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TRENDS AND PATTERNS IN FERTILIZER USE BY SMALLHOLDER FARMERS IN KENYA, 1997-2007

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Abstract

This study uses nationwide household panel survey data from 1996/97 to 2006/07 to examine trends in fertilizer use on maize by smallholder maize growers. The paper also compares these findings with fertilizer use rates according to other recent surveys in Kenya to assess comparability. We also examine the correlation between household fertilizer use and indicators of welfare such as wealth and landholding size. In addition, we use econometric techniques applied to household survey data to identify the main household and community characteristics associated with fertilizer purchases. Lastly, the study considers alternative policy strategies for maintaining smallholders' access to fertilizer in the current context of substantially higher world fertilizer prices.

Key Words: Fertilizer use, Household, Kenya

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1.0 Introduction: Implications of High Food and Fertilizer Prices

Increasing farm productivity is important in reducing poverty in rural agrarian societies. The structural transformation paradigm espoused by Johnston and Mellor (1961) and Mellor (1976) underscores the role of agricultural productivity growth in rural poverty reduction, demographic change, and economic development. This structural and demographic transformation was seen in many Asian countries during their Green Revolutions. There is general agreement among researchers and policy makers that increased levels of fertilizer use, improved soil fertility and farmer management practices, and improved seed technologies are also required in Africa to generate these gains in farm productivity growth (Morris et al., 2007).

The current spike in world food, fuel and fertilizer prices has led a number of developing countries to re-assess their agricultural and food security policies. The cost of white maize in international markets, as of August 2008, is in the range of US$240 per ton,[1] whereas its historical mean over the 2000-2006 period was roughly US$100 per ton. This means that the cost of landing maize in interior markets in Eastern and Southern Africa, factoring in substantially higher transport costs in 2008, is now in the range of US$400-450 per ton. As a result of considerably higher import prices, the costs and risks of national and regional food production shortfalls are more severe now than they used to be.

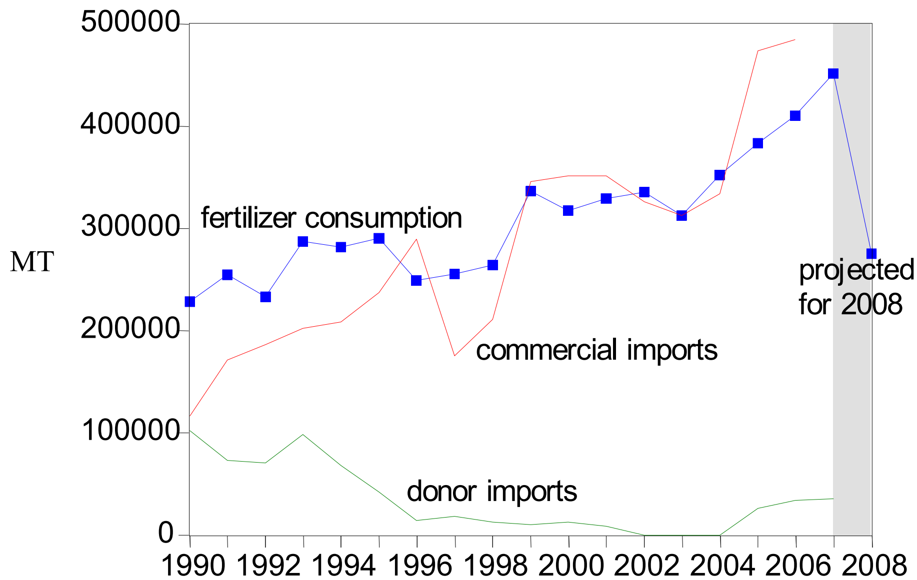
Increased fertilizer use is one of the important means by which households and nations can reduce the likelihood of having to rely on international markets for grain. However, world fertilizer prices have risen even more so than food prices. After accounting for inland transport costs, the wholesale price of DAP fertilizer in Nakuru, Kenya has risen from Ksh 1,750 per 50kg bag in 2007 (US$538 per ton) to nearly Ksh 4,000 per 50kg bag (US$1,283 per ton) in 2008. These world price conditions, combined with the civil disruptions experienced in early 2008, are likely to break the steady upward trend in fertilizer use that Kenya has experienced over the past 15 years (Figure 1).

Governments in the region are searching for options to reduce their reliance on international food markets at a time when food prices are very high but when the soaring

[1] Yellow maize #2 US Gulf was $243/mt as of August 30, 2008. White maize, SAFEX Randfontain South Africa was $241/mt as of August 30, 2008; white maize, fob Argentina, was $213/mt, August 15, 2008.

price of fertilizer has reduced farmers' effective demand for it. Many smallholder farmers may also lack the ability to afford fertilizer without seasonal finance. If fertilizer needs are not met and sufficient imports cannot be mobilized, widespread hunger may result, with negative social and political consequences at the national (and international) level, particularly if hunger turns into famine. It therefore may not be surprising that the Government of Kenya has announced in early September 2008 a plan to set aside Ksh 11 billion (US$183 million) for fertilizer imports, which farmers will access at discounted prices. However, the impact that a fertilizer subsidy program can make to mitigate hunger and poverty depend crucially on how the subsidy program is designed and implemented, and whether the other necessary conditions are put in place to enable farmers to benefit appreciably from increased use of fertilizer.

Figure 1: Trends in fertilizer consumption, commercial imports, and donor imports, 1990-2007, with projections for 2008.



Source: Ministry of Agriculture, 1990-2007; 2008 projections from interviews of fertilizer importers.

This study provides an empirical foundation to guide future fertilizer promotion policies and programs in Kenya. By obtaining a clear understanding of the farmer characteristics and geographic factors associated with commercial fertilizer purchase for use on maize, the major food security crop in the country, policy makers may be able to more accurately refine their programs to pinpoint where direct assistance may be necessary. The study tracks trends in fertilizer use among 1,260 small-scale farm households surveyed by Egerton University's Tegemeo Institute in 1997, 2000, 2004, and 2007.[2] The paper also compares fertilizer use rates in this data set with those of other recent surveys in Kenya to assess comparability. We also examine the correlation between household fertilizer use and indicators of welfare such as wealth and landholding size. In addition, we use fixed effects regression models to identify household and community factors associated with fertilizer use. Lastly, the study considers alternative policy strategies for maintaining smallholders' access to fertilizer in the current context of substantially higher world fertilizer prices.

[2] In other Tegemeo papers, the balanced panel consists of 1,275 households, but 15 households did not have complete information on all variables used in this study, hence the 1,260 sample size.

2.0 Data

Data for this study is from 3 sources: i) Tegemeo rural household survey data from 1997, 2000, 2004, and 2007; ii) interviews with key stakeholders in the fertilizer distribution system; and iii) statistics compiled by the Ministry of Agriculture on fertilizer prices at Mombasa and upcountry (Nakuru).

The panel household survey was designed and implemented under the Tegemeo Agricultural Monitoring and Policy Analysis Project (TAMPA), implemented by Egerton University/Tegemeo Institute, with support from Michigan State University. The sampling frame for the panel was prepared in consultation with the Kenya National Bureau of Statistics (KNBS) in 1997; although KNBS's agricultural sample frame was not made available. Twenty-four (24) districts were purposively chosen to represent the broad range of agro-ecological zones (AEZs) and agricultural production systems in Kenya. Next, all non-urban divisions in the selected districts were assigned to one or more AEZs based on agronomic information from secondary data. Third, proportional to population across AEZs, divisions were selected from each AEZ. Fourth, within each division, villages and households in that order were randomly selected. A total of 1,578 households were selected in the 24 districts within eight agriculturally-oriented provinces of the country. The sample excluded large farms with over 50 acres and two pastoral areas. The initial survey was implemented in 1997, which covered both the 1996/97 and 1995/96 cropping seasons. Subsequent follow up surveys were conducted in 2000, 2004, and 2007.

This analysis is based on 1,260 households which formed a balanced panel for each of the five cropping years, 1995/96, 1996/1997, 1999/2000, 2003/04 and 2006/07 (hereafter referred to as 1996, 1997, 2000, 2004 and 2007, respectively). The attrition rate for the panel was 19% over the 10-year period. Some of the main reasons for this attrition are related to death of household heads and spouses leading to dissolution of households, and relocation of households from the study areas. Households in Turkana and Garissa districts were not interviewed in the 2004 and 2007 surveys. The 22 districts in the survey were assigned to agro-regional zones as defined in Table 1.

Of the eight agro-ecological zones shown in Table 1, areas which have both a main season and short-rains season are found in Eastern Lowlands, Central Highlands, Western Highlands, and Western Lowlands. For these two-season areas, we focus on the main crop season only. Most of the districts covering the High-Potential Maize Zone, Western Transitional, Marginal Rain Shadow, and Coastal Lowlands have only one cropping season.

Table 1: Sampled districts in agro-ecological zones

Agro-ecological zone	Districts	Categorization	Number of households
Coastal Lowlands	Kilifi, Kwale	Low-potential	70
Eastern Lowlands	Machakos, Mwingi, Makueni, Kitui, Taita-Taveta	Low-potential	143
Western Lowlands	Kisumu, Siaya	Low-potential	149
Western Transitional	Bungoma (lower elevation), Kakamega (lower elevation)	Low/medium-potential	148
Western Highlands	Vihiga, Kisii	High-potential	128
Central Highlands	Nyeri, Muranga, Meru	High-potential	240
High-Potential Maize Zone	Kakamega (upper elevation), Bungoma (upper elevation) Trans Nzoia, Uasin Gishu, Bomet, Nakuru, Narok	High-potential	345
Marginal Rain Shadow	Laikipia	Low-potential	37
Overall sample			**1260**

A major advantage of panel data is that it overcomes problems of sample comparability over time. In many countries, various farm surveys can be drawn upon to measure trends in livelihoods and agricultural performance over time. However, the comparability of these surveys is often compromised by differences in sampled households, locations, month/season of interview, recall period, and the way in which data is collected. The findings reported in this study are based on a balanced panel of 1,260 households consistently interviewed in 1997, 2000, 2004, and 2007, which provides a unique opportunity to track changes in agricultural performance for a consistently defined nationwide sample of small-scale farmers.

Data on fertilizer use was collected at both the household and field levels, with field data covering field size in acres, crops cultivated and harvested from each field, amount of fertilizers applied on each field, amount of seed planted for each crop, and type of maize seed planted. For the regression analysis below dummies are used to represent type of seed planted for each observation. Data is also available on household demographics on age, years of education, gender, employment and on infrastructure like distance to extension service and to fertilizer sellers.

Table 2 shows some basic descriptive statistics for the household sample pooled across all four survey years (n=1,260 households * 4 years, giving 5,040 observations). The land under maize is very similar for fertilizer users and non users at 5.17 and 4.56 acres, respectively. The proportion of cropped land under maize fields is also very similar for fertilizer users and non-users, at 41% and 42%. Household size as measured in adult equivalents is almost identical. While 28% of inorganic fertilizer users also used manure on their maize fields, 38% of the households not using inorganic fertilizer did.

However, there are some notable differences in the attributes of fertilizer users and non-users. First, the mean value of household productive assets is considerably higher among fertilizer users (Kenya Shillings[3] 51,000) compared to non-users (Kenya Shillings 30,000). The fertilizer-using households were generally located in areas receiving higher and more stable rainfall. Main season rainfall was 697 mm on average among inorganic fertilizer users compared to 588 mm for non users. The water stress variable, defined as the fraction of 20- day periods receiving less than 40 mm of rainfall, was higher among fertilizer non users than users.

Also, fertilizer using households are in closer proximity to fertilizer retailers than non-users. The fertilizer using households were 3.15 km away on average from the nearest fertilizer retailer compared to 8.64 km for the non-using households. Fertilizer users were also only 0.84 km from the nearest motorable road, compared to 1.28 km for non users. Moreover, fertilizer users are found to be closer to agricultural extension services. Lastly, we find that maize yields in the main season for households using fertilizer averaged 1,332 kgs per acre over the four years compared to 665 kgs per acre among households not using inorganic fertilizer. More details, broken by percentiles (25^{th}, 50th, and 75^{th}), on these variables are presented in Table 2 below. A test of differences in means between users and non-users conditional on unequal variances was rejected for most of these variables.

[3] The average exchange rate over four survey years is Kenya Shillings 67=1US$).

Table 2: Descriptive characteristics of households using fertilizer on maize vs. not using, 1997, 2000, 2004, 2007 pooled.

	Households using fertilizer on maize (n=2660 households over 4 surveys)				Households not using fertilizer on maize (n=1480 households over 4 surveys)				Test of equality
	Value of variable at (percentile):				Value of variable at (percentile):				
	Mean (a)	25th	50th (median)	75th	Mean (b)	25th	50th	75th	(a)=(b)
Diversification Index[1]: Using crop revenue	0.37	0.23	0.37	0.51	0.48	0.36	0.49	0.63	Rejected**
% of cropped area under maize (both mono + intercrop)	0.41	0.21	0.34	0.57	0.42	0.26	0.38	0.50	
Household total area under crops (acres)	5.17	2.13	3.56	5.92	4.56	2.00	3.23	5.50	Rejected**
Fertilizer application rate on maize fields (kgs/acre)	64.31	25.00	50.00	100.00	0.00	0.00	0.00	0.00	Rejected**
Manure/compost use dummy	0.28	0.00	0.00	1.00	0.37	0.00	0.00	1.00	Rejected**
Household adult equivalents	5.00	3.26	4.68	6.45	4.97	3.10	4.65	6.39	
Household head education (years in school)	7.13	3.00	7.00	11.00	5.27	0.00	6.00	8.00	Rejected**
Dependency ratio[2]	0.55	0.00	0.31	0.83	0.65	0.00	0.43	1.00	Rejected**
Main season rainfall (mm)	696.78	503.70	756.00	914.30	588.10	330.60	681.00	831.00	Rejected**
Fraction of 20-day periods with <40mm of rainfall	0.21	0.00	0.19	0.33	0.25	0.00	0.15	0.44	Rejected**
Maize yield (kgs/acre)	1322.31	626.61	1062.95	1620.00	665.70	257.50	503.77	855.00	Rejected**
Household agricultural assets value	51225	2000	8000	31400	30436	1300	5500	24500	Rejected**
Distance from fertilizer seller	3.11	1.00	2.00	3.50	8.45	2.00	4.00	10.00	Rejected**
Distance to motorable road	0.84	0.10	0.30	1.00	1.28	0.20	0.50	2.00	Rejected**
Distance to tarmac road	6.57	2.00	6.00	10.00	10.01	2.00	6.00	14.00	Rejected**
Distance from extension advice	4.62	2.00	3.00	6.00	6.13	2.00	4.00	8.45	Rejected**

Source: Tegemeo Institute/Egerton University household surveys, 1997, 2000, 2004, and 2007. From the 1,260 households consistently interviewed all the four surveys, there are 5,040 household observations. Of these, 4140 households planted maize and had complete information on all variables. Of these, 5,040 observations, 2,660 used fertilizer and 1,480 households did not use fertilizer (i.e. approximately 36% did not use fertilizer over all four survey years).

Notes:

[1]Diversification index for the fields was generated from individual crop revenues using the Herfindahl index, a measure of concentration.

[2]This was calculated as the ratio of the sum of adult equivalents of households members below 15 years (x) to that of total household equivalents (N) minus (x) i.e. x/(N-x). Note: the test for equality of means was based on a prior test for equality of variances between the groups; the latter was rejected for all groups at 5% significance; therefore the tests for equal means are based on un-equal variances; **indicates significance of 5% while * is for 10%.

3.0 Methods

The study reports bi-variate tables and graphs to provide the reader with a basic description of key trends and patterns of fertilizer use. However, as we will see, bi-variate results may give misleading information about the factors associated with fertilizer use because they do not hold other factors fixed. To provide a more accurate assessment of the household and community factors associated with household purchase of inorganic fertilizer, we estimate Probit and two-step Tobit models. The latter models identify the factors that affect the decisions by farmers to participate in fertilizer markets and conditional on participation, their level of purchases.

There are different two-step econometric approaches for modeling household decisions to participate in the market and the level of participation (in this case how much fertilizer to buy). Much of the literature is based on the famous Heckman two-step procedure using maximum likelihood procedures to estimate both the underlying and selection equations simultaneously or sequentially depending on the assumptions about the distribution of the disturbances and the data generating process. Issues of sample selection in a two-stage procedure are accounted for by generating the Inverse Mills Ratio (IMR) which is then used in the second equation as an additional variable. Tests on the IMR can verify whether a two stage procedure is appropriate or not. However, the appropriateness of Heckman procedures depends on the underlying assumption that zero fertilizer use represents an unobserved or "censored" effect and hence is not a valid observation. By contrast, Cragg's double hurdle models treat zero dependent-variable values as valid observations and hence are more directly applicable for our case of modeling household decisions to purchase fertilizer (to be included in the final version of this paper).

Because two-step regression procedures may be prone to biased estimates, a systems approach using maximum likelihood methods is the more desired approach. Though likelihood functions for cross-sectional data do exist, there is no comparable alternative for panel data. Therefore, this study will use pooled cross-sectional and panel approaches where appropriate taking into account sample selection. We fit a pooled Tobit and Panel Random Effects Model that assumes that unobserved individual heterogeneity is exogenous with respect to explanatory factors.

4.0 Trends in Fertilizer Use

4.1 Trends in the Proportion of Smallholder Households Using Fertilizer, by Agro-Ecological Zone

The proportion of sampled smallholder farmers using fertilizer on maize in the main season has grown from 55% in 1996 to 70% in 2007 (Table 3). These rates vary considerably throughout the country, ranging from less than 10% of households surveyed in the drier lowland areas to over 95% of small farmers in Central Province and the maize surplus areas of Western Kenya. The highest proportion of smallholders using fertilizer is in Central, High Potential Maize Zone, and Western Highlands zones, where over 80% of all maize growing smallholders apply fertilizer on maize.

However, the percentage of households using fertilizer is much lower in the drier areas such as Eastern Lowlands (43% in 2007), Western Lowlands (13% in 2007) and Marginal Rain Shadow (16% in 2007), though this proportion has increased in all zones between 1997 and 2007.

Table 3: Percent of farm households using fertilizer on maize

Agro-regional zone	**1996**	**1997**	**2000**	**2004**	**2007**
	% of households using fertilizer on maize				
Coastal Lowlands	0	0	3	4	14
Eastern Lowlands	21	27	25	47	43
Western Lowlands	2	1	5	5	13
Western Transitional	39	41	70	71	81
High Potential Maize Zone	85	84	90	87	91
Western Highlands	81	75	91	91	95
Central Highlands	88	90	90	91	93
Marginal Rain Shadow	6	6	12	11	16
Total sample	**56**	**58**	**64**	**66**	**70**

Table 4: Fertilizer dose rates (kgs) applied on maize fields receiving fertilizer, main season.

Agro-regional zone	1997	2000	2004	2007
	Dose rate (kgs/acre) on fertilized maize fields			
Coastal Lowlands	11	5	3	7
Eastern Lowlands	10	18	15	16
Western Lowlands	24	14	10	12
Western Transitional	54	48	62	71
High Potential Maize Zone	65	67	74	75
Western Highlands	31	36	46	47
Central Highlands	68	64	64	58
Marginal Rain Shadow	12	15	43	43
National sample	**56**	**55**	**60**	**59**

This study defines fertilizer dose rates as the amount of fertilizer applied to fields receiving fertilizer. Unfertilized maize fields are not counted in this computation. By contrast, fertilizer application rates are defined as the amount of fertilizer applied to all maize fields in the sample, whether they received fertilizer or not. By definition, dose rates are higher than application rates.

Mean dose rates in the six districts sampled in the High-Potential Maize Zone in 2007 were 75kg per acre (187kg per hectare), comparable to or higher than post-Green Revolution dose rates on rain-fed grain crops in the relatively productive areas of South and East Asia. In the drier lowlands by contrast, dose rates are low, but it is unclear whether economically optimal dose rates in such areas are much higher than observed here (further analysis is needed on this question). Overall, Kenya's agricultural extension system recommends that farmers should apply 100kgs of fertilizer per acre of maize, but this recommendation may be based on high-potential rainfall and soil conditions and may therefore not be appropriate for the drier regions in the country nor may it be appropriate given post-liberalization maize/fertilizer price ratios.

Overall, fertilizer dose rates on maize fields have not increased appreciably. Mean dose rate was 56kg per acre in 1997, rising to only 59kg in 2007 (Table 4). Dose rates appear to be even declining somewhat in the lowlands zones, while it is increasing in the moderate-potential and high-potential areas.

The findings reported in Tables 3 and 4 from the nationwide Tegemeo survey data are largely consistent with those of other available studies. For example, a 2007 Rockefeller Foundation-funded study undertaken in four districts of Western Kenya (Siaya, Bungoma, Vihiga, which are included in the Tegemeo sample, and Butere-Mumias[4]) reports either a similar or higher proportion of small-scale farmers using inorganic fertilizer on maize than according to this study (Rockefeller Foundation, 2007). The mean district-level fertilizer application rates on fields receiving fertilizer are slightly higher in the Rockefeller study than in the Tegemeo survey for comparable districts. The study indicates that "The districts were stratified into High Potential Maize, Western Transitional, Western Highland and Western Lowland agro-ecological zones, based on the Tegemeo Institute's Rural Household classification" (pg. 6). We reproduce Tables 5-2 and 5-3 on page 37 of the Rockefeller study, which reports household fertilizer use on maize, here referred to as Tables 5 and 6.

Table 5: (Table 5-2 in Rockefeller Study): Fertilizer use and application rate in selected crops by beneficiary group, Western Kenya, 2005

	Market access category of household:					
	Cereal bank members	Non-cereal bank members	Spillover households (in proximity to cereal bank operation)	CNFA	Non-CNFA	Overall
Fertilizer use %	84.9	77.1	76.2	91.9	70.3	78.3
Rate (kg/acre), users only	83.2	66.2	82.2	76.0	66.3	68.3

Source: Rockefeller Foundation baseline survey, 2005
Note: CNFA refers to an input dealer training programme undertaken in parts of Western Kenya.

[4] Not in Tegemeo Sample

Table 6: (Table 5-3 in Rockefeller Study): Fertilizer use and application rates by District, Western Kenya, 2005 according to Rockefeller study compared to the 2004 Tegemeo survey.

	District				
	Bungoma	**Butere-Mumias**	**Vihiga**	**Siaya**	**Overall**
Fertilizer use %	86.8	64.6	82.4	49.7	78.3
Rate (kg/acre), users only	104.2	59.6	38.1	37.0	68.3
According to Tegemeo 2004 survey:					
Fertilizer use %	61.7	Not included in	78.8	24.1	66.2
Rate (kg/acre), users only	88.9	Tegemeo sample	32.9	34.8	41.1

Source: Rockefeller Foundation baseline survey, 2005

Another recent study by Marenya and Barrett (2008) of fertilizer use patterns in Vihiga and South Nandi Districts in 2005 found that 88% of the 260 farmers used fertilizer in the 2004 main crop season, compared to 78% in the Tegemeo sample in Vihiga District (South Nandi District was not included in the Tegemeo sample). In their study of Nakuru District, Obare et al (2003) found over 90% of farmers using fertilizer on maize. Nakuru District is also included in the Tegemeo sample, and we find that the proportion of households using fertilizer on maize in Nakuru varied between 83% and 91%, averaging 87% over the four years. Based on available corroborating evidence, we conclude that the findings reported in Tables 3 and 4 are comparable, and if anything may underestimate the extent of fertilizer use as compared to other studies.

4.2 Trends in Fertilizer Application Rates for Mono-cropped and Intercropped Maize Fields

Tables 7 and 8 present fertilizer application rates and doses per acre for different kinds of maize fields: pure stand maize fields, maize fields inter-cropped with less than 4 other crops, and maize fields intercropped with 4 or more other crops. Some interesting insights emerge. First, note that of the total maize area in the sample (2,260 acres), roughly two-thirds of this area was in maize fields intercropped with less than 4 other crops in 1997 (usually maize-bean), but over time, an increasingly higher proportion of maize area has been under the third category, maize fields intercropped with 4 or more other crops (Table 7). By 2006/07, 1,049 acres in the total nationwide sample were devoted to maize intercropped with 4 or more other crops (usually beans and/or other legumes, potatoes, and/or a horticultural crop), while 790 acres were to maize intercropped with less than 4 other crops, followed by only 473 acres under mono-crop maize. In both of the intercropped maize categories, the proportion of maize area under fertilization has risen dramatically (from 65% to 85% of the area with less than 4 other crops, and from 21% to 55% of the area with 4 or more other crops). By contrast, the percentage of area under maize pure stand receiving fertilizer has risen only slightly, from 74% in 1997 to 80% in 2007.

Table 7: Proportion of smallholder maize area fertilized, 1996/97 - 2006/07.

	% of maize area receiving fertilizer (total acres in sample)			
Category of maize field	**1996/97**	**1999/00**	**2003/04**	**2006/07**
Maize pure stand fields	74% (518)	73% (429)	76% (332)	80% (473)
Maize fields intercropped with < 4 other crops	63% (1 432)	71% (1 012)	70% (1 057)	85% (790)
Maize fields intercropped with > 4 other crops	21% (310)	53% (1 118)	49% (894)	55% (1 049)
All maize fields in sample	60% (2 260)	63% (2 560)	63% (2 283)	70% (2 312)

Table 8 presents trends over time in the intensity of fertilizer application on different categories of maize fields. The intensity of fertilizer application has increased dramatically on the intercropped fields. For example, on the maize fields intercropped with less than 4 other crops, mean dose rates rose from 60.9 kg/acre in 1997 to 74.2 kg/acre in 2007. When counting all fields, both fertilized and unfertilized fields in this category of maize field, mean application rates rose from 36.1 kg/acre in 1997 to 59.4 kg/acre in 2007 (Table 8, second row), a 65% increase. The dose rates on fertilized mono-cropped maize field were roughly constant over the 10-year period at just over 70kg per acre, but when accounting for the increased proportion of pure stand fields receiving fertilizer over time, the overall increase in application rates on maize pure stand fields has risen steadily over the decade, from 37.9 to 53.7kg per acre (Table 8, first row).

Table 8: Fertilizer use rates per acre of maize cultivated by smallholder farmers, and dose rates on fertilized maize fields, 1996/97, 1999/00, 2003/04, and 2006/07.

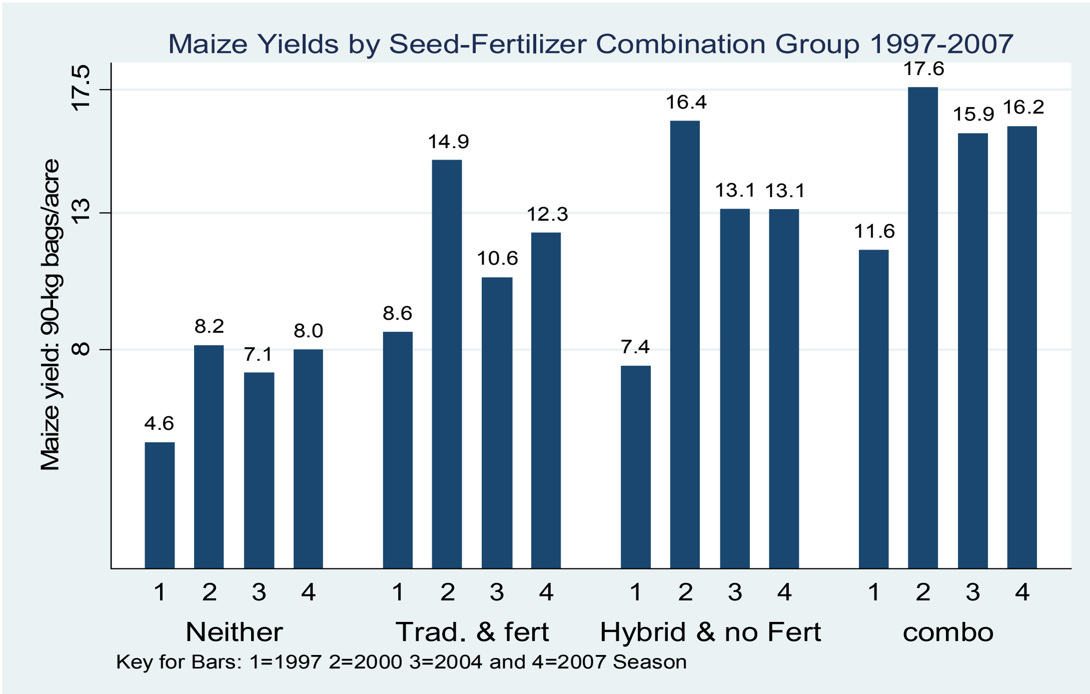
	Mean fertilizer use rates on maize fields, fertilized and unfertilized, kgs/acre (Mean dose rates on fertilized maize fields, kgs/acre)			
Category of maize field	**1996/07**	**1999/00**	**2003/04**	**2006/07**
Maize pure stand fields	37.9 (72.6)	36.4 (64.2)	49.3 (71.0)	53.7 (74.1)
Maize fields intercropped with < 4 other crops	36.1 (60.9)	37.5 (61.9)	46.7 (66.4)	59.4 (74.2)
Maize fields intercropped with > 4 other crops	13.5 (42.1)	30.7 (60.7)	32.2 (58.0)	33.3 (56.1)
All maize fields in sample	33.6 (61.3)	34.2 (61.6)	41.1 (64.1)	44.7 (63.5)

4.3 Maize Yields by Seed Use Type and Fertilizer Combination

To analyze the relationship between yields and seed-fertilizer combination, the sample was divided into four groups: (i) fields using use both hybrid seed maize and inorganic fertilizer; (ii) fields using hybrid seed but no fertilizer; (iii) fields using OPVs or traditional seed varieties with fertilizer, and (iv) fields using traditional seed and no fertilizer.

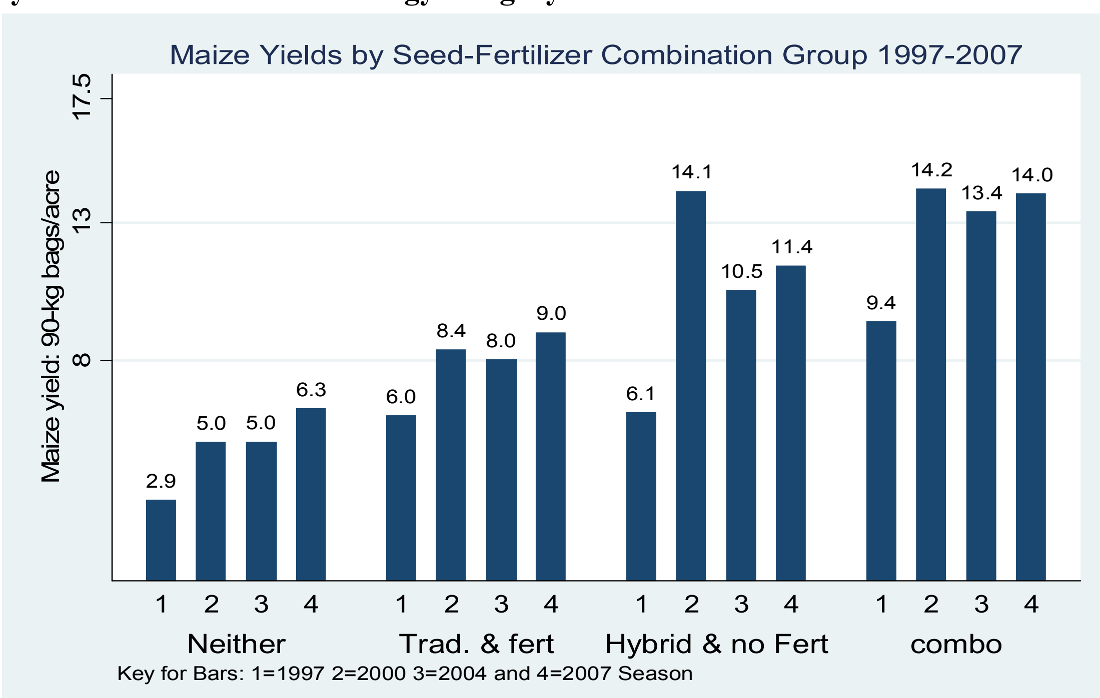
Given that the majority of maize fields in the sample are intercropped with other crops, it may be invalid to measure yields (a partial measure of land productivity) by counting the output of only one crop, especially if many other crops are harvested on the same area. For this reason, we present yields in two ways. We first count all crops harvested on the maize area, converting other crops to kgs of maize based on relative price ratios (Figure 2a). This provides a more complete picture of output per unit of land on area devoted to maize. In the second method, we ignore the production of other crops and count only the kgs of maize harvested on maize fields (Figure 2b).

Figure 2(a): Maize yields (converting other crops on intercropped maize fields to maize equivalents), by seed and fertilizer technology category.



Note: Yields used here are the maize-equivalent for mixed-crop fields where all each crop's production is converted to maize using the relative prices with maize as the numeraire.

Figure 2(b): Maize yields (not converting production of other crops into maize equivalents), by seed and fertilizer technology category



Several interesting observations come out of Figures 2a and 2b, which depict the yield outcomes for these different groups. First, maize yields generally appear to be increasing across the years from 1997 to 2007 for each of these four categories of maize fields. But the year 2000 stands out as recording the highest yields for each of these classes of technology use. Moreover, and most importantly, maize yields are consistently lowest among Category IV farms (those using neither hybrid seed nor fertilizer) and are highest among Category I farmers using both hybrid seed and fertilizer.

The findings in Figure 2a and 2b are surprisingly similar in the story they tell. The "*combo*" group (users of both hybrid seed and fertilizer) has higher yields relative to all the other combinations, while the "neither" group does poorest. The stark difference between the "*neither*" group and the 3 other groups for every year shows the effect of hybrid and fertilizer use on maize yields. The group that uses no fertilizer and plants traditional seed (neither) has an average yield of approximately 7 bags per acre of 90 kilograms each (when counting the other crops converted to maize equivalents) and only 5 bags per acre when counting only maize production. The groups that either use fertilizer with traditional seed or hybrid seed without applying fertilizer had an average yield of about 10 to 12 bags/acre (in maize equivalents, or 8 to 10 bags/acre when ignoring the other crops harvested). The group using both fertilizer and hybrid seed maize has the highest average yield of 15 bags /acre (13 when ignoring the other crops harvested). The yields for this latter group are twice as large as the group that uses neither hybrid nor fertilizer. Clearly, the adoption of a combination of appropriate technologies appears to be associated with smallholder productivity and therefore incomes which will raise food security status. However, as shown earlier, fertilizer use in Kenya is highest in the moderate- to high-potential areas, where maize yields are likely to be higher than in the semi-arid regions even without fertilizer. A multivariate analysis of the contribution of fertilizer to maize yield, holding geographic and other factors constant, is contained in Kibaara et al (2008).

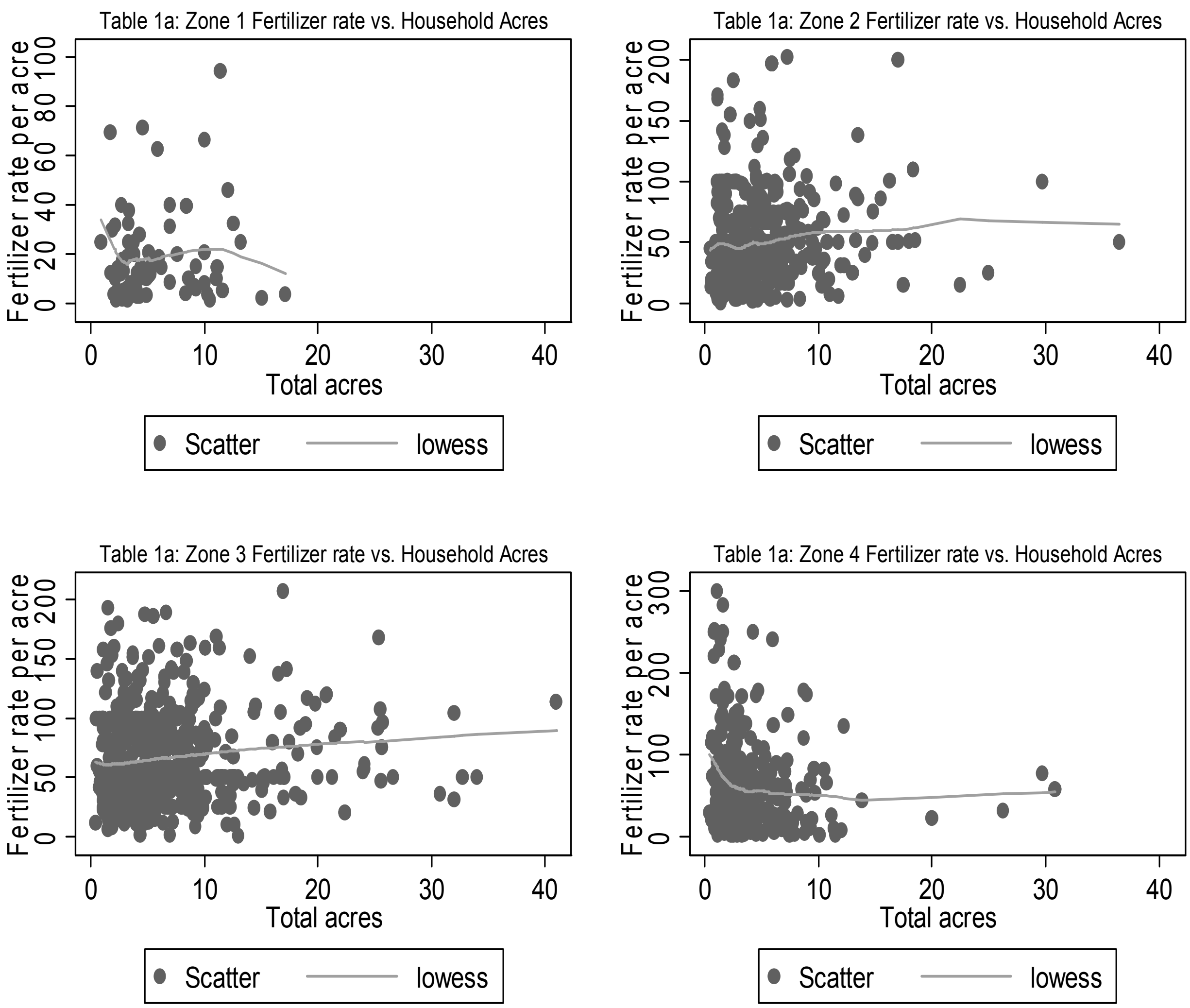
4.4 Relationship between Household Farm Size and Fertilizer Use Rates

A common worry is that the poor cannot afford to purchase fertilizer and that even if fertilizer use rates are increasing in Kenya, this may not have much of an impact on poverty if the poor cannot afford to purchase this key input. To assess this, we examine the relationship between farm size and fertilizer use. Landholding size is one of the most important indicators of wealth in Kenya. Across the 1997, 2000, and 2004 surveys, the majority of all households had 75% to 100% of the value of their total assets in land (Burke et al., 2006).[5]

Figure 3 shows Scatterplots of fertilizer use by farm size by region. Each dot represents a household in the sample. A bi-variate regression line was estimated for each figure, using Locally Weighted Smoothed Scatterplot regressions, or "lowess" (Cleveland, 1979). However, Figure 3 shows that for any given zone and among landholding size less than 20 acres, which accounts for nearly all of the sampled households, there is tremendous variation in the amount of fertilizer per acre used on maize. In Zone 1, for example, there appears to be a slight inverse relationship between farm size and intensity of fertilizer use, and mean dose rates in this semi-arid zone are in the range of 20-40 kg/acre throughout the farm size distribution. There is a slight positive relationship between farm size and fertilizer use intensity in the more productive Zones 2 and 3, but still the defining feature of Figure 3 is great variation in fertilizer use regardless of farm size, in every zone. Many small farms use fertilizer very intensively, and many other farms of similar size do not. Household characteristics associated with fertilizer use are discussed below. Differences in fertilizer use appear to be greatest across the zones, with the most productive Zone 3 achieving substantially higher mean use than in Zone 1, the semi-arid lowlands regions.

[5] When this study was undertaken, the 2007 survey had not been initiated.

Figure 3: Scatter plot of household acres cultivated vs. fertilizer use per acre (each dot is a household), by region



Notes:

Zone 1: Eastern and Western Lowlands (Kitui, Mwingi, Machakos, Makueni, Siaya, Kisumu);

Zone 2: Western Transitional and Western Highlands (Bungoma, lower elevation divisions in Kakamega, Kisii, and Vihiga)

Zone 3: High-potential maize zone (Trans-Nzoia, Uasin Gishu, Bomet, Nakuru, upper elevation divisions in Kakamega)

Zone 4: Central Highlands (Muranga, Nyeri, Meru, Laikipia).

Source: Tegemeo Institute/Egerton University household surveys, 1997, 2000, 2004, and 2007.

4.5 Relationship between Household Assets and Fertilizer Use

We now examine the relationship between fertilizer use and the total value of remaining household assets other than land. This includes livestock, small animals such as chickens, goats, and sheep, draft equipment such as ploughs and harrows, irrigation equipment, ox-carts, bicycles, cars, etc. Table 9 breaks fertilizer use and area under all crops across asset levels. After ranking all households in the sample according to their asset values, we then divided the sample into four asset quartiles. The lowest asset quartile has a mean value of agricultural assets of approximately 3,000 Kenya Shillings, the second quartile at around Ksh 12,000, the third at Ksh 25,000, and the highest group at Ksh 170,000 worth of assets. The asset values of the lowest group are a quarter of the second higher group, which in turn are half of that of the next group, which are one-sixth that of the top group – clearly there are great disparities in wealth in Kenya's smallholder farming areas.

Here, we start to find some systematic positive association between household assets and fertilizer use rates (Table 9). Fertilizer use rates increase across asset quartiles for each maize field category. Counting all fields cultivated, households in the top asset quartile used 42 kgs/acre on crops compared to 31kg/acre for the poorest asset quartile (a difference of 35%). Area under cultivation also increases even more dramatically across the asset quartiles. However, within each group, fertilizer rates decline as the number of mixed crops surpasses three per field.

Table 9: Field fertilizer use on maize and area under all crops by asset levels

	Asset Quartiles			
	1 (lowest)	2	3	4 (Highest)
Maize pure stand fields				
Assets (Kenya shillings)	3,303	12,262	27,259	235,820
Fertilizer dose rate (kgs/acre) *	65	60	66	79
Fertilizer application rate (kgs/acre) **	32	42	40	51
Total household area cropped (acres)	4.01	5.13	5.79	11.03
Maize mixed fields <4 crops				
Assets (Kenya shillings)	3,518	14,967	29,231	163,242
Fertilizer dose rate (kgs/acre) *	60	61	66	68
Fertilizer application rate (kgs/acre) **	33	41	46	46
Total household area cropped (acres)	3.79	4.10	5.29	6.00
Maize mixed fields >=4 crops				
Assets (Kenya shillings)	1,693	5,560	14,962	107,501
Fertilizer dose rate (kgs/acre) *	53	58	63	59
Fertilizer application rate (kgs/acre) **	24	30	33	32
Total household area cropped (acres)	4.10	4.93	6.33	4.75
All maize fields in sample				
Assets (Kenya shillings)	2,982	12,106	25,633	166,919
Fertilizer dose rate (kgs/acre) *	59	60	66	68
Fertilizer application rate (kgs/acre) **	31	38	42	42
Total household area cropped (acres)	3.91	4.47	5.60	6.45

Note: *For fields receiving fertilizer. **For all fields, including those not receiving any fertilizer.

4.6 Trend in Distance to Fertilizer Seller by Agro-Ecological Zones

One of the causes of increased fertilizer use in Kenya since the de-regulation of fertilizer trade in the early 1990s has been the improvement in market access to fertilizer which might be measured by the distance from the farm gate to the purchase point.

After the elimination of retail price controls, import licensing quotas, foreign exchange controls, and the phase-out of external fertilizer donation programs that disrupted commercial operations, Kenya has witnessed rapid investment in private fertilizer distribution networks, with over 10 importers, 500 wholesalers and 7,000 retailers now operating in the country (Ariga, Jayne, and Nyoro, 2006).

As a direct result of an increasingly dense network of fertilizer retailers operating in rural areas, the mean distance of small farmers to the nearest fertilizer retailer has declined from 7.4 km to 3.2 km between 1997 and 2007 (Table 10). This has greatly expanded small farmers' access to fertilizer, reduced their transactions costs, and thereby raised the profitability of using fertilizer, other factors held constant. Therefore, the reduction in distance travelled to access fertilizer is likely to be an important factor behind increased fertilizer use by smallholders as seen in the longitudinal survey data.

Table 10: Distance in kilometers to the nearest fertilizer seller

Zones		1997	2000	2004	2007	All Years
Zone 1						
	Fertilizer users	5.29	4.23	3.38	2.54	3.66
	Fertilizer non-users	13.73	8.94	6.28	3.56	8.68
	Both	12.67	8.37	5.64	3.32	7.81
Zone 2						
	Fertilizer users	4.45	2.63	2.00	2.91	2.9
	Fertilizer non-users	6.01	5.52	3.06	3.42	5.3
	Both	5.22	3.28	2.19	2.98	3.57
Zone 3						
	Fertilizer users	4.58	4.00	3.06	3.56	3.89
	Fertilizer non-users	6.89	2.91	3.40	4.11	5.02
	Both	4.99	3.88	3.11	3.62	4.05
Zone 4						
	Fertilizer users	2.45	1.39	1.31	1.25	1.78
	Fertilizer non-users	4.97	2.88	2.27	1.96	3.10
	Both	2.72	1.57	1.42	1.31	1.92
Zone 5						
	Fertilizer users	27.50	9.10	13.00	2.70	9.77
	Fertilizer non-users	23.93	19.62	11.14	5.67	16.57
	Both	24.03	19.23	11.21	5.29	16.21
Total						
	Fertilizer users	4.03	3.08	2.40	2.88	3.15
	Fertilizer non-users	11.98	9.39	6.07	3.92	8.64
	Both	7.38	5.65	3.70	3.22	5.26

Long distances to purchase point may imply higher transport and transaction costs in acquiring inputs which can inhibit use. The longest distances are generally in the drier Zone 5 (Kwale/Kilifi/Laikipia) and Zone 1 (see Note to Figure 3 for details of which areas fall in these zones). Central Highlands (Zone 4) has the lowest distances, a legacy of the cooperative movement organized around cash crops like coffee, tea, and horticulture.

Another noteworthy finding is that distances to motorable and tarmac roads have also declined dramatically over the 1997-2007 period (Kibaara et al., 2008). There is a significant decline in distances to a motorable road from an average of 1 km in 1997 to 2004 to 0.5 km in 2007. The reduction in distances to motorable road could be associated with investments in maintenance of feeder roads (graders, bridges, culvert, murram) in the rural areas following the introduction of the Constituency Development Fund (CDF). This is a decentralised fund introduced in 2003 where all the 210 constituencies are allocated 2.5% of the total government revenue. Analysis show that in 2005, road related projects at the constituency level accounted for 11% of the total constituency budget (authors' calculation from www.cdf.go.ke).

4.7 Trends in Fertilizer Trade Margins

Figures 4 and 5 plot trends in the c.i.f. price of DAP fertilizer ex Mombasa and the wholesale price of DAP in wholesale Nakuru markets in Western Kenya. Both price series are collected annually by the Ministry of Agriculture. DAP is the main planting basal fertilizer applied on maize in Kenya. The Mombasa prices are a reflection of world DAP prices plus port charges and duties, which were reduced in 2003. The difference between the Nakuru and Mombasa prices thus reflect domestic fertilizer marketing costs. Figure 4 shows the trends in nominal Ksh, while Figure 5 deflates these nominal prices by the consumer price index.

Figure 4 shows that between 1994 and 2002, DAP prices in Nakuru were basically flat even in nominal terms even though Mombasa prices roughly doubled over the same period. From 2002 to 2007, DAP prices rose by 25% in nominal terms in Nakuru and by about 30% at Mombasa. Between 2007 and 2008, both Nakuru and Mombasa prices have shot up dramatically due to soaring world prices.

However, by deflating prices by the CPI, we see how fertilizer prices have moved relative to the general price index of consumer goods and services in Kenya (Figure 5). While world prices, c.i.f. Mombasa have stayed roughly constant over the 1990 to 2007 period, real DAP prices at Nakuru have declined substantially, from roughly 3800 Ksh/50kg to 2000 Ksh/50kg in constant 2007 shillings. While both import prices and upcountry prices have shot up in 2008, in relation to the general price index, DAP prices in 2008 are in real terms about equal to where they stood in the mid-1990s, about the time that the substantial decline in marketing costs began. Prices of Urea show a similar pattern. Clearly there have been some positive developments in Kenya's fertilizer marketing system that have accounted for this cost reduction.

Figure 4: Price of DAP (Di-Ammonium Phosphate) in Mombasa and Nakuru (nominal shillings per 50kg bag)

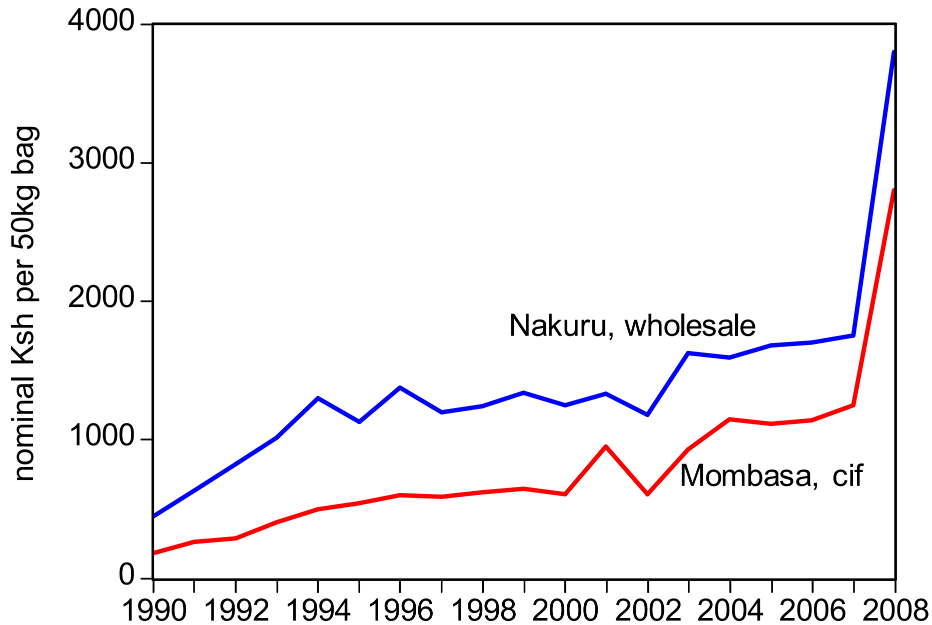
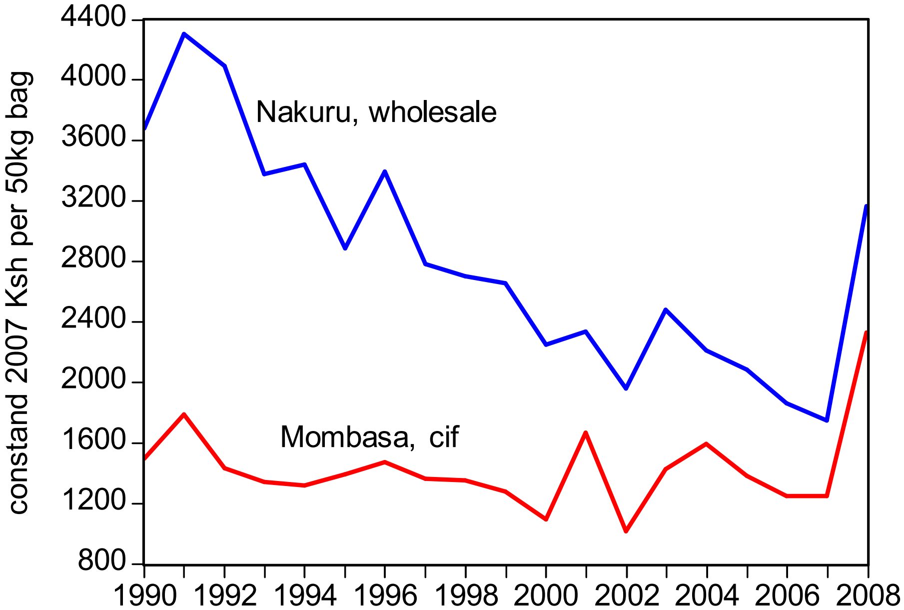


Figure 5: Price of DAP (Di-Ammonium Phosphate) in Mombasa and Nakuru (constant 2007 shillings per 50kg bag)



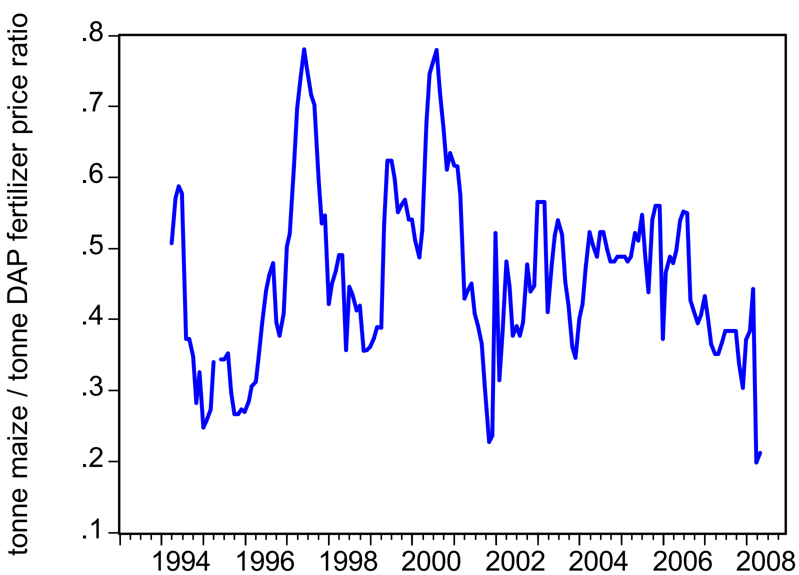
Note: Nakuru is a maize-producing area in the Rift Valley of Kenya, 400 miles (645 km) by road west of the port of Mombasa.

Source: Ministry of Agriculture. FMB weekly fertilizer reports for CIF Mombasa.

Recent interviews of key informants in Kenya's fertilizer sector undertaken for this study identify four factors responsible for the declining fertilizer marketing costs observed in Kenya: (i) exploiting the potential for cheaper backhaul transportation, taking greater advantage of trucks transporting cargo from Rwanda and Congo to the port of Mombasa; (ii) private importers are increasingly using international connections to source credit at lower interest and financing costs than are available in the domestic economy; (iii) mergers between local and international firms in which knowledge and economies of scope enable cost savings in local distribution; and (iv) increased competition among local importers and wholesalers given the expansion of firms engaged in fertilizer marketing since the early 1990s. In fact, it is likely that the fourth factor – increased competition – has stimulated firms to exploit the other cost-reducing innovations identified in order to maintain their market position. Intense competition has caused some shake-out in the fertilizer import stage, as firms that did not innovate quickly enough soon found themselves uncompetitive and lacking sufficient volume to continue in the business (2008 interviews of fertilizer industry representatives).

Notwithstanding these efficiency gains in Kenya's fertilizer marketing system, the world realities in 2008 have caused domestic fertilizer prices to be extremely costly relative to the price of maize. Figure 6 plots monthly wholesale maize to wholesale fertilizer price ratios per tonne at Nakuru. The higher the ratio, the more profitable and the greater the incentive to apply fertilizer on maize. While this ratio has historically ranged between 0.4 and 0.6, at the time of planting in 2008, it has plunged to below 0.25. The price of maize in Kenya has not risen nearly as dramatically as fertilizer. This, along with the civil disruptions earlier in 2008, is likely to disrupt the steady upward trend in total fertilizer use by smallholder farmers since the early 1990s. Initial projections are that only 275,000 tons of fertilizer were purchased this year by Kenyan farmers, compared with 451,000 tons in 2006/07. The conclusions section of the report considers alternative approaches to sustain fertilizer use and food security in Kenya.

Figure 6: Maize / fertilizer price ratios, Nakuru, Kenya, 1994-2008.



Notes: Price ratio defined as wholesale market price per metric tonne, Nakuru, divided by DAP, c.i.f. Nakuru per metric tonne, in nominal shillings.
Sources: Ministry of Agriculture Market Information Bureau, Nairobi.

Over 90% of up-country fertilizer distribution is done by road, with rail covering less than 10%; the direct cost of rail is cheaper by a third compared to road but rail costs are associated with delays and unreliable deliveries, thus forcing fertilizer wholesalers to use more expensive road transportation. Road transport is becoming increasingly expensive as road conditions deteriorate, competition for transport services have increased due to WFP food distribution, and increasing fuel costs which have doubled between 2006 and 2008. Fertilizer importers also indicate that waiting times at weighbridges along the road adds to fertilizer marketing costs. Recently the Prime Minister has ordered that the number of weigh-bridges and road blocks be reduced along the highways and the port of Mombasa to be open 24 hours in order to reduce costs and accelerate clearing cargo from the port (Daily Nation, August 2008). A serious rehabilitation of the Kenya railways could reduce fertilizer marketing costs further and thereby help offset the effects of higher world fertilizer prices over time.

According to a recent Ministry of Agriculture report (Sikobe and Ulare, 2008), increased fertilizer prices are mostly due to changed international market conditions, port handling costs, and transport and not collusion among importers (as far as a recent MoA report reveals and interviews carried out with importers for this study). The MoA estimates importer margins at about 7-8% and at the retail level at 3-4% due to increased competition.

5.0 Econometric Model Findings

5.1 Factors Affecting Household Fertilizer Use Decisions in the Low Potential Agro-Ecological Zones

The results from Probit, OLS, and Fixed Effects (FE) regressions on the decision to buy fertilizer or not to buy and the decision on fertilizer intensity per acre are shown in Table 11(a) for zones consisting of low potential areas. Since the proportion of households using fertilizer is relatively low in these predominantly semi-arid areas, we first estimate Probit models of the decision to purchase fertilizer, and then estimate OLS and Fixed Effects models on the sub-sample of fertilizer users. We construct four landholding size quartile categorical variables,[6] four

[6] We used this measure as a proxy for landholding size (which is missing for year 2000 panel survey)

household asset quartile variables,[7] dummies for four agro-ecological zones, five dummies of categories for education of household heads based on years at school, four dummies for maize seed type, five dummies for land tenure system types, and distance to fertilizer seller as the major explanatory variables of interest. For each of these categories we dropped one dummy to avoid perfect co-linearity. The advantage of using a dummy variable approach is that the relationship between a particular variable and fertilizer use may be non-linear. Even using a quadratic term may not accurately capture complex non-linear relationships, and with highly skewed distributions for variables like assets and landholding size, extreme values have a relatively large impact on estimated coefficients. The use of multiple dummy variables circumvents this problem.

The results from Probit and OLS on pooled data and Fixed Effects (FE) models are shown in Table 11a. In these zones (Zone 2=Coastal Lowlands, Zone 3=Eastern Lowlands, Zone 4=Western Lowlands, and Zone 5=Western Transitional) only 44% of the sample used fertilizer. Statistics on key variables of interest including number using fertilizer, asset values, acres, and proportion of sample under different categories of variables for this regression sample are provided in Table 11b.

It is noteworthy that some of the factors may have different signs or effects on the two decisions (participation and fertilizer intensity). Though the price of maize has a significant but extremely small negative effect on the probability of participating in the fertilizer market in the relatively low potential zones, the sign and magnitude are different for the decision on fertilizer intensities. This implies that for these zones, though higher prices for maize have practically no effect on households' decision to purchase fertilizer, a higher maize price does affect the amount of fertilizer purchased. A 10 percent increase in maize price is found to lead to a 11 percent increase in the intensity of fertilizer use for those purchasing the input, which amounts to roughly 6 kgs per acre on average.

The level of education category has a large and significant effect on the decision to purchase fertilizer. Households containing a member with more than 12 years of education have a 40

[7] Assets are defined as the aggregated value of livestock and other animals, ploughs, tractors, animal housing units, ox carts, bicycles, other farm transport equipment, pumps, irrigation equipment, wells, and vehicles.

percentage point greater likelihood of purchasing fertilizer compared to households with heads having between 1 to 4 years of education. Approximately 39% of those using fertilizer have more than nine years of education compared to only 20 % of those not using fertilizer with similar education levels (Table 11b).

Just like for education, farm size (acres) has a positive effect on participation (the probability increases by 14 percentage points moving from lowest farm size group to the middle two farm size quartiles). The probability of fertilizer purchase is not statistically different between the smallest 25 percent of farms and the largest 25 percent of farms in the lowland areas. Farm size also appears to have no effect on the level of intensity of fertilizer use in the low potential zones.

Though there is a positive relationship between household asset levels and intensity of fertilizer use, this is not significant. A simple t-test for differences between the means of asset values and acres cropped for fertilizer users and non-users is rejected, implying that in these low potential zones, fertilizer use is not related to differences in household wealth across the sample. The proportional distribution of asset values and acres cropped across quartiles for those using or not using fertilizer is fairly similar as shown in Table 11b.

Zonal dummies offer some insights into market participation trends across agro-ecological zones. We have dropped Zone 2 (coastal lowlands) as a base for comparing the other zones in Table 11(a). There is no significant differences in the probability of participation compared to Zone 4 (western lowlands covering Siaya and Kisumu districts) though intensities are higher. However, the probability of participation when compared to Zones 3 (Western Lowlands) and Zone 5 (Western Transitional) are higher by .38 and .60 respectively. Moving from Zone 2 to Zone 4 raises intensity by 18 kgs per acre; a log-linear specification (not included here) shows a more than 150% increase in intensity in Zones 3, 4, and 5 compared to Zone 2. Interacting distance to fertilizer seller with zonal dummies (not shown in Table) shows a negative relationship for all zones except for Zone 3 where it is insignificant, showing that distance to fertilizer sell point is inversely related to the decision to buy in most zones except in the High-Potential Maize Zone, where the rainfall and soils are favorable enough to generate strong effective demand for fertilizer even when households have to travel relatively far to purchase it.

Table 11(a): Probit regression on pooled data plus OLS and Fixed Effects on fertilizer users for low potential zones (Zones 2, 3, 4, 5)*

Model / dependent variable	Probit: 1=Purchased fertilizer for use on maize	OLS: Fertilizer use intensity (kgs /acre)	Fixed Effects: Fertilizer use intensity (kgs /acre)
CPI-Indexed lagged prices of maize (90-kg bag MoA data)	-0.000**	0.033***	-0.004
	(0.000)	(0.010)	(0.017)
CPI-Indexed price of DAP fertilizer (50-kg bags Tegemeo survey data)	-0.000	-0.009	-0.017**
	(0.000)	(0.005)	(0.007)
Acre: 2nd Quartile	0.140*	-12.490	7.617
	(0.070)	(8.162)	(11.980)
Acre: 3rd Quartile	0.147*	-3.004	1.542
	(0.067)	(8.013)	(11.035)
Acre: 4th Quartile	0.091	-4.782	-6.542
	(0.065)	(7.474)	(11.691)
Asset: 1st Quartile	0.060	-3.637	14.190*
	(0.046)	(5.794)	(6.835)
Asset: 2nd Quartile	0.033	-7.178	-0.895
	(0.044)	(4.477)	(6.185)
Asset: 3rd Quartile	-0.040	-0.876	-7.188
	(0.043)	(4.282)	(6.221)
Dummy zone=3 Eastern Lowlands	0.385***	-1.383	
	(0.074)	(12.428)	
Dummy zone=4 Western Lowlands	0.025	18.193*	
	(0.096)	(8.698)	
Dummy zone=5 Western Transition	0.600***	18.052	
	(0.067)	(20.222)	
Education head: None	0.001	14.269**	20.238
	(0.053)	(5.471)	(10.546)
Education head: 5 to 8 Years	0.049	8.682	23.188*
	(0.046)	(4.958)	(9.293)
Education head: 9 to 12 Years	0.234***	1.024	20.067
	(0.049)	(8.335)	(15.300)
Education head: Over 12 years	0.403***	-10.507	37.478*
	(0.055)	(12.232)	(19.006)
Seed type: Hybrid	-0.006	15.319**	9.595
	(0.057)	(4.800)	(9.741)

Model / dependent variable	Probit: 1=Purchased fertilizer for use on maize	OLS: Fertilizer use intensity (kgs /acre)	Fixed Effects: Fertilizer use intensity (kgs /acre)
Seed type: Retained hybrid	-0.288***	12.016	-23.269
	(0.058)	(10.407)	(19.234)
Seed type: Local seed	-0.235***	5.166	-27.360
	(0.051)	(8.182)	(16.108)
Distance to fertilizer seller: 1st nearest Quartile	0.135**	-28.645***	12.084
	(0.051)	(6.263)	(10.025)
Distance to fertilizer seller: 2nd nearest Quartile	0.112*	-27.113***	7.006
	(0.047)	(5.561)	(10.025)
Distance to fertilizer seller: 3rd nearest Quartile	0.131**	-25.589***	2.047
	(0.045)	(6.164)	(8.727)
Tenure; Own with title	-0.245***	25.499*	3.533
	(0.061)	(10.322)	(9.548)
Tenure; Own without title	-0.185**	25.022**	4.755
	(0.064)	(8.609)	(7.639)
Tenure; Owned by parents of user	-0.214**	18.951	-8.016
	(0.069)	(10.450)	(10.153)
Tenure: Communal ownership	-0.218	63.334***	-10.021
	(0.118)	(10.941)	(40.539)
Inverse Mills Ratio		40.782*	
		(17.470)	
Constant		-49.143*	173.422
		(23.373)	(104.222)
Number of observations	1,366	599	599
Adjusted R2	0.314	0.305	-0.547
note: *** p<.001, ** p<.01, * p<.05			

Note: Zone 2=Coastal Lowlands, Zone 3=Eastern Lowlands, Zone 4=Western Lowlands, and Zone 5=Western Transitional

Households planting hybrid or open pollinated varieties (OPV, the omitted dummy) seed maize, have a 25 percentage point higher probability of purchasing fertilizer than those planting retained hybrids or local seed maize. The OLS results indicate a 15 kg per acre increase in fertilizer use intensity for fields planted with hybrid seed compared to OPVs. i.e. hybrid seed maize growers use 15 kgs more per acre compared to OPV growers. From Table 11b, 64% of farmers using fertilizer plant hybrid seed maize while 58% of fertilizer non-users plant local seed maize in these zones. Clearly there is a correlation between hybrid seed and fertilizer use. We can conclude the decision to buy improved seed (hybrid and OPV) positively raises the probability of buying fertilizer too; farmers appear to be aware of some synergy between these technologies.

Table 11(b): Descriptive statistics for fertilizer users and non-users in the low-potential zones sample, pooled statistics for 1997, 2000, 2004, and 2007

Statistic	Users (n=599)	Non-users (n=767)
Education head: None	13%	21%
Education head: 1 to 4 Years	18%	21%
Education head: 5 to 8 Years	30%	38%
Education head: 9 to 12 Years	30%	16%
Education head: Over 12 years	9%	4%
Seed type: Hybrid	64%	25%
Seed type: Retained hybrid	10%	16%
Seed type: OPV	1%	1%
Seed type: Local seed	25%	58%
Acre: 1st Quartile	6%	9%
Acre: 2nd Quartile	22%	22%
Acre: 3rd Quartile	30%	26%
Acre: 4th Quartile	42%	43%
Distance to fertilizer seller: 1st nearest Quartile	24%	11%
Distance to fertilizer seller: 2nd nearest Quartile	26%	26%
Distance to fertilizer seller: 3rd nearest Quartile	31%	29%
Distance to fertilizer seller 4th nearest Quartile	19%	34%
Asset: 1st Quartile	18%	23%
Asset: 2nd Quartile	23%	20%
Asset: 3rd Quartile	21%	24%
Asset: 4th Quartile	38%	33%
Tenure; Own with title	38%	43%
Tenure; Own without title	44%	45%
Tenure; Owned by parents of user	9%	8%
Tenure: Communal ownership	0%	1%
Tenure: Rented for fee	9%	3%
Distance to fertilizer seller (kilometers):		
Mean	3.4	6.9
25th percentile	1.5	2.0
50th percentile (median)	2.5	3.5
75th percentile	4.0	7.0

Note: The descriptive statistics for this sub-sample of households in low-potential zones is the sub-sample used in the estimation of models in Table 11a.

The Tegemeo data shows that there has been a major reduction between 1997 and 2007 in the mean distance from households to the nearest fertilizer seller. This is consistent with IFDC's finding that there has been major new investment in fertilizer stockists in rural Kenya during this period. The model results in Table 11a indicate that the household decision to participate in the fertilizer market and the level of intensity are both related to the distance to the nearest fertilizer stockist. For the low potential areas, moving from the furthest 4th quartile (omitted dummy from regression) to the group in closest proximity to fertilizer stockists raises the probability of participation by more than 13 percentage points. Households in the first three distance quartiles (from zero to four kms) have roughly the same probability of purchasing fertilizer, so the impact of distance on access appears to take hold at distances greater than four kms. The fixed effects model results show no significant differences in fertilizer use intensities across distances to seller. This implies that though the decision to participate in the fertilizer market is dependent on distance to fertilizer seller, how much to apply per acre does not. The OLS pooled results, however, indicate the unexpected finding that households further away from fertilizer stockists tend to purchase greater quantities, other factors constant. Therefore, while proximity to the nearest stockist tends to positively influence farmers' decisions to purchase fertilizer, the amounts purchased appear to be inversely related to proximity. Overall however, and as seen in Table 11b, the fertilizer users in the low-potential areas are on average clearly closer to fertilizer stockists than the non-users.

The land tenure relationships offer an interesting view of how the type of tenure affects the probability of participation and level of fertilizer intensity. Nine percent of fertilizer users rent land for a fee while three percent of those not using fertilizer rent land for a fee (Table 11b). In the low potential areas, the probability of purchasing fertilizer is higher for renters than those who own land with or without title (by 24 and 18 percentage points, respectively) as well as for those who use their parents' land (by 21 percentage points). One possible explanation is that renting puts pressure on the renter to maximize returns in order to recoup their costs including the risk of losing use of the land to the landlord or some other third party. But once they decide to buy fertilizer, renters are probably faced by other limiting factors that force them to apply less fertilizer per acre compared to similar renters in high potential zones (Section 5.2). However, the levels of intensity in fertilizer use are not different across these land tenure types from the FE regression. However, the OLS regression indicates higher intensities when moving from renter types to the other types of tenure. It is also important to note that land title in Kenya is not an iron-clad safe instrument of property ownership. It is widely believed that it is possible to have more than one person having title to the same piece of land. When coupled with a weak legal/judicial land dispute adjudication system, multiple land titles create uncertainty which hinders long-term investments in land.

5.2 Factors Affecting Household Fertilizer Use Decisions in High Potential Areas

We now look at the three relatively high-potential zones where over 90% of the households use inorganic fertilizer on maize. These three zones (Zone 6=High Potential Maize Zone; Zone 7=Western Highlands, and Zone 8=Central Highlands) account for over two-thirds of the total sample in the nationwide Tegemeo Institute surveys. Consequently, for these zones we did not include a probit analysis of the decision to participate in the fertilizer market because there is not a censored problem or pile-up of zero values. The results from pooled OLS and Fixed Effects (FE) models on the quantity of fertilizer used per acre of maize crop are shown in Table12a. Statistics on key variables of interest including number using fertilizer, asset values, acres, and proportion of sample under different categories of variables for this regression sample are provided in Table 12b.

Table 12a presents OLS and FE results for two different specifications to examine the robustness of results to alternative ways of accounting for maize and fertilizer prices. The first specification includes maize prices from the six-month period prior to planting (a simple naïve expectations specification) and DAP fertilizer prices as separate variables (columns A and B). The other specification uses these same variables as a maize-DAP fertilizer price ratio (columns C and D).

From models A and B in Table 12a, the price of maize taken alone has no discernible effect on fertilizer intensity. However, the ratio of maize to DAP fertilizer price has a positive and significant impact on fertilizer intensity. Increasing this ratio by one raises fertilizer intensity by 15 and 20 kgs per acre for OLS and FE results (C and D) respectively. A test for differences in this ratio between users and non-users of fertilizer is rejected indicating that both groups face similar maize-fertilizer price conditions on average. The elasticity estimate for the change can be interpreted as a 3 percent change in fertilizer intensity per acre given a 10 percent change in the price ratio i.e. about 2 kgs per acre using the average intensity for the group. This is significantly less than what we estimated for the low potential areas in Section 5.1 for a change in maize prices.

As shown in Table 12a, fertilizer intensity is negatively related to the size of the farm, decreasing with farm size for all FE models while decreasing up to some level and then tapering off for OLS models (A and C). Moving from the group with the lowest total acres under all crops to the third group implies a decrease in fertilizer intensity of 13 kilograms per acre of maize for both OLS and FE models. Moving from the third largest group to the largest farm cultivation group increases the intensity of fertilizer on maize by 2 kgs per acre (approximately 14-12=2 kgs) using FE model (B and D), while the OLS models indicate an increase of 13 kgs per acre. This indicates a non-linear relationship between fertilizer intensity and farm size with highest intensity at low farm sizes, followed by a decline and then increase again after some farm size threshold. Overall, the results indicate that the smallest farms use the most fertilizer per acre of maize.

The level of education category has a significant effect on fertilizer use rates in the high potential zones. Using OLS results, those in the highest education level category (more than 12 years in school) on average apply 13 more kgs per acre than all the other household education categories. The FE regression shows no significant differences in fertilizer use rates with education. Approximately 33% of those using fertilizer have more than nine years of education compared to only 21 % of those not using fertilizer with similar education levels (Table 11b).

Perhaps surprisingly, none of the four models show any significant relationship between household assets/wealth and the quantity of fertilizer applied per acre of maize. The mean asset value for fertilizer non-users is nearly two-fifths that of fertilizer users.

Fertilizer use rates vary across these relatively high-potential zones. We have dropped Zone 7 (Western Highlands) as a base for comparing the other zones in Table 12a. According to the

OLS results, farms in the High-Potential Maize Zone use an average of 15-18 kgs more fertilizer per acre of maize than farms in the Western Highlands. Farms in Central Highlands also tend to use fertilizer on maize more intensively than in the Western Highlands, by 8-12 kgs per acre. Interacting distance to fertilizer seller with zonal dummies (not shown in Table) shows a negative relationship for all zones except for Zone 3 where it is insignificant, showing that distance to the nearest fertilizer stockist is inversely related to the decision to buy (as expected) in most zones except in the HPMZ, where the rainfall and soils are favorable enough to generate strong effective demand for fertilizer even when households have to travel relatively far to purchase it.

Table 12(a): OLS and Fixed Effects on fertilizer intensity for high potential zones (Zones 6, 7, 8)*

Model type	(A) Pooled OLS	(B) Fixed Effects	(C) Pooled OLS	(d) Fixed Effects
Dependent variable	Fertilizer rate (kgs/acre)	Fertilizer rate (kgs/acre)	Fertilizer rate (kgs/acre)	Fertilizer rate (kgs/acre)
CPI-Indexed lagged maize price (90-kg bag)	-0.01	0.01	-	-
	(0.01)	(0.01)	-	-
CPI-Indexed price of DAP fertilizer (50-kg bags: Tegemeo survey data)	-0.01***	-0.005*	-	-
	(0.00)	(0.00)	-	-
Price ratio (Maize/DAP)			15.44*	19.55*
			(7.00)	(7.89)
Dummy zone=6 High-Potential Maize Zone	15.27***		18.41***	
	(2.55)		(2.40)	
Dummy zone=8 Central Highlands	12.88***		8.60**	
	(3.63)		(3.29)	
Farm size: 2nd Quartile	-11.36***	-9.49*	-11.18***	-9.41*
	(3.12)	(4.23)	(3.14)	(4.24)
Farm size: 3rd Quartile	-13.05***	-13.92***	-12.71***	-13.77***
	(3.04)	(4.10)	(3.05)	(4.11)
Farm size: 4th Quartile	-4.88	-11.80**	-4.56	-11.69*
	(3.16)	(4.57)	(3.17)	(4.57)
Household assets: 1st Quartile	0.22	-0.08	0.16	-0.27

Model type	(A) Pooled OLS	(B) Fixed Effects	(C) Pooled OLS	(d) Fixed Effects
Dependent variable	Fertilizer rate (kgs/acre)	Fertilizer rate (kgs/acre)	Fertilizer rate (kgs/acre)	Fertilizer rate (kgs/acre)
	(2.98)	(3.34)	(3.00)	(3.33)
Household assets: 2nd Quartile	-3.79	-2.38	-3.88	-2.44
	(2.51)	(3.16)	(2.52)	(3.16)
Household assets: 3rd Quartile	2.02	0.79	1.61	0.74
	(2.82)	(3.31)	(2.83)	(3.32)
Education head: None	-2.57	-0.44	-2.49	-0.35
	(3.38)	(4.33)	(3.38)	(4.32)
Education head: 5 to 8 Years	-1.20	1.38	-0.81	1.50
	(3.05)	(3.71)	(3.05)	(3.71)
Education head: 9 to 12 Years	4.91	-0.76	5.18	-0.70
	(3.04)	(4.79)	(3.04)	(4.77)
Education head: Over 12 years	12.84**	-0.457	12.51**	-0.388
	(4.29)	(6.25)	(4.32)	(6.23)
Seed type: Hybrid	-1.40	12.05	-3.74	12.16
	(15.17)	(14.79)	(15.01)	(14.79)
Seed type: Retained hybrid	-19.40	-3.75	-20.50	-3.56
	(15.82)	(16.34)	(15.68)	(16.34)
Seed Type: local seed	-29.13	-8.45	-30.14*	-8.35
	(15.29)	(14.87)	(15.15)	(14.87)
Distance to fertilizer seller: 1st nearest Quartile	-8.54**	-1.80	-8.83**	-1.45
	(3.05)	(3.29)	(3.06)	(3.28)
Distance to fertilizer seller: 2nd nearest Quartile	-5.03	2.77	-5.41	2.94
	(3.04)	(3.11)	(3.03)	(3.09)
Distance to fertilizer seller: 3rd nearest Quartile	-3.57	-0.15	-4.09	-0.12
	(3.10)	(3.17)	(3.11)	(3.16)
Tenure; Own with title	-8.28**	-1.88	-8.49**	-1.90
	(3.11)	(3.50)	(3.14)	(3.50)
Tenure; Own without title	-13.74***	-3.05	-14.18***	-2.94
	(3.24)	(3.40)	(3.25)	(3.41)
Tenure; Owned by parents of user	-12.28*	-5.20	-14.37**	-5.18
	(5.47)	(5.62)	(5.52)	(5.62)
Tenure: Communal ownership	-7.73	-3.76	-9.03	-3.75
	(16.62)	(11.20)	(16.81)	(11.15)
Soil: % of clay=35	36.03***		38.18***	
	(5.86)		(5.86)	

Model type	(A) Pooled OLS	(B) Fixed Effects	(C) Pooled OLS	(d) Fixed Effects
Dependent variable	Fertilizer rate (kgs/acre)	Fertilizer rate (kgs/acre)	Fertilizer rate (kgs/acre)	Fertilizer rate (kgs/acre)
Soil: % of clay=50	-3.69		-2.85	
	(3.94)		(3.91)	
Soil: % of clay =58	15.89***		16.47***	
	(3.59)		(3.58)	
Soil: % of clay =70	32.94***		34.45***	
	(3.236)		(3.206)	
Constant	82.29***	68.19***	40.37*	51.92**
	(18.81)	(18.37)	(16.85)	(16.16)
Number of observations	2,698	2,698	2,698	2,698
Adjusted R^2	0.134	0.020	0.129	0.021
note: *** p<.001, ** p<.01, * p<.05				

Note: The zones covered here include 6 (HPMZ), 7(Western Highlands), and 8 (Central Highlands).
Standard errors are in parentheses: * Significant at 5%; ** Significant at 1%

Households planting Open Pollinated Variety (OPV, the omitted dummy) seed maize have higher intensity (30 kgs per acre) compared to those planting local seed. However comparing with other seed types (hybrid and retained seed) for all model results indicates no significant differences in intensity between these seed types and OPVs. From Table 12b, 87% of the households using fertilizer plant hybrid seed maize compared to 53% of fertilizer non-users in these high potential zones.

Table 12(b): Statistics from regression sample of Table 12(a): Proportions of observations in each category of fertilizer users and non-users for high potential zones (see notes below the table for interpretation)

Statistic	Users: n=2473	Non-Users: n=225
Education head: None	17%	21%
Education head: 1 to 4 Years	18%	22%
Education head: 5 to 8 Years	32%	36%
Education head: 9 to 12 Years	24%	12%
Education head: Over 12 years	9%	9%
Seed type: Hybrid	87%	53%
Seed type: Retained hybrid	3%	5%
Seed type: OPV	1%	1%

Statistic	**Users: n=2473**	**Non-Users: n=225**
Seed type: Local seed	9%	41%
Acre:Ist Quartile	22%	32%
Acre: 2nd Quartile	26%	24%
Acre: 3rd Quartile	25%	24%
Acre: 4th Quartile	27%	2%
Distance to fertilizer seller: 1st nearest Quartile	38%	33%
Distance to fertilizer seller: 2nd nearest Quartile	29%	28%
Distance to fertilizer seller: 3rd nearest Quartile	18%	19%
Distance to fertilizer seller: 4th nearest Quartile	15%	2%
Asset: 1st Quartile	17%	21%
Asset: 2nd Quartile	21%	16%
Asset: 3rd Quartile	21%	2%
Asset: 4th Quartile	41%	43%
Tenure; Own with title	53%	51%
Tenure; Own without title	27%	32%
Tenure; Owned by parents of user	7%	8%
Tenure: Communal ownership	0%	3%
Tenure: Rented for fee	13%	6%
Distance to nearest fertilizer seller (Kilometers)		
Mean	2.8	3.2
P25	1.0	1.0
P50	2.0	2.0
P75	3.0	4.0
Farm size(acres cropped)		
Mean	5.4	3.9
P25	2.1	1.7
P50	3.5	2.9
P75	5.9	4.6
Value of household assets (Kenya shillings)		
Mean	49962	19705
P25	900	150
P50	5240	3000
P75	24000	17000

Note: The descriptive statistics for this sub-sample of households in high-potential zones is the sub-sample used in the estimation of models in Table 12a, accounting for roughly 69% of the households nationwide Tegemeo sample.

Just like in Section 5.1 the effect of distance to nearest fertilizer seller is analyzed here as well. The results from the FE regression show no significant differences in fertilizer intensity between groups based on how far they are from the seller. Though OLS results follow similar trends, one result indicates a decrease in intensification from the furthest group moving to the closest group, which is counter-intuitive. The FE results are appropriate in this case considering that these high potential regions are covered with one of the densest road network system in the country compared to low potential zones discussed in Section 5.1. As shown in Table 12b, over 75% of the households reside less than 5.9 kms from the nearest fertilizer stockist among users (and less than 4.6 kms from the nearest stockist among non-users). Given these relatively short distances and the dense network of rural stockists in these areas, distance to fertilizer seller appears to not be a big factor affecting fertilizer use in these high-potential zones. Fertilizer appears to be profitable and worth the effort to acquire even for the relatively remote households, given that over 90% of the households in these zones are purchasing fertilizer already.

The land tenure relationships provide some insights into how tenure type affects the level of fertilizer intensity. Thirteen percent of fertilizer users rent land for a fee while six percent of those not using fertilizer rent land for a fee (Table 12(b)). The levels of intensity in fertilizer use are not different across these land tenure types from the FE regression. However, the OLS regression indicates lower intensities when moving from renter types to the other types of tenure, which is the opposite result compared to the low potential zones in Section 5.1 above. One possible explanation is that renting puts pressure on the renter to maximize returns in order to recoup their costs including the risk of losing use of the land to the landlord or some other third party.

6.0 Summary and Policy Implications

This study has so far addressed three major issues. First, using nationwide household panel data from four surveys between 1997 and 2007, we examine trends in fertilizer use on maize by smallholder maize growers. Since the survey is a balanced nationwide panel of 1,260 households, the results provide a fairly reliable indicator of the changes in fertilizer use patterns over time, although the survey is not strictly nationally representative. There are seven main findings from examination of this first objective:

1. The percentage of sampled smallholders using fertilizer on maize has increased from 56% in 1996 to 70% in 2007.

2. Fertilizer application rates (which include all maize fields regardless of whether they received fertilizer or not) rose from 34kgs/acre in 1997 to 45kgs/acre in 2007, a 32% increase.

3. Fertilizer dose rates on maize (which include all maize fields receiving fertilizer) have increased only slightly, from 61kg/acre in 1997 to 63kg/acre in 2007.

4. There are great variations regionally in fertilizer use on maize. Over 90% of smallholders use fertilizer on maize in three of the broad zones surveyed: the High Potential Maize Zone; Western Highlands, and Central Highlands. Fertilizer use is low and barely rising in most of the semi-arid regions (Coastal Lowlands, Western Lowlands, and the Marginal Rain Shadow). However, fertilizer use has risen impressively in the medium-potential Eastern Lowlands and Western Transitional Zones, where the percentage of households using fertilizer on maize has risen from 21% and 39%, respectively, in 1997 to 43% and 81% in 2007.

5. While the total area under maize has remained largely constant over the decade, maize yields have increased quite impressively over the 1997-2007 period, which is correlated with the rise in fertilizer use. Paying attention to the different types of maize production technologies and maize cultivation techniques is important to carefully control for confounding factors when examining trends in maize yields in Kenya. After stratifying between hybrid seed vs. non-hybrid users, and between maize intercrop vs. monocrop fields, we find that maize yields of all types of field has risen over time, which reflects the influence of many factors in addition to fertilizer use.

6. There has been a relative shift over time in the proportion of maize area under monocrop to intercrop, and increasing numbers of crops grown with maize on intercropped fields.

Fertilizer use has increased especially rapidly on the intercropped fields, and less so on monocropped fields.

7. Fertilizer marketing costs have declined substantially in constant shillings between the mid 1990s and 2007. Interviews of key informants in Kenya's fertilizer sector identified four factors responsible for the declining fertilizer marketing costs observed in Kenya: (i) exploiting the potential for cheaper backhaul transportation, taking greater advantage of trucks transporting cargo from Rwanda and Congo to the port of Mombasa; (ii) private importers are increasingly using international connections to source credit at lower interest and financing costs than are available in the domestic economy; (iii) mergers between local and international firms in which knowledge and economies of scope enable cost savings in local distribution; and (iv) increased competition among local importers and wholesalers given the expansion in the number of firms engaged in fertilizer marketing since the early 1990s. It is likely that the fourth factor – increased competition – has to some extent stimulated firms to exploit the other cost-reducing innovations identified in order to maintain their market position.

The second objective of the study was to compare the aforementioned findings about the proportion of smallholder households purchasing fertilizer with estimates based on other analyses during the same general time period. Based on three other studies that could be found covering a sub-set of the same districts as in the Tegemeo survey (Rockefeller Foundation, 2007, Obare et al., 2003, Marenya and Barrett, 2008), we find that the Tegemeo survey estimates are comparable and in some case lower than estimates of fertilizer purchase and dose rates of other studies. The rise in smallholder use of fertilizer as seen in the Tegemeo survey data is also consistent with official Ministry of Agriculture figures (shown in Figure 1) indicating that total fertilizer consumption in Kenya has risen 65% between 1997 and 2007.

Third, we examine the association between household fertilizer use and indicators of welfare such as wealth and landholding size. The study estimates alternative probit, OLS, and Fixed Effects models applied to household survey data to identify the main household and community characteristics associated with fertilizer purchases. The model results provide three general insights:

1. The dominant factor influencing smallholder households' decisions to use fertilizer on maize is location. Use rates are much higher in areas where main season rainfall is relatively high and stable than they are in the drier areas. Fertilizer use appears to be highly risky in many of the semi-arid regions, and its role in contributing to poverty alleviation and food security is likely to be limited by these environmental factors unless accompanied by other actions to improve soil organic matter and moisture (Marenya and Barrett, 2008).

2. Within a given agro-ecological zone, the decision of households to purchase fertilizer is slightly related to farm size, and unrelated to household wealth. In relatively productive areas, the proportion of poor and relatively wealthy households applying fertilizer on maize is similar. In risky environments, a relatively small proportion of poor and wealthy households apply fertilizer on maize. Among households that do apply fertilizer, the quantities applied are positively and significantly related to farm size.

3. Distance to the nearest fertilizer retailer has an important influence on households' decision to purchase fertilizer in the relatively low-potential areas. But once the decision to buy has been made, distance has very little influence on the quantity of fertilizer purchased. Since the liberalization of the fertilizer market in the early 1990s, there has been massive new entry and investment in fertilizer wholesaling and retailing, with the IFDC estimating over 500 wholesalers and 7,000 retailers operating in the country. This has led to a more dense network of rural stockists and a major reduction in the distance between farms and fertilizer stockists, which has contributed to the impressive growth in fertilizer use by Kenyan smallholders from the early 1990s to 2007. However, in the high-potential zones, fertilizer use appears to be largest unrelated to distance, although it bears repeating that almost all households in the high-potential zones are relatively close to fertilizer stockists, with more than 90% of the households being within 8.8kms of a stockist in 2007.

However, in 2008, the positive trends in fertilizer use by Kenyan farmers have been partially reversed by both civil disruption and the unprecedented surge in world fertilizer prices. Early 2008 witnessed the destruction of quite a bit of physical infrastructure in western Kenya (e.g., petrol stations and grain storage) as well as the closing of many input supply stores. Moreover, the incentives to use fertilizer in Kenya have been adversely affected by world events as maize/fertilizer price ratios have plunged to their lowest level in at least 18 years. While farmers may not stop using fertilizer completely, they are at least likely to apply less of it until maize-fertilizer price ratios rebound.

This brings us to our fourth and last objective, which is to consider alternative policy strategies for maintaining smallholders' access to fertilizer in the current context of substantially higher world fertilizer prices. There are two clear options which pose little cost and should be actively pursued. First, focus on identifying way to reduce the costs of supplying fertilizer to farmers, and second, focus on raising the efficiency of fertilizer use. Both of these general strategies will help to offset the impact of higher world fertilizer prices. Specific examples for consideration include:

1. *Consider changes in government roles that could reduce fertilizer distribution costs.* For example, because of frequent delays in offloading of commodities at the port of Mombasa, it is difficult to arrange for transport for upcountry fertilizer distribution which coincide when the shipment is fully offloaded at the port. Because of this coordination problem, fertilizer importers have invested in storage facilities near the port, where fertilizer can be temporarily stored to wait until trucks arrive for loading and upcountry distribution. These investments make sense if the delays and inefficiency at the port of Mombasa is taken as given. However, if procedures for streamlining the efficiency of off-loading at the port could be achieved (e.g., through privatization of stevedoring services and issuing performance contracts, or devolving wider management of port operations to professional firms), then it would be possible for fertilizer importing firms to avoid both demurrage charges and redundant storage charges near the port by achieving greater certainty about the time of full offloading. These

reductions in fertilizer marketing costs under a competitive marketing environment would then be passed along in the form of lower farm-gate prices.[8]

2. *Reducing transactions costs associated with VAT and port operations:* Currently fertilizer, as well as most other farm inputs, is zero-rated with respect to import duties. This means that no duty is charged on fertilizers, although at least up till 2007, VAT on related services was still levied. VAT is charged, for example, on transport and services like bagging at the port of Mombasa. Although VAT is supposed to be refunded, the process is lengthy and is a source of continuing frustration for market participants. In addition, the port handling charges coupled with Kenya Bureau of Standards (KEBS) charges and other taxes account for 17% of CIF (Gitonga). Port fees, levies and accessorial charges need to rationalized and aggregated. In addition, the numerous documentation procedures need to be reduced and some of these services possibly be provided through the electronic means. Interviews with key informants in the fertilizer industry have identified numerous other potential sources of cost savings, many of which require action on the part of government to improve efficiency.

3. *Investing in the eroded rail, road, and port infrastructure* would reduce distribution costs. The farm-gate price of fertilizer in Western Kenya is roughly twice as high as the landed cost at Mombasa, and transport costs are the major component of this cost difference. High farm-gate prices of fertilizer restrict demand for its use and depress agricultural productivity. Hence efforts to improve the efficiency of port costs and upland shipping would bring major economy-wide benefits.

4. *Tailoring fertilizer packages to local demand conditions* would increase demand from smaller farmers who require and are able to purchase only small packets. Repackaging of fertilizers from 50 kg into 25 kg, 10 kg, 2 kg and 1 kg packets is increasingly taking place, but this is sometimes associated with fertilizer adulteration and counterfeit products. While adulteration and sales of counterfeit products continues to be a problem, these are often isolated events,

[8] Some efficiency improvements in Mombasa port operations have recently been implemented, and more comprehensive reforms are currently under consideration.

rather than a well organized activity (GDS, 2005, p. 71).[9] Part of the wide fluctuations in the nitrogen and phosphorous concentration in fertilizers can be accounted for by the absence of effective measurement and calibration facilities. In this context, Kenya Plant Health Inspectorate Service should become more effective in monitoring and controlling adulteration and counterfeit products, as well as intensifying farmer and stockist awareness program to help protect farmers from sub-standard products.

5. *Raise fertilizer response rates through agronomic training of farmers.* The profitability of fertilizer use could be enhanced by improving the aggregate crop yield response rates to fertilizer application. This requires making complementary investments in training for farmers on agronomic practices, soil fertility, and water management and efficient use of fertilizer, and investing in crop science to generate more fertilizer-responsive seeds.[10] Survey data commonly indicate that the contribution of fertilizer to food grain yields varies tremendously across farms even within the same villages. Simply bringing fertilizer response rates among the bottom half of the distribution up to the mean would contribute substantially to household and national food security (Nyoro, et al., 2004).

6. Finally, *producer organizations, despite their poor track record, will increasingly be crucial for rural income growth*. Assuming that the management and politicization of producer organizations/cooperatives could be minimized, they might afford an important pathway for smallholders to use much higher levels of input use and achieve better production and marketing practices than the current separate and uncoordinated stages in the supply value chains. The role of independent producer groups would be to reduce the transaction costs and risks of private marketing firms dealing with farmers and developing a production base through the transfer of credit, inputs, and know-how. Programs such as the Farm Inputs Promotion and KMDP/CGA farmer training programs are the examples of successful work with groups to combine farm extension knowledge, supply chain development, and supply of fertilizer by small dealers.

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[9] According to GDS, nearly 3-5 percent of repackaged fertilizers are sold using counterfeit labels and packages. Specifically, fake brand name labels are used to sell inferior quality fertilizers.

[10] Research indicates that the highest crop yield response is obtained when improved seed, fertilizer and good agronomic practices are combined (Heinrich, 2004; Marenya and Barrett, 2008). In some areas, improved management practices may have greater impact on yields than fertilizer alone (Haggblade and Tembo, 2003).

While all of these measures can contribute to increased fertilizer use, none is likely to prove effective in isolation. Policy makers should, therefore, select strategic combinations of supply- and demand-side measures to allow supply and demand to grow in parallel – strengthening the basis for viable private sector-led commercial fertilizer markets.

The final question is about the role of fertilizer subsidies. The greatest scope for subsidies to promote fertilizer use is in the areas where fertilizer use is relatively low. According to the Tegemeo survey finding, this is in semi-arid areas (Coastal Lowlands, Eastern Lowlands, and Western Lowlands). The distribution of subsidized fertilizer in these areas is likely to contribute positively to fertilizer use, but its contribution to yields and smallholder incomes are likely to be limited, because of the environmental riskiness and low response rates in many of these areas. A major question, therefore, is whether poverty reduction and food security objectives can be best achieved through fertilizer subsidies or other types of public programs and investments.

In the high potential areas, the large majority of farmers are already purchasing fertilizer and use rates are quite high as of 2007, although use rates are likely to have fallen since then. Fertilizer subsidies are seductive in that they promise increased fertilizer use and food production, but these outcomes are by no means assured. Providing subsidized fertilizer in areas where commercial purchases are high will almost certainly result in a partial crowding out of commercial sales, as shown by findings in Zambia and Malawi where fertilizer use rates are considerably lower than in Kenya (see Xu, 2008; Dorward et al., 2008). Where purchase of commercial fertilizer is high, then a ton of subsidized fertilizer distributed by government is unlikely to result in an additional ton of fertilizer on farmers' fields since the farmers previously purchasing fertilizer are no longer likely to buy it if they can acquire the same amount more cheaply from a government program.

As a tool for increasing overall agricultural productivity, especially for small, poor farmers, fertilizer subsidies have a questionable record. Long experience with input subsidy programs in Africa is not encouraging on several points: (a) there is very little evidence from Africa that fertilizer subsidies have been a sustainable or cost-effective way to achieve agricultural productivity gains compared to other investments, (b) there are no examples of subsidy programs where the benefits were not disproportionately captured by larger and relatively better-off farmers, even when efforts were made to target subsidies to the poor,[11] and (c) there is little evidence that subsidies or other intensive fertilizer promotion programs have "kick-started" productivity growth among poor farmers in Africa enough to sustain high levels of input use once the programs end.[12]

Notwithstanding these caveats, fertilizer subsidies are one of the few tools in the arsenal of policy responses that can be implemented in a fairly short time frame and which have widespread support in rural areas. For these reasons, fertilizer subsidies are likely to be the first line of response by many governments in the region despite having a mixed track record in Africa (Morris et al., 2007). Minde et al., (2008) provide a number of implementation guidelines about how to improve the effectiveness to fertilizer subsidies, once the decision to implement them has been made. Some of them are mentioned here:

1. ***Use input vouchers that can be redeemed at local retail stores rather than direct distribution*** in order to maintain or improve the capacity of the private sector input delivery system.
2. ***Involve a wide range of fertilizer importers, wholesalers, and retailers in the input voucher scheme,*** even if it entails additional logistical costs. Providing tenders to only 2-3 firms to import fertilizer can entrench their position in the market, cause other firms to cease making investments in the system or drop out altogether, leading to a more concentrated input marketing system and restricted competition when the input subsidy

[11] The logical response is to call for better targeting of future input subsidy programs. However, Dorward et al. (2008, section 7.2.3) includes an illuminating discussion of the practical difficulties involved in targeting subsidized fertilizers to poor households, including lack of information on who the poor households are, and unwillingness of some communities to exclude any households from receiving subsidized fertilizer. The daunting variety of difficulties described here makes it hard to be optimistic about the prospects for significantly improved targeting. In a recent interview of the President of Malawi in August 2008 admitted that the Malawi fertilizer subsidy program was failing the poor. "Sadly it is the rich who are benefiting a great deal. They are selling to the poor at exorbitant prices" (The Guardian, August 12, 2008). An IFDC report (2008) indicates that "In many Nigerian states, 75% or more of the subsidized fertilizer goes to large farms or political patrons, leaving very little for smallholder farmers who need it most."

[12] Countries such as Malawi and Zambia have had almost continuous fertilizer subsidy programs each year for the past several decades even during the so-called liberalization process (e.g., see Dorward et al., 2008; Jayne et al., 2002).

program comes to an end. A system that allows farmers to redeem coupons at the full range of existing independent agro-dealer retail stores will promote additional investment in remote rural areas where it is most needed. By contrast, failure to involve the small rural retailers may lead many of them to stop carrying fertilizer, as was the case in Malawi after the 2005/06 season, leading to erosion rather than development of a private retailing system.

3. ***Before deciding to target the input vouchers***, carefully consider the objectives of the targeting and the practical feasibility and costs of implementing a targeted program, including personnel costs, time requirements and potential delays, leakage, and displacement of commercial sales by subsidized inputs.

4. ***If effective targeting does not seem feasible or achievable at an acceptable cost, then a small universal voucher program would be worth considering.*** For example, a program designed to provide all farmers with inputs for 0.2 ha would primarily benefit small farmers while at the same time limiting the displacement of commercial purchases by larger higher-income farmers, some degree of which might occur anyway under a program that fails to successfully target small farmers.[13]

5. ***Address infrastructure and input supply constraints as well as improving procurement efficiency*** (joint procurement arrangements and regional procurement hubs). This will help achieve the goal of enhancing farm-level fertilizer supplies at a lower price. Facilitating the movement of fertilizers across borders (removing customs duties and export taxes) will also contribute to overall improvements in supply efficiency.

6. ***Facilitate private sector partnerships with farmers***, such as through contract farming where conditions are suitable, would go a long way toward reducing the financial burden on government.

In the current high price environment, the availability of seasonal loans for input purchase takes in heightened importance for maintaining farmers' effective commercial demand for fertilizer. Many Kenyan farmers have been able to finance fertilizer through the credit offered in the

[13] The option of a small universal subsidy program is discussed in Imperial College et al. (2007). See also Chinsinga (2005) for a discussion of the earlier experience in Malawi with universal and targeted input subsidy programs.

integrated input-output chains for crops such as tea, sugar, and coffee. These integrated marketing arrangements have also provided the means for farmers to obtain fertilizer for their food crops, since the companies can recoup their loans for other crops as well when the farmers sell their cash crop back to the company. But in areas where fertilizer use on a particular crop is profitable, such as maize in Western Kenya and horticulture throughout the country, most farmers have achieved reasonable levels of fertilizer use without credit. Support for the development of viable credit programs may also help smallholders maintain their access to fertilizer use despite current high prices, for households in which liquidity constraints are the main problem.

To build durable input and output markets, governments should establish a supportive policy environment that attracts local and foreign direct investment. The experience of Kenya shows how a stable policy environment can foster an impressive private sector response that supports smallholder agricultural productivity and poverty alleviation. These goals remain elusive in countries lacking a sustained commitment to the development of viable commercial input delivery systems. Output price stability has also facilitated the impressive growth in fertilizer use in Kenya. The operations of the National Cereals and Produce Board since the early 1990s, and the elimination of regional trade barriers since the inception of the East African Commission Custom Union in January 2005, have both promoted maize price stability (Jayne, Myers, Nyoro, 2008; Chapoto and Jayne, 2007). Complementary programs to support small farmer productivity, such as the Farm Input Promotions (FIPS) program, the CNFA agro-dealer training and credit program, and the organization of farmers into groups to facilitate their access to extension and credit services under the Kenya Market Development Programme, have also been important factors in raising fertilizer use in Kenya.

Because mean household incomes are higher in Kenya compared with many other African countries, the impressive market-led growth in smallholder fertilizer use in Kenya may not be easily transferable to areas where effective demand is highly constrained. And the Kenya success story is fragile. Sustaining its momentum will depend on commitment to supportive public investment and policy choices. Governance problems and civil disruption are jeopardizing the sustainability of the commercially driven input distribution system and rural development more generally. Continued access to input credit for small farmers in many parts of the country will require government commitment to limit the potential for politicization and interference in the management of the interlinked crop marketing systems for sugarcane, tea, and coffee, which have provided a means for farmers to acquire additional fertilizer on credit for use on food crops. Also, new investment is needed in Kenya's eroded rail, road, and port infrastructure to maintain Kenya's competitiveness. Lastly, effective systems to improve smallholders' crop husbandry and management practices are needed to provide incentives for continued expansion of fertilizer use and productivity growth in areas where fertilizer is only marginally profitable at present.

References

Allgood J.H., and Kilungo J, 1996. An Appraisal of the Fertilizer Market in Kenya and Recommendations for Improving Fertilizer Use Practices by Smallholder Farmers: A Field Report. Muscle Shoals: International Fertilizer Development Center (IFDC).

Ariga J, Jayne T, and Nyoro J, 2006. Factors Driving Fertilizer growth in Kenya, 1990-1995: Sustaining the Momentum and Lessons for Broader Replicability in Sub-Saharan Africa. Working Paper 24, Tegemeo Institute, Egerton University, http://www.aec.msu.edu/agecon/fs2/kenya/wp24.pdf

Burke W, Jayne T.S, Freeman A, Kristjanson P, 2007**.** Factors Associated with Farm Households' Movement Into and Out of Poverty in Kenya: The Rising Importance of Livestock. International Development Working Paper 90, Michigan State University, East Lansing.

Chapoto A, and Jayne T.S, 2007. Price Instability, Trade Policy, and the Demand for Food Staples: An Application of the ARCH Model in Eastern and Southern Africa. Antony Chapoto and T.S. Jayne, December 10-11, 2007, paper presented at the FAO workshop on "Appropriate Trade Policies for Agricultural Development in a Globalizing World", FAO Headquarters, Rome, Italy, December 10-11, 2007.

Chinsinga B, 2005. Practical and Policy Dilemmas of Targeting Free Inputs. In Sarah Levy (Ed.), *Starter Packs: A Strategy to Fight Hunger in Developing Countries? Wallingford, UK: CABI Publishing*.

Cleveland W, 1979. Robust locally-weighted regression and smoothing scatterplots. Journal of the American Statistical Association 74 (368), 829– 836.

Dorward A, Chirwa E, Kelly V, Jayne T.S, 2008. Evaluation of the 2006/7 Agricultural Input Supply Programme, Malawi. Final report, School of Oriental and African Studies (SOAS), Wadonda Consult, Michigan State University, and Overseas Development Institute (ODI), undertaken for the Ministry of Agriculture and Food Security, Government of Malawi. March.

GDS, 2005. From Laboratory to the Dining Table: Tracing the Value Chain of Kenyan Maize. Global Development Solutions, LLC. Prepared for the World Bank.

Haggblade S, and Gelson T, 2003. Development, Diffusion and Impact of Conservation Farming in Zambia. Food Security Research Project Working Paper No. 8. Lusaka, Zambia, November.

IFDC, 2008. IFDC Report, Volume 33, No 2, page 2, June 2008.

Imperial College London, Wadonda Consult, Michigan State University, and Overseas Development Institute. 2007. Evaluation of the 2006/7 Agricultural Input Supply Programme, Malawi Interim Report Undertaken for the Ministry of Agriculture and Food Security. Revised, May.

Jayne T.S, Myers R.J, and Nyoro J, 2008. The Effects of Government Maize Marketing Policies on Maize Prices in Kenya. *Agricultural Economics,* 38(2008): 313–325.

Johnston B.F, and Mellor J, 1961. The Role of Agriculture in Economic Development. *American Economic Review* 51(4): 566-593.

Kibaara B, Ariga J, Olwande J, and Jayne T.S, 2008. Trends in Kenyan Agricultural Productivity: 1997-2007, draft working paper, Egerton University, Tegemeo Institute, Nairobi.

Mellor J, 1976. *The New Economics of Growth: A Strategy for India and the Developing World*, Cornell University Press, Ithaca.

Minde I, Jayne T, Crawford E, Ariga J, and Govereh J, 2008. Promoting Fertilizer Use in Africa: Current Issues and Empirical Evidence from Malawi, Zambia, and Kenya. Working Paper for Re-SAKSS/Southern Africa, Pretoria, South Africa.

Obare G. A, Omamo S.W, and Williams J.C, 2003. Smallholder Production Structure and Rural Roads in Africa: the case of Nakuru District, Kenya. *Agricultural Economics* 28 (2003) 245-254.

Marenya P, and Barrett C, 2008. Soil quality and fertilizer use rates among smallholder farmers in western Kenya. Draft working paper, Cornell University, Ithaca.

Ministry of Agriculture, Republic of Kenya. 2008 Program Implementation Guidelines. The National Accelerated Agricultural Inputs Access Program, NAAIAP. July 2008, Nairobi.

Morris M, Kelly V.A, Kopicki R, and Byerlee D, 2007. *Promoting increased fertilizer use in Africa: Lessons learned and good practice guidelines*. Washington, D.C.: World Bank.

Mosley P, 1994. Policy and Capital Market Constraints to the African Green Revolution: A Study of Maize and Sorghum Yields in Kenya, Malawi, and Zimbabwe, 1960-91. In G. Andrea Cornia and G. Helleiner (Eds). *From Adjustment to Development in Africa: Conflict, Controversy, Convergence, and Consensus?* New York: Macmillan.

Nyoro J, Kirimi L, and Jayne T.S, 2004. Competitiveness of Kenyan and Ugandan Maize Production: Challenges for the Future. Working Paper 10, Egerton University, Tegemeo Institute, Nairobi, Kenya.

Rockefeller Foundation. 2007. Enhancing Market Access and Technology Adoption among Smallholders. A Baseline Report for Evaluating Agricultural Interventions Funded by the Rockefeller Foundation in Western Kenya. Consultant services by the Tegemeo Institute, Egerton University, Kenya: February 2007.

Sikobe R, and Ulare T, 2008. Kenya Fertilizer Survey report. Draft for Ministry of Agriculture. May, Nairobi.

The Guardian, 2008. Soaring fertiliser prices threaten world's poorest farmers, August 12, 2008, http://www.guardian.co.uk/environment/2008/aug/12/biofuels.food

Xu Z, 2008. Profitability of Applying Fertilizer on Maize for Smallholder Farmers in Zambia. Essay 2 of Ph.D. dissertation, Department of Agricultural, Food, and Resource Economics, Michigan State University, East Lansing.