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Factors Influencing the Profitability of Fertilizer Use on Maize in Zambia

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Major Findings:

- The additional maize produced from a given amount of fertilizer applied varied widely across households even after largely controlling for soil and rainfall conditions. The median estimated response rate was 15.9kgs of maize per kg nitrogen applied;
- Under the range of conditions and smallholder management practices, average maize-fertilizer response rates declined as the application rate increased beyond 2 bags of urea and 2 bags of D compound;
- Factors raising the response rate and profitability of fertilizer use included timely availability, application rates less than the MOA 4x4 recommendation, use of animal draft power in land preparation, and use of hybrid seed. In remote areas, and given current management practices, fertilizer use appears to be profitable only for a minority of smallholder farmers in the relatively remote areas. For farmers in the more accessible areas, profitability of fertilizer use depends on timely availability. If fertilizer is not available on time, even farmers in the more accessible parts of this area of relatively high agronomic suitability for maize production are largely unable to use fertilizer profitably.
- Because over 30 percent of the households reported that fertilizer was delivered late, these findings indicate that efforts to ensure timely distribution can contribute substantially to the productivity gains achievable from fertilizer use.

INTRODUCTION: Agricultural policy in Zambia has for the past several decades focused on fertilizer subsidies and targeted credit programs to stimulate small farmers' agricultural productivity, enhance food security and ultimately reduce poverty. Improving maize productivity has been a major goal of the government's agricultural policy over the past several decades. Despite these efforts, overall fertilizer consumption has expanded slowly. Mean maize yields even in the relatively high-potential zones of Zambia remain at 1.2 to 1.8 tons per hectare over the past decade. Maize yields vary greatly among households, but 75 percent of households obtain between 0.7 and 2.5 tons per hectare. Slow growth in fertilizer use underscores the need for a better understanding of the factors affecting the profitability of fertilizer use under small farm conditions so as to inform the policy process aimed at achieving sustainable increase in maize productivity and smallholder incomes.

While weak input, credit, and output markets, poor soils, and high production risks have often been identified as the main reasons for low uptake of fertilizer among African farmers, there is a relative dearth of insight about why fertilizer use remains low even in relatively high-potential and accessible areas where fertilizer use is believed to be

profitable. This note synthesizes evidence on the factors affecting the profitability of smallholder farmers' use of fertilizer on maize in Natural Region IIA in Zambia, a relatively high-potential area of Zambia well suited to maize production.

Extension messages in Zambia have been based on one nationally recommended application rate of 200 kilograms of basal fertilizer (Compound D, 10-20-10 NPK) and 200 kilograms of top dressing fertilizer (Urea, 46-0-0) per hectare of maize. This one-size-fits-all recommendation ignores the major differences in small farm conditions and differing market conditions. Efforts to raise the profitability and effective demand for fertilizer will depend on helping farmers to use the input efficiently, which in turn depends on management practices, use of fertilizer-responsive seeds, and taking into consideration how agro-ecological and market conditions affect appropriate application rates.

Data and Methods: Household-level data used in this study are from three surveys, the 1999/2000 Post Harvest Survey (PHS), the linked First Supplemental Survey to the 1999/2000 PHS, and the Second Supplemental Survey to the 1999/2000 PHS. All three surveys were conducted by the Central Statistical Office. A panel data set for two agricultural seasons, 1999/2000 and 2002/2003, is available from these surveys. The panel consists of 707 farmers in two periods, producing a total of 1,414 observations. Details of sampling are contained in Xu et al (2009).

Our study area is the primary maize surplus production region, Zone IIA (medium rainfall area) with dominant soil type acrisols or ferrolsols. The parts of Zone IIA with these soil types are considered to be relatively well suited to maize production and responsive to fertilizer application. Households were also separated into two equal groups according to their distance to the nearest district town. We differentiate between these relatively accessible and remote areas in the assessment of fertilizer use profitability.

The analysis is based on estimation of a maize response function. We specifically determine the impact of nitrogen (the most important nutrient in maize growth) application rate[1] in kg per hectare, as well as the percentage of basal fertilizer in total kilograms fertilizer usage. We account for the possibility that the effect of fertilizer use on maize yield may be influenced by whether animal draught power was used during land preparation, whether fertilizer was available at the time of planting, whether fertilizer was acquired from the government fertilizer subsidy program, whether the household received advice from the national extension service, the size of the maize plot, characteristics of household head (age, gender, and education), number of adults above age 14, and whether the household incurred the death of a prime-aged adult between the first and second surveys. Details of the model and estimation procedure are described in Xu et al. (2009).

In the absence of data on full production costs such as labor input, value cost ratios have often been employed to assess the profitability of fertilizer use (Crawford and Kelly, 2002). The average value cost ratio (AVCR) measures the average gain in the value of maize output per kg of nitrogen applied. If the response function were known with certainty and there were no transaction costs in the acquisition of fertilizer, the incentive would be to apply nitrogen to the point where the VCR is 1.0. However, there is clearly substantial uncertainty about the outcome of applying fertilizer as well as substantial transaction costs associated with acquiring fertilizer and marketing maize. For these reasons, researchers have suggested that a VCR of 2.0 or greater is generally required for farmers to use fertilizer in appreciable

[1] It is calculated based on the amount of basal fertilizer and top dressing fertilizer used per hectare and the nutrient components in these fertilizers. 100kg of Compound D basal fertilizer contains 10kg nitrogen (*N*), while 100kg of urea top dressing contains 46kg *N*.

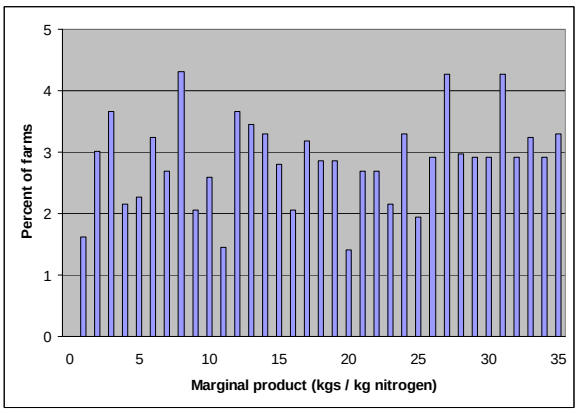
amounts (Crawford and Kelly, 2002). Our analysis adopts this convention and considers AVCR of at least 2 as an indicator that fertilizer use is likely to be profitable.

Main findings on maize response to fertilizer application: The estimation results highlight four main findings. First, maize yields were significantly positively related to fertilizer use but declined as the application rate increases. During these two years (considered neither abnormally good nor poor in terms of rainfall), maize yield increased up to roughly 80 kilograms of nitrogen (this is equivalent to roughly 2.5 50kg bags of Compound D and 2.5 50kg bags of urea per hectare of maize. After that point, maize yields tend to respond relatively little to additional fertilizer use. If best practices were followed, it is likely that diminishing marginal returns would set in at a higher level of fertilizer application. Other factors positively related to maize yield included whether purchased hybrid seed was applied and whether animal draft power was used in land preparation (as opposed to traditional hoe cultivation practices). The area planted to maize, age and gender of the household head, and the number of adults in the household did not contribute to or explain any of the differences in yields.

Second, fifty percent of the farmers using fertilizer applied less than 46 kgs N per ha (about 1.5 bags of Compound D and 1.5 bags of urea per hectare), and 75 percent applied less than 69 kgs N per ha (a little more than 2 bags of each). Clearly, the nationwide recommended application rate of 4 bags Compound D and 4 bags urea (which amount to approximately 112 kgs of nitrogen) per hectare of maize is well beyond the rates used by the majority of fertilizer users.

Third, the additional maize produced from a given amount of fertilizer applied varied widely across households even after largely controlling for soil and rainfall conditions. The median estimated response rate was 15.9kgs of maize per kg nitrogen applied, but as shown in Figure 1, it was under 10kgs maize per kg nitrogen for 25.6% of the sample, between 10 to 20kgs for 29.9% of the sample, between 20 to 30kgs for 27.2%, and over 30kgs maize per kg nitrogen applied for 18.3% of the farms.

Figure 1. Histogram of estimated marginal product of nitrogen for farmers using fertilizer.



Fourth, the most important factors accounting for this huge variation in maize yield response to fertilizer across households in this Zone IIA were the fertilizer application rate and whether fertilizer was available to farmers on time. Table 1 presents the estimated average products of N for households applying fertilizer and dependent upon whether nitrogen was available in a timely manner (67% of the time for fertilizer received through the government subsidy program and 70% of the time for fertilizer purchased from private stockists). The yield response to fertilizer falls as the application rate increases. However, the most striking feature is the impact of the timeliness of fertilizer availability. Comparing cases 1 vs 2, cases 3 vs 4, and cases 5 vs. 6 in Table 1 reveal that acquiring fertilizer on time roughly doubles the maize response rate to fertilizer. Because over 30 percent of the households reported that fertilizer was delivered late, these findings indicate that efforts to ensure timely distribution can contribute substantially to the productivity gains achievable from fertilizer use.

Main findings on factors influencing profitability of fertilizer use: Based on input and output prices prevailing in the two years of analysis, the average VCR at the median fertilizer application rate of 46kg N was 2.2 if fertilizer was available on time and 1.2 if not. At the higher level of fertilizer application (the 75th percentile), the VCR drops to 1.9 and 0.96.

We differentiate households into two groups according to their degree of remoteness or accessibility to markets, according to their distance to the nearest district town. The relatively remote group face maize-fertilizer price ratios roughly 20 percent lower than for the relatively accessible group. The majority of farmers in relatively remote areas have VCRs less than two. During 1999/2000, only one case out of 6 cases presented in Table 1 had VCRs above 2; 2 of the 6 cases have VCRs above 2.0 in the 2002/2003 season. In the more accessible areas, only 2 of the 6 cases shown in Table 1 had VCR above 2.0 in 1999/00 while half of the cases had VCRs above 2.0 in 2002/03. At a given level of nitrogen use, and given current management practices, fertilizer use appears to be profitable only for a minority of smallholder farmers in the relatively remote areas. For farmers in the more accessible areas, profitability of fertilizer use depends on timely availability. If fertilizer is not available on time, even farmers in the more accessible parts of this area of relatively high agronomic suitability for maize production are largely unable to use fertilizer profitably.

On the other hand, beneficiaries of the government fertilizer program are more likely to find fertilizer use profitable because they were able to acquire fertilizer at roughly half of the full retail price and this would effectively double the VCR values.

As a final exercise, we compute the level of nitrogen (N^*) at which the marginal VCR is equal to 2 for each case. Nitrogen applied at a level higher than N^* is considered unlikely to be profitable. The recommended nitrogen application rate by Zambia extension message (112kg of nitrogen per hectare) is higher than N^* in all cases for both years of analysis. The median N^* was found to be in the range of 44 to 71kg of N for cases in which fertilizer was delivered on time. Of course these findings are sensitive to maize/N price ratios observed in the two years of the study. In subsequent years since 2002/03, the maize-to-N price ratio has been more than 10% higher than those observed in 2002/03 in two years, while being more than 10% lower in two years. These findings suggest that fertilizer applied at the recommended level is unlikely to be economically viable for most farmers given the range of market prices for maize and fertilizer observed in recent years in Zambia.

Policy Implications: Strategies to make fertilizer use more profitable for farmers will require raising yield response rates and reducing input and output marketing costs. Our study finds that farmers' ability to acquire fertilizer in a timely manner has a strong positive effect on maize yield response to fertilizer. Subsidized fertilizer under government programs in Zambia has often been distributed late. These programs have also caused uncertainty for private traders who often assess whether subsidized government fertilizer will be circulated in a certain area of operation before determining where to stock fertilizer (Govereh et al., 2003). These dynamics give rise to the late acquisition of fertilizer through both public and private channels. Fertilizer use in any appreciable amount is unlikely to be profitable until efforts are made to ensure more timely delivery of fertilizer. Moreover, the extension service may consider revising downward their recommended fertilizer application rates taking into consideration relevant factors that will influence profitable use of fertilizer. Under prevailing management conditions, lower application rates are necessary for most households to achieve minimum threshold conditions of profitability. Higher fertilizer application rates may become more profitable if there are concomitant improvements in the use of draft power, improved cultivars, timely availability of fertilizer, improved agronomic practices,

and investments in physical infrastructure to reduce the costs of acquiring fertilizer and marketing maize.

These findings suggest that improving the efficiency of fertilizer use among smallholder farmers through more effective extension messages and timely fertilizer availability could make fertilizer use profitable even at much higher application rates. We find that if farmers in the bottom half of the distribution ranked by their marginal product of nitrogen were able to achieve the mean marginal product level of 15.9kgs maize per kg N applied, this itself would raise maize production among the entire sample of fertilizer using households by 15.2 percent. The findings of this study indicate that efforts to raise the efficiency of fertilizer use by smallholder farmers could make great strides in raising the profitability of, and hence the effective demand for fertilizer in Zambia.

References

Crawford, E. and V. Kelly. 2002. Evaluating Measures to Improve Agricultural Input Use. Staff Paper 01-55. Department of Agricultural Economics, Michigan State University, East Lansing, Michigan.

Govereh, J., Jayne, T.S., Sokotela, S. Lungu, O.I., 2003. "Raising maize productivity of smallholder farmers in Zambia: what can fertilizer consumption alone do or not do?" Working Paper. Food Security Research Project, Lusaka, Zambia.

Xu, Z., Z. Guan, T. Jayne, R. Black. 2009. Factors Influencing the Profitability of Fertilizer Use on Maize in Zambia. *Agricultural Economics*, forthcoming, November 2009.

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Table 1. Estimates of marginal and average products of nitrogen and estimated value-cost ratios for alternative rates of nitrogen application dependent upon timeliness of fertilizer availability.

	25th percentile	50th percentile	75th percentile	Fertilizer available on time		MP of nitrogen (kg/kg N)		AP of nitrogen (kg/Kgs N)		Average Value-Cost Ratio (AP nitrogen*Pmz/Pnitrogen)			
										Remote area		Accessible area	
Case	28 kgs	46 kgs	69 kgs	no	yes	1999	2002	1999	2002	1999	2002	1999	2002
1	x			x		9.2	13.8	10.1	15	1.02	1.66	1.17	1.86
2	x				x	19.2	23.4	20.9	25.5	2.11	2.81	2.43	3.16
3		x		x		8.2	12.2	9.5	14.2	0.90	1.46	1.04	1.65
4		x			x	16.9	20.6	19.7	24.1	1.86	2.47	2.15	2.78
5			x	x		6.9	10.1	8.9	13.2	0.75	1.21	0.87	1.36
6			x		x	14.1	17.2	18.2	22.3	1.55	2.06	1.79	2.32

Note: green cells denote average VCRs over 2.0 which signify profitable usage of fertilizer at the specified N application rate.
N / maize price ratios were 8.60 in 1999/00 and 8.06 in 2002/03 in the accessible areas. These N/maize price ratios were 18% lower in the relatively remote areas.