, a country that recently implemented a fertilizer subsidy program, to compare maize yield response to fertilizer from farmers who received subsidized fertilizer with yield responses from those who paid commercial prices for the input. Descriptive results indicate that maize plots using commercial fertilizer obtain higher yields per kilogram of fertilizer than maize plots that used subsidized fertilizer. Conversely, the results obtained using a fixed-effects estimator indicate that when other factors are controlled for, maize plots that use subsidized fertilizer obtain a higher yield response than other plots. The results seems to be influenced by a group of farmers who used no fertilizer before the subsidy program began, but used subsidized fertilizer after the program was implemented. This group of farmers obtained significantly higher yields in the year when they receive the subsidy than did the rest of the farmers in the sample during that year. These findings indicate that in order to be effective, government officials should specifically target fertilizer subsidies to farmers who lack access to commercial markets or would not otherwise find it profitable to purchase the input.

Key words: Malawi, Fertilizer Subsidies, Production Function

I. Introduction

Governments in Sub-Saharan Africa (SSA) have been working for decades to improve agricultural productivity in staple crops like maize. Fertilizer subsidies are a policy tool that has been used in various countries to improve yields by inducing farmers to use larger quantities of fertilizer. While inorganic fertilizer may increase yields in SSA, subsidizing fertilizer purchases also strains limited government and donor budgets. For example, during 2005 and 2006, the government of Malawi distributed vouchers to farmers for 131,803 metric tons of fertilizer at a price substantially below commercial market price. The program cost U.S. $60.5 million per annum (Dorward et al. 2008). The high price (both in accounting dollars and opportunity cost) of funding fertilizer subsidies warrants thorough evaluation of the policy.

The purpose of this paper is to determine whether or not farmers who receive subsidized fertilizer obtain similar yield response as farmers who pay commercial prices. Policy makers often justify the cost of fertilizer subsidies by arguing that farmers who receive subsidized fertilizer at a discounted price through the government channel are able to obtain similar output responses from fertilizer as farmers receive who pay commercial prices for fertilizer obtained through the private channel. This assumption raises numerous questions about farmer behavior and government decision making which are not well understood. It is clear that the break even yield level for a farmer who pays discounted prices for subsidized fertilizer is lower than for a farmer who pays commercial prices. Therefore the farmer who uses subsidized fertilizer may have incentive to over-apply fertilizer and under-apply other inputs such as seed, irrigation and labor thus receiving a lower marginal product from (Morris et al, 2007). Conversely it would seem that a farmer has incentives to use a productive asset as efficiently as possible regardless of how much he paid for it. In this sense one might expect farmers who received subsidized fertilizer obtain similar response rates to farmers who purchase commercial fertilizer.

This study advances the literature because it is the first to explicitly compare production functions for farmers who received subsidized fertilizer with those who purchased commercial fertilizer. Literature dating back to Shultz (1945) indicates that farmers in developing country are poor but efficient, indicating that they maximize the potential of all of their available inputs. Therefore making fertilizer accessible to farmers at subsidized rate has the potential to enhance their productivity by making it profitable for farmers to use more of the input.

In recent years numerous studies have examined fertilizer as an input in the production function of farmers in SSA (Kelly and Murekezi 2000, Duflo et al. 2008, Marenya and Barrett 2008a, Marenya and Barrett 2008b). Marenya and Barrett (2008a) look at yield response and profitability using a Linear Response and Plateau (LRP) production function. They conclude that since many low income farmers cultivate plots with poor soil quality the yield response to fertilizer is low. The authors conclude that poor soil quality may limit the effectiveness of fertilizer policy intervention. This study does not specifically address fertilizer subsidies as an input in the production function or compare it to non-subsidized fertilizer.

Another recent study looks at the rate of return to fertilizer in Kenya finds it to be positive (Duflo et al. 2008). However other literature finds that response and returns to fertilizer vary by region even with in a country (Kelly and Murekezi, 2000).

Two recent studies use the idea that two distribution channels, government and private may affect farmer behavior in different ways and use it to investigate how receiving subsidized fertilizer affects demand for commercial fertilizer (Xu et al. 2009, Ricker-Gilbert and Jayne 2008). These studies build off earlier market participation models that find fixed costs such as distance to market and variable costs such as price per unit affect market participation (Bellemare et al. 2006, Key et al. 2000). Other literature shows that of credit and insurance has also been found to be a reason why farmers do not purchase inputs like fertilizer (Kherallah et al. 2000, Croppenstedt et al. 2003, Jayne et al. 2003). While the effect of having two input distribution systems on market participation has been investigated, the next step is seeing how the government and commercial channels affect yield.

Our study uses household panel data from Malawi to determine whether yield response to fertilizer varies depending upon which channel farmers obtained the input. The fertilizer subsidy was implemented during the 2005/06 growing season and we use data from 2002/03, 2003/04 and 2006/07 to get a before and after measure of the subsidies impact on yield. Panel data provides an additional advantage of being able to use a fixed-effects estimator to control for unobserved heterogeneity that often biases cross-sectional analysis. The unit of analysis for this study will be at the plot level so we minimize aggregation bias that occurs in studies which attempt to measure yield using data at the household level. This paper should benefit 1) researchers interested in how farmers use inputs when two distribution systems exist and 2) policy makers who need to know whether farmers who receive fertilizer at a subsidized price obtain yields similar to other farmers.

The rest of the paper is organized as follows. Section two presents a conceptual framework for yield response to fertilizer. Section three lays out an empirical model used in the analysis. Section four displays the results and section five discusses the study's conclusions.

II. Conceptual Framework

One can think of yield for farmer (i) on plot (j) at time (t) as being a function of the following factors.

(1) $$Y_{ijt} = f(F_{ijt}, ?_{ijt}, O_i, ?_{ijt}, | C_i)$$

Where (F) represents a vector of inputs applied to the plot in the current time period. These inputs include fertilizer and seed. (?) stands for a vector of agronomic conditions on the plot that vary over time. These include sunlight and precipitation. (O) indicates agronomic conditions on the plot such as soil quality, and nutrient content that stay roughly constant over time. (?) represents the labor practices that the farmer conducts on the plot in the current time period. These practices include weeding and scouting for pests.

All of the factors that influence yield are conditioned on (C), which represent factors like a farmer's ability, risk aversion and land tenure status. Ability is a function of factors like experience and education. Land tenure arrangements such as share-cropping may cause a farmer to apply inputs at a rate that is lower than he would under full ownership (Hyami and Otsuka, 1993). Risk aversion may also cause a farmer to under-apply an input like fertilizer if he feels that it will not be profitable in bad states of nature.

Figure 1 represents a simple yield response function for maize to fertilizer. When other factors like soil quality, seed and management ability have been controlled farmers should all be on the same production function. The tangent lines to the production function represent the input/output price ratio of fertilizer to maize. Point C represents the yield maximizing level of fertilizer per hectare. Before a subsidy is introduced points A represents the profit maximizing level for fertilizer for a farmer who does not use fertilizer while point B represents the profit maximizing level of fertilizer for a farmer who uses fertilizer a positive quantity of fertilizer.

Offering fertilizer to farmers at a subsidized rate lowers the input output price ratio. We would expect this price change to cause a farmer to apply more fertilizer and move up the production function towards point C (Ellis 1992). Because the input/output price ratio becomes flatter once the subsidy is implemented we would expect the farmer who is at point B before the subsidy to receive a lower yield response from fertilizer as he moves up the production function. However, the farmer who is at point A before the subsidy gets no response to fertilizer. If the subsidy causes him to use positive amounts of fertilizer, we would expect him to get a positive response to the input as he increases his use and moves up the production function. According to this scenario the overall effect of subsidized fertilizer depends on the quantity of fertilizer farmers use before the subsidy.

III. Methods

The study uses the following empirical model to test the effect of yield response to subsidized fertilizer.

$$(2)\ Y_{ijt} = ß_0 + ß_1X_{1ijt} + ß_2 X^2_{1ijt} + ß_3D_{1ijt} + ß_4D_{1ijt}{}^{*}X_{1ijt} + ß_5X_{2ijt} + ß_6X_{1ijt}{}^{*} X_{2ijt} + ß_7D_{2it} + ß_8D_{2ijt}{}^{*} X_{1ijt} + ß_9D_{3ijt} + ß_{10}D_{4ijt} + ß_{11}X_{3it} + ß_{12}X^2_{3it} + ß_{13}D_{5t}\ c_i + v_{ijt}$$

Where X_1 is the amount of fertilizer (either subsidized or commercial) applied per hectare. We expect $ß_1$ to have a positive sign. $ß_2$ represents the quadratic affect of fertilizer, which we would expect to be negative. The polynomial term in the quadratic captures the fact that increasing an input like fertilizer increases yield up to a point and then any increase in that input decreases yield. Polynomials have been used often in the literature when estimating production functions in developing countries (Traxler and Byerlee 1993, Kouka et al. 1995). A polynomial response function fits our theoretical fertilizer response production function well.

D_1 is a dummy variable that takes on a value of one if the famer applied subsidized fertilizer to the plot. The coefficient on $ß_3$ allows us to test whether farmers who receive subsidized fertilizer are on the same initial intercept before using fertilizer as other farmers and $ß_4$ lets us test if the marginal product of subsidized fertilizer is significant. X_2 is the number of ten day periods with no rain which gives us an idea of if the farm experienced drought. Thus ?$_5$ indicates how drought affects yield and $ß_6$ measures how fertilizer interacts with drought.

D_2 is a dummy variable for whether or not the farmer used hybrid seed on the plot. One would expect hybrid seed to increase yield and have a positive interaction with fertilizer (Ellis, 1992). D_3 is a dummy variable for the texture of the soil on the plot. D_4 is a dummy variable for whether or not the famer hired labor to tend to the plot. X_3 represents the amount of land the farmer has at time t. Farm size should be considered in the regression because numerous studies have found a significant inverse relationship between yields and farm size (Sen 1966, Feder 1985, Kimhi 2006). One expects $ß_{11}$ to be negative initially as plot size increase because larger plots require more labor and are harder to manage. One might expect $ß_{12}$ to be positive because after reaching a certain farm size a producer may find it profitable to invest in labor saving, yield increasing inputs like machinery. In this way farm can be used as a proxy in our model for some of the labor practices that a farmer applies to the plot at time (t). D_5 controls for the year effect on yield.

C_i is the time constant unobserved household level heterogeneity such as management ability and risk aversion that influences yield. We use a fixed effects estimator control for C_i. Using fixed-effects ensures that household level heterogeneity is uncorrelated with the independent variables. It should be noted that there is also plot level heterogeneity that does not change over time. Due to the way data was collected, we are able to identify households in both time periods but we are not able to always identify the same plot in both time periods. Therefore we cannot control for plot level unobserved heterogeneity, however by including controls in equation for soil quality, rainfall and seed, the amount of plot level heterogeneity should be minimal. v_{it} represents the time varying idiosyncratic shocks that affect yields, which we assume to be uncorrelated with the independent variables. One additional benefit of our study is that we cluster our sample at the household level to allow for correlation among plots that the household cultivates (Wooldridge, 2009). Clustering also makes our results robust to serial correlation and heteroskedasticity.

IV. Results

Table 1 lists the distributions of the variables used in the analysis. The table indicates that there is a wide range of yields in the sample and that many households do not apply fertilizer. The mean amount of fertilizer applied per hectare is also significantly greater than the median, indicating that a small number of people use a great deal of fertilizer. Only 53% of the plots use hybrid seed, while 33% of the plots in both years are cultivated by people who received subsidized fertilizer. 14% of plots had a sandy texture, 65% had soil that was a mix between sandy and clay and 21% of plots had soil with clay texture. Most farms are very small with a mean farm size of 1.5 hectares.

Figure 2 presents a scatter plot of the variance of yields regressed against the variance of fertilizer applied per hectare. The Red line represents the production function for yield response to commercial fertilizer, while the blue line depicts the production function for subsidized fertilizer. There are many plots of roughly the same size that use similar amounts of fertilizer per hectare. However yields vary widely among these plots. Nevertheless Figure 1 shows that throughout most of the data range plots with commercial fertilizer obtained higher yields per kilogram of applied than did plots with subsidized fertilizer.

The findings from Figure 2 are supported by the evidence from table 2. This table reveals that in both years on average plots using commercial fertilizer obtained higher yields than plots using subsidized fertilizer. It is also interesting to note that in the first survey year plots that did not use any fertilizer obtained higher yields on average than plots that used subsidized fertilizer. This may provide some justification of the idea that farmers are poor but efficient. It is also worth mentioning that yields were much higher during the first survey (2002/03, 2003/04) than in the second survey (2006/07).

The results from table 3 present different results than the descriptive statistics regarding subsidized fertilizer's response to maize yields. There is marginal evidence that farmers who receive subsidized fertilizer may be at a lower intercept than other farmers however their yield response to fertilizer is significantly higher. The coefficient on the interaction between receiving the subsidy and the amount of fertilizer applied per hectare indicates that on average each kilogram of subsidized fertilizer increases yield by 2.28 kg/ha. The number of ten day periods with no rain negatively affects yields as we would expect, while using hybrid seed has a positive significant effect on yield. Farm size has a negative effect on yield but its squared term is positive. This is consistent with past literature and is what we would expect ex ante.

The descriptive statistics indicate that farmers who received subsidized fertilizer get lower yields than farmers who purchased commercial fertilizer while the regression results indicate that farmers with subsidized fertilizer receive a higher marginal product from fertilizer. Perhaps these results can be explained by looking at the group of 338 farmers who did not use any fertilizer in the first year of the survey but received subsidized fertilizer in the second year of the survey. It would seem that this would be the group of farmers who the government officials organizing the subsidy program would want to target. These people fertilize 110 plots of mono-cropped maize during the 2006/07 growing season. The average yield in 2006/07 for this group of people is 453 kg/ha while the average yield for the rest of that sample during that year is 431 kg/ha. The significantly higher yield of this group of people when they receive subsidized fertilizer may help explain why table 3 indicates that the marginal product of subsidized fertilizer is positive and significant.

V. Conclusions

This analysis presents several important conclusions about farmer behavior regarding subsidized fertilizer and following specific conclusions and policy recommendations about fertilizer subsidies.

1) The descriptive statistics indicate that for most of the range of data farmers who purchase commercial fertilizer obtain higher yields than farmers who obtain subsidized fertilizer.

2) Regression results indicate that farmers using subsidized fertilizer obtain a higher yield response than farmers using commercial fertilizer. These results seem to be influenced by farmers who did not use fertilizer in the first year of the survey but received subsidized fertilizer in the second year. These people obtained significantly higher yields than other people in the sample. Policy makers should target fertilizer subsidies to people who purchase very little fertilizer.

3) Hybrid seeds also have a positive impact on yield. Policy makers should consider seed as another important input to improving agricultural productivity.

Future versions of this paper will address functional form issues and deal with the possible endogeneity issue surrounding who receives subsidized fertilizer.

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Figure 1. Yield Response to Fertilizer

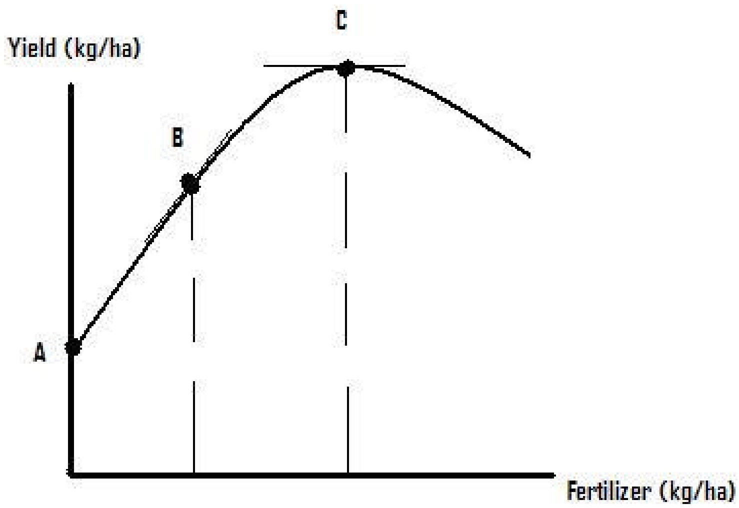
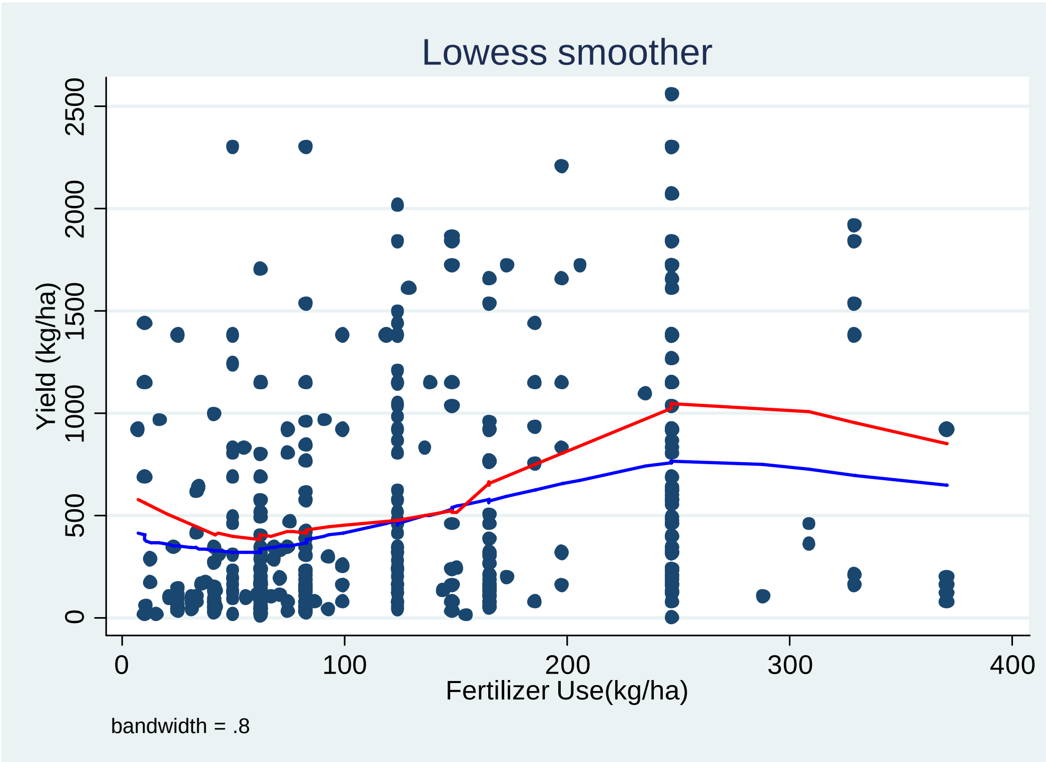


Figure 2: Production Function for Commercial and Subsidized Fertilizer



Red = Subsidized fertilizer

Blue= Commercial fertilizer

Table 1: Distribution and Description of Variables Used in the Study

	Value at Different Percentages of the Distribution					
Variable	**10%**	**25%**	**50%**	**75%**	**90%**	**mean**
Maize yield on Plot(kg/ha)	79.68	159.36	345.61	921.64	1440.06	593.34
Applied fertilizer on Plot (kg/ha)	0.00	0.00	0.00	98.77	235.16	55.72
Subsidized fertilizer applied to plot (binary)	0.00	0.00	0.00	1.00	1.00	0.33
Number of ten day periods without rain	7.00	8.70	10.00	11.00	15.00	10.15
Hybrid seed on plot (binary)	0.00	0.00	1.00	1.00	1.00	0.53
Plot has sandy soil texture (binary)	0.00	0.00	0.00	0.00	1.00	0.14
Plot has soil texture between sandy and clay (binary)	0.00	0.00	1.00	1.00	1.00	0.65
Hired labor tended the plot (binary)	0.00	0.00	0.00	0.00	1.00	0.18
Farm size (kg)	0.41	0.71	1.22	1.92	2.84	1.51

Table 2: Average Maize Yield by Year and Source of Fertilizer

	Year 1		Year 2	
Source of fertilizer on plot	**Number of Plots**	**Mean Yield (kg/ha)**	**Number of Plots**	**Mean Yield (kg/ha)**
Subsidized	26	776	437	578
Commercial	34	931	73	516
No fertilizer	538	806	328	366

Table 3: Mono-Cropped Maize Production Function Using Fixed Effects Estimator

R-sq: within = 0.30	Number of obs	=	1416
between = 0.10	Number of groups	=	1058
overall = 0.14			
corr(u_i, Xb) = -0.10	**Obs per group:**		
	min	=	1
	avg	=	1.3
	max	=	5
	F(15,1401)	=	10.61
	Prob > F	=	0

Variable Y = Maize Yield (kg/ha)	**Coefficient**	**P-Value**
Fertilizer (kg/ha)	-2.34	0.22
Fertilizer^2	0.00	0.71
Subsidized fertilizer on plot (binary)	-231.34*	0.14
Subsidy*Fertilizer	2.28***	0.05
Number of ten day Periods Without Rain	-23.32*	0.14
No Rain*Fertilizer	0.17	0.26
Hybrid Seed (binary)	118.57**	0.07
Hybrid*Fertilizer	-0.81	0.31
Sandy Soil (binary)	-95.36	0.22
Mixed texture Soil (binary)	-51.48	0.54
Hired Labor (binary)	8.57	0.92
Farm size (kg)	-65.10*	0.12
Farm size^2	2.51**	0.09
First survey year 1 (binary)	452.85****	0.00
First survey year 2 (binary)	577.36****	0.00
Intercept	709.09****	0.00

Note: *, **, ***, **** indicate corresponding coefficients are significant at the 15%, 10%, 5%, 1% level respectively.