MAIZE RESPONSE TO FERTILIZER AND FERTILIZER-USE DECISIONS FOR FARMERS IN GHANA

BY

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THESIS

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ABSTRACT

Current maize yields in Ghana average only one-third of their estimated potential, but this yield gap can be reduced by improving farming practices and growing conditions in Ghana; specifically, yields in Ghana can likely be increased by intensifying the use of fertilizer, other inputs, and irrigation systems. Recently, Ghana introduced a fertilizer subsidy program to help increase fertilizer-use rates, however, little work has been done to examine the effectiveness of this program, or to determine the viability of using fertilizer to increase yields in Ghana. This paper (1) determines the marginal effects of inorganic fertilizer on maize output using OLS and quantile regressions, (2) determines the profitability of fertilizer at the subsidized and unsubsidized prices using the value-cost ratio, and (3) examines alternate instruments for increasing fertilizer use using a linear probability model. I find that fertilizer use has a positive and significant effect on maize yields in all models that I consider; despite this positive correlation, however, I find that fertilizer is not sufficiently profitable for the average Ghanaian farmer to incentivize additional application. Finally, I find that the farmer's distance from the closest weekly market, whether the farmer has a pre-harvest contract, and whether the farmer has property rights on the field have significant correlations with fertilizer use.

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1 Motivation

Current economic conditions in Sub Saharan Africa (SSA) indicate a slow but increasing growth in GDP and other development indicators, but the most recent data reveal very troubling trends in the agricultural sectors of these countries. Cereal production is increasing on average, but this is mainly a result of increases in agricultural area and labor, rather than increases in yields. Additionally, while modern inputs such as irrigation and fertilizer have spread to developing countries world wide, usage rates are lowest in SSA, with the percentage of irrigated and fertilized cropland barely increasing from 1962 to 2002 (The World Bank, 2008). Since irrigation systems and fertilizer application can substantially increase agricultural yield, expanding their use in SSA could lead to sustainable increases in production.

Overall, soil conditions in SSA present many problems for agriculture, and these conditions have only been exacerbated through historical land-use practices (Morris et al., 2007). Annual nutrient losses in SSA range from 14 kg NPK (Nitrogen- Phosphorus-Potassium) to 136 kg NPK per-hectare, with a majority of countries showing per-hectare annual nutrient losses greater than 24 kg NPK (Stoorvogel and Smaling, 1990; Henao and Baanante, 1999). The most effective method to combat soil nutrient losses is to apply nutrient fertilizer; unfortunately, SSA currently has the lowest fertilizer use per cropped hectare in the world at 9 kg per-hectare, about 9 percent of the global average— 118 kg/Ha. Increasing these fertilizer-use rates in SSA would not only decrease soil nutrient losses, but would also serve as a mechanism to increase agricultural yields (Wallace and Knausenberger, 1997).

To increase fertilizer use in SSA, countries have several options: decrease the cost of fertilizer; increase the availability of fertilizer; educate farmers on proper application and the benefits of fertilizer (Druilhe and Barreiro-hurlé, 2012). Several African countries have recently begun fertilizer subsidy programs in an attempt to reduce the cost of fertilizer to farmers, including Burkina Faso, Ghana, Malawi, Nigeria, Rwanda, Senegal, Tanzania, and Zambia. Among these countries Ghana serves as an interesting example of a growing economy in which increases in agricultural yields could contribute significantly to economic development. The GDP of Ghana has more than quadrupled since 2004, from $8.9 billion to $40.7 billion, and while the share of the agricultural sector with respect to GDP has been decreasing, the sector remains a large part of the economy; as of 2010, the agricultural sector accounted for about 30% of GDP and employed 42% of the labor force (FAOstat, 2014). The aggregate value of agricultural production has been significantly increasing, from $5.4 billion in 2004 to $13.2 billion in 2011, despite this decreased share of GDP (FAOstat, 2014).

Agriculture in Ghana is primarily smallholder, consisting mainly of farms less than two hectares in size. On average Ghanaian farmers do not use very many inputs and very few have established irrigation

systems. As a result, agricultural yields vary greatly with the quantity and distribution of rainfall, as well as with the soil quality (MoFA, 2010). Fertilizer application could decrease yield variability by replenishing soil nutrients, however, current fertilizer use in Ghana averages 6 kg/Ha, representing one of the lowest rates in SSA (FAOstat, 2014; Banful, 2009).

In 2008, Ghana's Ministry of Food and Agriculture (MoFA) launched a fertilizer and seed subsidy program to prevent fertilizer use from further decreasing due to its rising cost (Banful, 2009). Since then, the government of Ghana has continued the subsidy program with the additional objective of increasing fertilizer application rates in Ghana to at least 20 kg/Ha by 2015 in order to reduce food insecurity, hunger and malnutrition, and rural poverty (Banful, 2010). This subsidy program has the potential to have a very positive impact on the agricultural sector in Ghana, but additional research is necessary to assess the utility of the program and to determine if a fertilizer subsidy is a suitable policy for increasing agricultural yields in Ghana.

In this paper, I examine the importance of fertilizer use for maize production in Ghana, examine the profitability of fertilizer, and discuss the factors that significantly influence whether or not a farmer applies fertilizer in the Ghanaian context. In the following chapter I provide background information on maize production and fertilizer use in Ghana and discuss relevant literature. In chapter 3 I introduce the data and provide summary statistics of relevant variables. In chapter 4 I discuss my empirical methods and provide a conceptual framework. In chapter 5, I present the results from my ordinary least squares and quantile regressions to predict maize response to fertilizer. In chapter 6, I use these regression results to calculate the profitability of fertilizer using the value-cost ratio. Finally, in chapter 7, I examine the significant factors in determining whether or not farmers choose to apply fertilizer.

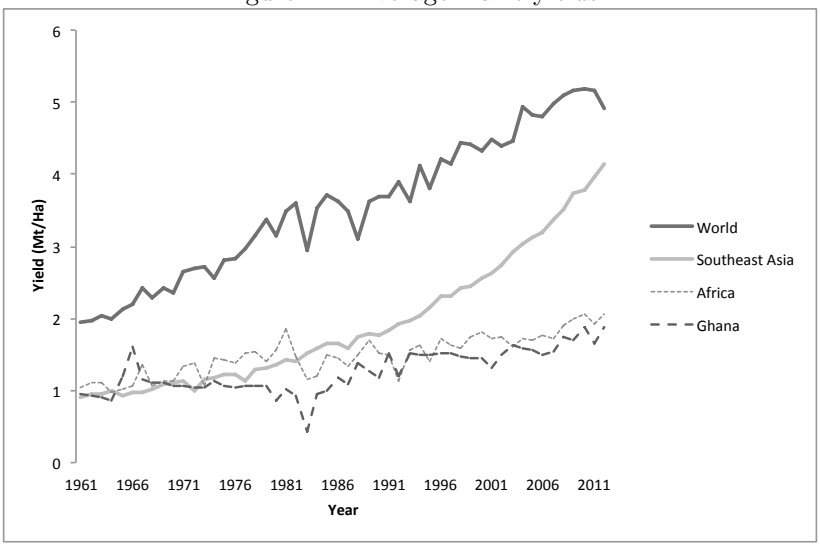
2 Literature Review

The following review of literature provides necessary background information for the paper, motivates my choice of analytical method and control variables, and provides summary statistics and results to compare to my own. In this literature review I first present background information on maize yields, soil quality, and fertilizer use in Ghana; I then discuss previous work modeling maize response to fertilizer, calculating fertilizer profitability, and determining significant factors in the farmer's fertilizer-use decision.

2.1 Maize in Ghana

Maize is the most important smallholder cereal crop in Ghana; it accounts for about 20 percent of their calories, roughly half of it enters into the market, and it accounts for the largest planted area of all food crops in Ghana (Braimoh and Vlek, 2006; Morris et al., 1999). Current yields average 1.7 mT/Ha, roughly a quarter of their potential according to Ghana's MoFA, despite the importance of maize in Ghanaian agriculture (MoFA, 2010).

Figure 2.1: Average maize yields



Source: FAOstat, 2014

Figure 2.1 shows that average per hectare maize yields in Ghana are lower than the average for Africa, less than one-half of the world average, and less than one-third of the average for Southeast Asia. Due to the importance of maize in Ghanaian agriculture, the entire agricultural sector would benefit from increasing maize yields. Determining methods for increasing maize yields in Ghana requires first understanding

current growing conditions; so next I discuss current soil characteristics and fertilizer usage in Ghana.

2.2 Soil Quality and Fertilizer Use in Ghana

Soil Quality

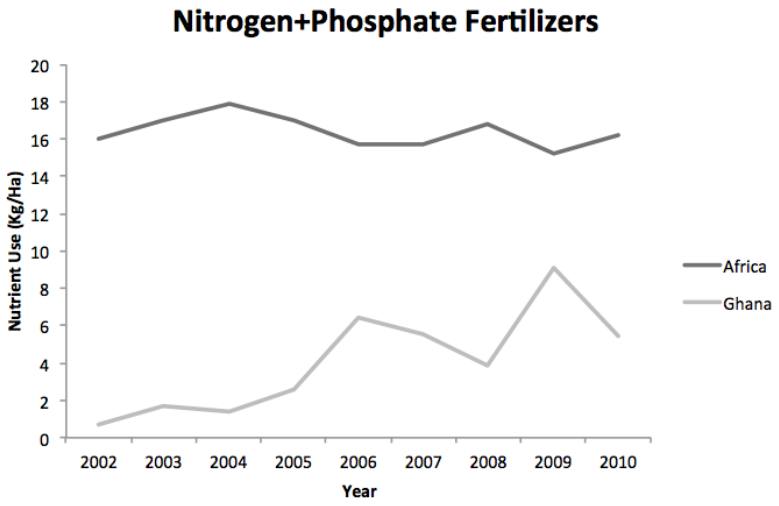
Soil quality in SSA has long been deteriorating, and the soil in Ghana is no exception. Significant soil multinutrient (NPK) deficiencies have been found throughout Ghana and appear to be at least partially due to poor cultivation practices. In the North, significantly lower chemical and nutrient properties have been found in permanently cultivated soils compared to soils under natural vegetation (Braimoh and Vlek, 2004). In the South, rice yields were shown to increase significantly with the application of mineral fertilizer to correct these deficiencies (Moro et al., 2008). Overall, Ghana is estimated to have annual nutrient losses around 60 kg/Ha NPK, among the highest rates in SSA (Henao and Baanante, 1999; Stoorvogel et al., 1993).

Fertilizer

Several studies have suggested that large increases in fertilizer usage are necessary to correct the massive nutrient losses of much of the arable land in SSA (Morris et al., 2007; Crawford et al., 2005; Heisey and Mwangi, 1997; Wallace and Knausenberger, 1997). Currently, SSA has the lowest fertilizer application rates of any region, with application rates around 10 kg/Ha. Africa contains 25 percent of the world's arable land, yet represents less than 1 percent of global fertilizer consumption (Kariuki, 2011; Morris et al., 2007).

As of 2010, fertilizer use in Ghana was well below the average in SSA at less than 6 kg/Ha (FAOstat, 2014). Historically, Ghana has seen some fluctuations in fertilizer usage, but the rates have always remained relatively low (FAO, 2005). Figure 2.2 shows average Nitrogen and Phosphate fertilizer application rates per hectare of total arable land in Africa and Ghana. This figure shows that while the gap between the rates has decreased in recent years, the average fertilizer application rates in Ghana are still well below the average of Africa overall. Fertilizer application rates are relatively low for all crops, but the rates average slightly higher on maize fields; application rates average around 14 kg/Ha on maize fields, accounting for about 64 percent of total fertilizer use (Heisey and Mwangi, 1997; Kherallah et al., 2002).

Figure 2.2: Average fertilizer nutrient application



Source: FAOstat, 2014

Average fertilizer use on maize fields is higher than on all fields in Ghana, but the application rates are still low. Numerous studies have shown that increasing these fertilizer-use rates and the efficiency of its application can significantly increase agricultural yields, so in an effort to increase yields through increasing fertilizer use, in 2008 Ghana launched the fertilizer and seed subsidy program (Ersado et al., 2003; Kherallah et al., 2002; Weight and Kelly, 1999; Yanggen et al., 1998).

The fertilizer market in Ghana and the fertilizer subsidy program

The fertilizer and seed subsidy program in Ghana utilizes the private sector for fertilizer supply, distribution, and retailing; In 2008 and 2009 agricultural extension agents issued fertilizer-specific and region-specific vouchers; the vouchers could be used as partial payment for fertilizers at any retailer who would accept them (Baltzer and Hansen, 2012; Banful, 2010). This voucher system received heavy criticism for aspects of its distribution and effectiveness, so in 2010 the government discontinued the voucher program in favor of directly paying for half of the cost of fertilizer and absorbing all transportation costs (Banful (2009, 2010, 2011)). Since the subsidy program's introduction maize yields in Ghana have been increasing significantly more than yields in other West African countries without subsidy programs, despite the program's initial shortfalls (Druilhe and Barreiro-hurlé, 2012).

2.3 Modeling Maize Yield Response to Fertilizer

Given the current low fertilizer application rates in Ghana and the current use of policy to increase these rates, I am interested in determining how fertilizer impacts yields in Ghana. In particular, due to the importance

of maize in Ghanaian agriculture, I am interested in determining how fertilizer affects maize yields. To model this relationship, I first consider and discuss relevant literature to identify important control variables and to determine an appropriate empirical method.

In a paper by Braimoh and Vlek (2006), using a multiple linear regression, they find that five variables significantly affect maize yields in Northern Ghana: soil quality index, fertilizer use, household size, distance from main market, and the interaction between fallow length and soil quality. They find that soil quality is the most important determinant of maize yield in Northern Ghana. They further suggest that inorganic fertilizer is necessary to correct the depleting soil quality, because organic techniques and inputs alone cannot restore depleted soils and can only sustain crop yields at limited levels.

In a paper by Xu et al. (2006), they attempt to determine whether fertilizer use is profitable for small farms in Zambia, or whether high prices and low response rates make fertilizer use unprofitable. To determine fertilizer profitability, Xu et al. estimate maize yield response to fertilizer under a range of small farm conditions. They find that the marginal product of nitrogen is highest for households that obtain fertilizer on time and use animal draft or mechanical power for land preparation; these farmers are also more likely to find fertilizer use profitable than other households within the same district.

Through field studies in Southern Nigeria, Onasanya et al. (2009) find that applying 120 kg/Ha of nitrogen fertilizer by itself or applying 60 kg/Ha of nitrogen with 40 kg/Ha of phosphorus fertilizer significantly increases maize yields. This study is somewhat limited because it was a field study in a small area in southern Nigeria, but these application rates provide some background of the rates of fertilizer application that should be expected to significantly increase maize yields.

In a policy brief on Malawi's Farm Input Subsidy Program, Shively and Ricker-Gilbert (2013) discuss the effectiveness of the subsidy program at increasing fertilizer use, and further examine whether increasing fertilizer application affected maize yields. They find that (1) female-headed households tend to use less fertilizer for maize than male-headed ones, (2) chemical fertilizer use is positively correlated with the overall wealth of a household, (3) farmers that plant improved varieties of maize tend to use about 50 kg more fertilizer than those that do not, (4) the subsidy program increases total fertilizer use for maize, (5) plots with improved varieties of maize on average produce higher yields compared to plots with traditional maize, and finally (6) the authors find a significant and positive correlation between the amount of fertilizer application and yield, however at higher rates of fertilizer use this relationship exhibits declining returns to fertilizer use.

In addition to utilizing the literature examining yield response to fertilizer, I also consider literature on other determinants of yield to help me control for confounding factors and isolate the effects of fertilizer. An important variable to control for appears to be farm size, based on the large array of literature

observing and examining the negative effects of total farm size on crop yields, known as the inverse farm size-productivity relationship. Many papers have specifically noted this relationship in Africa and while many of these papers postulate the causes of this relationship, there is no one widely accepted explanation (Barrett, 1996; Barrett et al., 2010; Collier, 1983; Kimhi, 2006). Barrett et al. (2010) outline the three primary explanations of this relationship as: (1) imperfect markets, (2) omitted soil quality variables, and (3) measurement error (specifically with plot size). In their paper, however, they find that only a small portion of the inverse farm size-productivity relationship is explained by market imperfections, and none of it seems attributable to the omission of soil quality measurements.

2.4 Fertilizer Profitability

After calculating how fertilizer impacts maize yields, I discuss further implications of those results by analyzing the profitability of fertilizer. Determining the profitability of fertilizer requires comparing the costs of applying fertilizer with the value of output that it generates. A simple and commonly used method for calculating fertilizer profitability is the value-cost ratio (VCR). Morris et al. (2007) and Kelly (2006) both examine fertilizer profitability in SSA using this method, accepting that a VCR greater than two indicates that fertilizer use is profitable, despite that a VCR of one should indicate that the revenues outweigh the costs. A VCR of two is a more certain indication of profitability, considering that the actual VCR may fluctuate with prices, weather, and other uncontrollable exogenous factors. I adopt this method in this paper to evaluate the profitability of fertilizer use, accepting that fertilizer-use is profitable if the VCR is at least two. More specific information on this technique can be found in my methods chapter (chapter 4). Morris et al. (2007) find that fertilizer tends to be profitable for maize farmers in West Africa, yet less than half of maize farmers in Ghana apply fertilizer. Farmers are expected to make their fertilizer application decision based on profitability, but there may be other factors in their decision; so, next I examine how farmers make the decision to apply fertilizer.

2.5 Potential Determinants of Fertilizer Use

Kherallah et al. (2002) give some potential reasons for the low fertilizer use rates in Africa as: (1) high fertilizer costs, (2) lack of irrigation systems, (3) the prevalence of traditional crop varieties that are less responsive to fertilizer, and (4) low incentives to invest in land-saving technologies. Other factors that may impact fertilizer use include availability of information on correct usage, information on the effects of fertilizer use on yields and profits, and the effectiveness of fertilizer on a particular field.

Among these potential reasons for low fertilizer use in Africa, high fertilizer costs and the lack of

irrigation systems are the most apparent in Ghana. In 2008, Ghana's fertilizer subsidy reduced the price of fertilizer by one half, yet even at those prices some farmers claimed that the subsidized fertilizer was not affordable (Yawson et al., 2010). Farmers who did not use fertilizer or used it at less than recommended rates stated they did so because of the high prices of the product (Banful, 2009). The lack of irrigation systems in Ghana is another potential deterrent of fertilizer use, since only 0.4 percent of the area under cultivation is under irrigation (MoFA, 2010).

I do not find significant indication of the last two reasons for low fertilizer use as suggested by Kherallah et al. (2002) above. The main crops produced in Ghana are maize, cassava, and cocoa, so the prevalence of crops that are unresponsive to fertilizer is unlikely to explain the low fertilizer usage (Braimoh and Vlek, 2006; Ruf and Bini, 2011; Olasantan et al., 1997). Since population density in Ghana is low outside the southern regions, there may be reduced incentive to invest in land-saving technology since expansion of the cropped area is relatively inexpensive, but I have not found any indication of this in the literature.

These potential determinants of fertilizer use only begin to explain the low application rates in Ghana; the literature suggests many other factors that may affect fertilizer application. Neighbors or "information neighbors" have been found to contribute to the farmer's knowledge of fertilizer profitability and management (Conley and Udry, 2010; Duflo et al., 2006; Foster and Rosenzweig, 1995; Munshi, 2004). Lack of access to credit markets has been found to reduce farmers' ability to afford fertilizer at planting season (Ouma et al., 2006). A farmer's perception of their risk may alter their fertilizer-use decision (Reardon et al., 1999). Finally, poor road infrastructure, distance from the market, and lack of suitable transportation can cause the farmer difficulty in physically accessing fertilizer (Fufa and Hassan, 2006).

2.6 This Paper

The literature above suggests important control variables, some causal relationships, and methodologies that are relevant for this paper. In this paper I will utilize these ideas to contribute to the literature on agriculture in Ghana. Farmers in Ghana have faced many agricultural difficulties that have been exacerbated by poor farming practices; by improving some of these farming practices, farmers may be able to overcome some of these difficulties and significantly increase their yields. With this paper I (1) determine whether increasing fertilizer use would serve as an effective mechanism for increasing yields in Ghana, (2) examine the fertilizer prices farmers face and determine whether farmers should be incentivized to increase fertilizer application at any of those prices, and (3) determine if there are factors other than price and profitability that contribute to the farmer's decision to apply fertilizer. The results from this paper then provide insight into potential policy solutions to increase maize yields in Ghana.

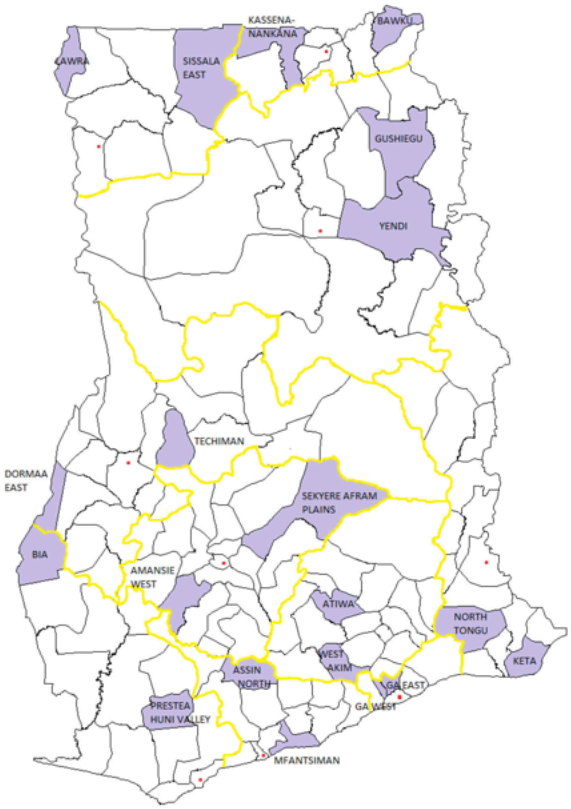
3 Data and Summary Statistics

In this chapter, I describe the data, discuss some issues and limitations, and present sample summary statistics. I briefly introduce summary statistics on fertilizer use and maize yields to assess district variation, give background on my sample, and to compare the characteristics of farmers in my sample to the ones presented in the literature review.

3.1 Data

The data are from the Ghana Agricultural Production Survey (GAPS), a project spearheaded by the Ministry of Food and Agriculture of Ghana (MoFA), with support from the Ghana Strategy Support Program (GSSP) of the International Food Policy Research Institute (IFPRI). The GAPS includes questions on plot level production, inputs, revenues, and farmer demographics. So far, data are available for the GAPS I, spanning the 2011-2012 major growing season, and the GAPS II, spanning the 2012-2013 minor growing season; the final GAPS I survey is shown in Appendix A. The GAPS I is a household-level survey collecting data from a total of 8,000 agricultural holders in the country: 10 randomly selected holders in each of 40 enumeration areas in each of 20 districts (two randomly selected districts in each region). Each holder was visited twice during the major season— once during the land preparation and planting period and once after harvest and marketing. Figure 3.1 shows the regions and districts where the GAPS were employed. The final cleaned GAPS I dataset contains observations on 6,102 crops grown by 4,291 holders and includes responses to 297 questions.

Figure 3.1: The GAPS Districts



The GAPS II is a very similar survey observing some, but not all, of the same households as GAPS I and collecting data from a total of 4,000 agricultural holders in the country, including around 500 of the holders from the GAPS I. Due to the reduced size of the GAPS II and the limited overlap with holders from the GAPS I, this paper will concentrate on a cross-sectional analysis of data from the GAPS I. Focusing on the GAPS I data gives me a larger sample size and allows me to concentrate on the major growing season. By only using the GAPS I dataset, however, I cannot control for time-invariant farm characteristics and I cannot observe the effects of fluctuations in fertilizer use on particular fields over time. The main time-invariant characteristic that a panel dataset would better control for is the soil quality; with the regular use of fertilizer and fallow periods, farmers can correct soil nutrient deficiencies in the long run, but in the short run soil quality is relatively static. In addition to soil quality, some unobservable farmer characteristics that impact their farming practices are likely time-invariant, so the use of panel data would also allow me to control for some of these characteristics as well. The cross-sectional approach does allow me to compare the yields of different farmers, and to determine some factors that contribute to these differing yields, despite its limitations; however, panel analysis would allow me to do this as well as examine trends in yield over time while controlling for unobserved time-invariant characteristics.

3.2 Challenges with the Data

The main challenges with these data are with data aggregation, measurement error/recording problems, and omitted variables. Data aggregation problems mainly arise because farmers were visited once during the planting season and once after harvest, and their responses about planting and harvesting seem to differ greatly. In some cases farmers report production numbers for a crop they never report planting, and in other cases they do not report production numbers for crops they report planting. Second, farmers record inputs by field, but then report production by crop. This created two main problems: (1) if the farmer grew multiple crops on one field I do not know how much of the field was allocated to each crop or how much of the inputs were dedicated to each crop and (2) if the farmer grew the same crop on multiple fields I cannot determine differences in productivity between the fields. The first problem forces me to make assumptions about the farmer's allocation of inputs and dispersion of maize on the field since these are not explicitly discussed; specifically, I assume that all the inputs applied on a maize field were applied to maize, and that the entire field was allocated to maize, regardless of whether other crops were planted in the same field. The later problem forces me to use a farm level analysis rather than field, since I only have output values by farm.

Measurement error likely occurred in several variables, but it is most obvious and most prevalent in the area measurements. There were some obviously inaccurate field area values in the GAPS dataset, and there were some field area values that appeared unlikely after considering the reported inputs and production. I believe that most of the errors in the area variable are due to measurement error, but I do believe that they can serve as a proxy for field size. To account for this measurement error I also consider a model using total production and total fertilizer use, while using field size as an additional control variable. Measurement error may also be prevalent in the amounts farmers report paying for inorganic fertilizer use on each field, because these amounts appear very high for some farmers. Since farmers are unlikely to purchase fertilizer separately for each field, they are unlikely to recall the exact amount allocated to each field, and may not accurately recall the exact amount they paid for fertilizers.

Finally, the data does not include some valuable information. In this survey, a few variables that would have been useful but were omitted in the GAPS I were actually included in the GAPS II, such as data on the occurrence of various poor weather conditions, estimated crop loss due to these weather conditions, and the exact amounts of fertilizers purchased by type. Further variables that would have been useful for this paper are more detailed data on soil quality, for instance the inclusion of pH levels and information on fallow periods. More detailed data on the application of fertilizer, such as when it was applied and more accurate measures of the quantity used per crop, would also be helpful. The omitted variable that is most

relevant to this paper is a variable on the quantity of fertilizer application; the survey provides a dummy variable for whether or not fertilizer was applied, and further provides the amount the farmer spent on fertilizer by field, but does not provide information on the quantity applied. Since farmers are unlikely to make separate fertilizer purchases for each field, this estimation of fertilizer cost per field has some inherent problems as I discussed previously, but it should roughly estimate the amount of fertilizer purchased and how it was allocated across fields. The main problem with this cost variable is that farmers only report the total amount they spent on all inorganic fertilizers, so I do not have data on which fertilizer nutrient the farmer used.

3.3 Summary Statistics

While the national level fertilizer use trends I presented already are helpful, looking at district level fertilizer use as found in the GAPS datasets will (1) allow me to compare the results of the survey to the established country level estimates and (2) provide insight into how fertilizer use varies by region and district.

Table 3.1: Share of fields using inorganic fertilizer by district

Region	District	Maize	All Fields
Northern Ghana		66.24	30.11
Northern	Yendi	79.73	33.16
	Gushiegu	0	0
Upper East	Kasena Nankana East	14.89	3.58
	Bawku Municipal	96.25	81.98
Upper West	Sissala East	59.15	27.45
	Lawra	74.14	21.58
Southern Ghana		16.73	13.12
Western	Prestea Huni Valley	−−	25.00
	Bia	−−	24.83
Central	Mfantsima	8.00	5.14
	Assin North Municipal	16.67	7.99
Greater Accra	Ga West	0	0
	Ga East	30.28	28.63
Volta	Keta	67.74	69.06
	North Tongu	1.69	21.82
Eastern	West Akim	2.04	2.85
	Atiwa	3.41	4.76
Ashanti	Amansie West	13.64	13.76
	Sekyere Afram Plains	23.21	18.01
Brong Ahafo	Techiman Municipal	43.56	16.64
	Dormaa East	0	0.73
	Total sample	32.10	17.50

Table 3.1 shows the share of fields using inorganic fertilizer in each district during the 2011-2012 major growing season as reported in the GAPS I. The share of maize producing fields that applied inorganic

fertilizer was larger than the share of all fields that applied inorganic fertilizer, which agrees with the literature discussing fertilizer use trends in Ghana. This table also shows that there is considerable variation of fertilizer application across regions and districts; specifically, farmers in the North are far more likely to apply fertilizer than farmers in the South. Given the variation in fertilizer use between districts, I will next consider how maize yields fluctuate by location.

Table 3.2: Mean maize yield by district

Region	District	Yield (mT/Ha)
Northern Ghana		1.45
Northern	Yendi	1.23
	Gushiegu	1.23
Upper East	Kasena Nankana East	1.65
	Bawku Municipal	1.09
Upper West	Sissala East	2.64
	Lawra	1.26
Southern Ghana		2.02
Western	Prestea Huni Valley	- -
	Bia	- -
Central	Mfantsima	1.00
	Assin North Municipal	0.88
Greater Accra	Ga West	1.53
	Ga East	1.81
Volta	Keta	1.53
	North Tongu	1.53
Eastern	West Akim	1.69
	Atiwa	- -
Ashanti	Amansie West	2.03
	Sekyere Afram Plains	3.11
Brong Ahafo	Techiman Municipal	2.93
	Dormaa East	1.92
	Total sample	1.78

Table 3.2 shows average maize yield by district. This table shows that there is considerable variation in maize yields between regions and districts in Ghana. This variation is not surprising since there are significant differences in the weather, soil quality, and farm characteristics throughout Ghana, particularly between the North and the South. This table shows that despite the higher fertilizer use rates for farmers in Northern Ghana, those farmers, on average, have lower maize yields than the farmers in the South.

The yield difference between the North and South may be attributable to several factors, but the main culprit is likely the climate differences between the North and South. Ghana is comprised of 6 primary agro-ecological zones with very different climates, but the most notable differences occur between the North and South. Figure 3.2 outlines 7 different climate zones in Ghana, but generally the moist and wet evergreens are combined as the rain forest zone; table 3.3 shows the average annual rainfalls, rainfall ranges, and rainy season months for each of these regions. This table shows the large differences in rainfall between these zones,

Figure 3.2: Agro-ecological zones of Ghana



Source: Germer and Sauerborn, 2008

Table 3.3: Average rainfalls by agro-ecological zone (mm)

Agro-ecological Zone	Mean Annual Rainfall	Rainfall Range	Major Rainy Season
Sudan Savannah	1000	- -	May-Sept.
Guinea Savannah	1000	800-1200	May-Sept.
Transitional Zone	1300	1100-1400	March-July
Deciduous Forest	1500	1200-1600	March-July
Rain Forest	2200	800-2800	March-July
Coastal Savannah	800	600-1200	March-July

Source: FAO, 2005

and particularly between the North and South. The lowest mean rainfalls occur in the Coastal Savannah in the South, but figure 3.2 shows that this climate zone is relatively small; the second lowest mean rainfalls span the entirety of Northern Ghana, creating a large discrepancy in average rainfall rates between the North and South. These differences in fertilizer application, yields, and weather patterns between the North and South are important to consider in evaluating yield-increasing policy solutions; the effectiveness of policy solutions may differ between the North and South due to these varying characteristics. Because of these differences between the North and South, I will consider separate models for the North and South in addition to my model for farmers throughout Ghana.

These summary statistics reveal major differences between farmers in the North and South and they further suggest some differences between farmers in each district. My separate models for farmers in

the North and South account for the major differences between the agro-ecological zones, but to further control for geographic heterogeneity I include district fixed effects in all of my models. District fixed effects allow me to compare farmers within districts, limiting bias from the varying weather, soil quality, and farmer characteristics between districts.

These summary statistics highlight the region and district variation of fertilizer application and maize yields, and are consistent with the literature; which leads me to believe that the farmers in the sample are representative of the population of maize farmers in Ghana. Having introduced and briefly described the data, I next discuss the methods I use to analyze this data.

4 Methods

In this chapter, I first explain how I conceptually maize yields and profitability, and how I frame the decision to apply fertilizer. I then discuss the empirical methods I use to model maize response to fertilizer, and expanding on this model I then discuss the method I use to determine fertilizer profitability. Finally, I briefly discuss my model for examining the significant determinants of fertilizer use.

4.1 Conceptual Framework

Maize response to fertilizer

In addition to the large regional differences in weather, farm and farmer characteristics tend to vary throughout Ghana as well; farm sizes tend to increase from the South to the North while productivity tends to decrease; in Southern Ghana, farmers tend to have more diversified income sources, whereas in the North there are far fewer off-farm employment opportunities. Given the diverse farm characteristics throughout Ghana, performing an analysis using actual farm conditions and outputs rather than using a limited field study is necessary to accurately determine how fertilizer use impacts maize yield for farms in Ghana.

Maize yield is a function of inputs, soil/farm conditions, and farmer characteristics. Maize yield Y for farmer j in field i in year t is thus a function of inputs x, field, farm, and environmental characteristics y, and farmer characteristics z:

$$Y_{jit} = f(x_{jit}, y_{jit}, z_{jit}).$$

A function that includes variables on all inputs and field, farm, and farmer characteristics would most accurately assess the impact of additional fertilizer use on maize yield. The impact of additional fertilizer use is determined by holding all other variables constant at some observed level, but increasing the amount of fertilizer applied.

The value-cost ratio

Using the estimated impact of additional fertilize use, I then determine the value-cost ratio (VCR) for additional fertilizer application. The VCR is a common method for examining the financial incentives to use fertilizer; it is the ratio of technical response to fertilizer use and the fertilizer-output price ratio (adopted from Kelly, 2006):

$$\frac{O/N}{P_N/P_O}.$$

The output-nutrient ratio ($^{O}/_{N}$) is the amount of maize output (O) per N units of fertilizer; the nutrient-output price ratio ($^{P_N}/_{P_O}$) is the ratio of the cost per one unit of fertilizer (P_N) to the value of one unit of output (P_O).

If the VCR>1 then fertilizer use is profitable and incentivized since this indicates that the value of the output generated is greater than the cost of the fertilizer; however, the literature suggests that for developing countries the general rule is that the VCR must be above 2 before a farmer will consider using fertilizer, and in particularly high-risk environments the VCR may need to be as high as four (Morris et al., 2007; Kelly, 2006). This is because farmers may face additional costs to applying fertilizer and they may face risks each year that could lower output, lowering their VCR. For the purposes of this paper, I consider the farmer to have sufficient incentive to apply additional fertilizer if the VCR is greater than 2. I use a VCR of 2 or greater to indicate profitability for three main reasons: (1) to provide a buffer for errors in the data, (2) to account for additional costs that may be associated with producing or selling maize, and (3) to provide a buffer for risks that could affect costs or maize prices.

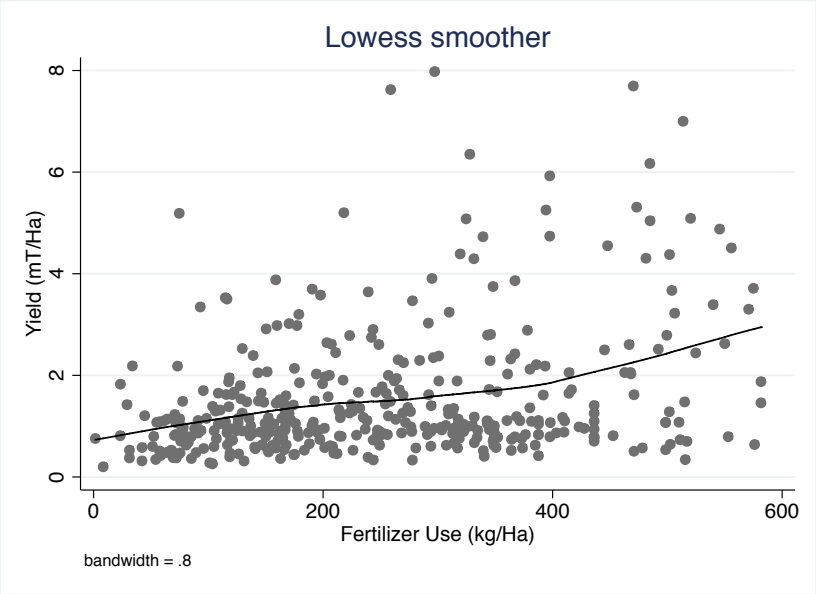
The farmer's fertilizer-use decision

After determining the profitability of fertilizer use, I examine the farmer's fertilizer-use decision. More specifically, I determine what factors besides profitability affect the farmer's decision to apply fertilizer. This decision can depend on many factors, and these factors may differ by farmer, but I expect the decision to depend on (1) fertilizer profitability, (2) having accurate information on the profitability, (3) knowing how and when to apply fertilizer, (4) having access to fertilizer at the time it is needed, and (5) being able to afford fertilizer at the time it is needed. Using this simplistic model, the binary decision to apply fertilizer or not (F) of farmer j on field i in year t can be represented by:

$$F_{jit} = f(p_{jit}, k_{jit}, a_{jit}).$$

Where p is the profitability of fertilizer application, k is the farmer's information, and a is the ability of the farmer to access and afford fertilizer. In reality this function is difficult to model due to the complex nature of the predictor variables since they are each dependent on a large number of factors, but despite this inherent difficulty, I determine some factors that significantly affect Ghanaian farmers' decision to apply fertilizer, particularly factors that can be influenced through policy solutions.

Figure 4.1: Lowess Curve for Yield and per Hectare Fertilizer Use



4.2 Empirical Methods

Maize Response to Fertilizer

OLS Regressions

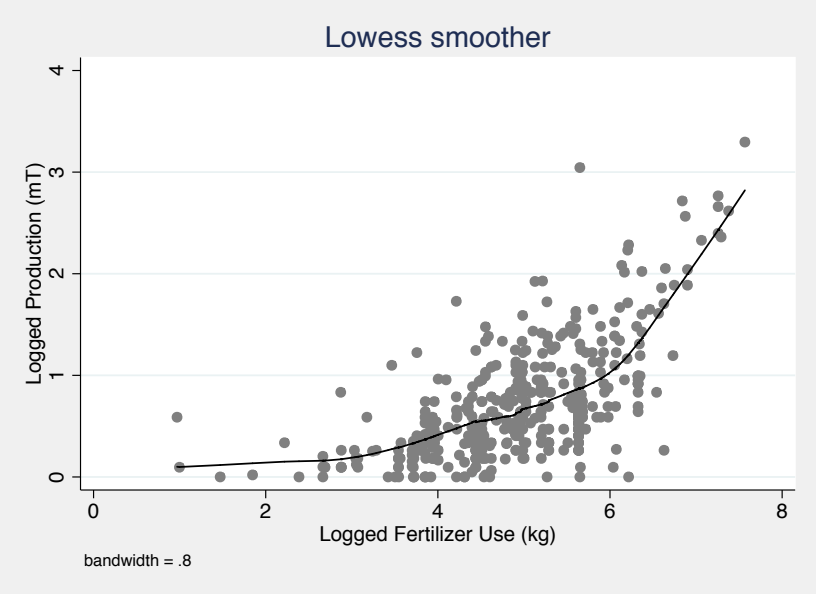
The literature indicates that fertilizer use has decreasing marginal returns to yield, so a quadratic equation that allows for concavity would be expected to best model the relationship; however, the Lowess curve (figure 4.1) for yield and fertilizer use reveals a roughly linear relationship between the two, so I employ an ordinary least squares regression to model this relationship. My equation for modeling yield on field i for the 2011-2012 major cropping season is thus:

$$y_i = \beta_0 + \beta_1 x_i + \sum_{j=2}^{n} \beta_j z_{ji} + \delta_i + \alpha_d + \varepsilon_i. \tag{4.1}$$

Where x_i is fertilizer use per hectare on field i, z_{ji} $(j = 2, 3, ..., n)$ is the set of all other predictor variables, including other inputs, farmer characteristics, and field characteristics, δ_i is the set of field-specific soil colors and soil types, and α_d is the unobserved district effect.

In addition to this model, I also consider a logged regression model of total production for several reasons. First, I want to consider production and total input application while controlling for field size to determine whether the results are similar when I use yield and per hectare input levels. Second, the logged model's coefficients represent elasticities, which makes the results much easier to interpret and compare. Finally, logged models can reduce the impact of the outliers and improve normality for variables in my

Figure 4.2: Lowess Curve for Production and Total Fertilizer Use



sample. This model is similar in construction to the yield and fertilizer model, however, the Lowess curve for total production and fertilizer use reveals a curvilinear relationship between the two (figure 4.2), so I also include a squared term for fertilizer use.

So, my equation for modeling log total maize production (P) on field i is:

$$ln(P_i) = \beta_0 + \beta_1 ln(x_i) + \beta_2 ln(x_i)^2 + \sum_{j=2}^{m} \beta_j ln(w_{ji}) + \sum_{k=m+1}^{n} \beta_k z_{ki} + \delta_i + \alpha_d + \varepsilon_i. \tag{4.2}$$

Where $ln(x_i)$ is logged total fertilizer use on field i, $ln(w_{ji})$ $(j = 2, 3, ..., m)$ is now the set of all logged predictor variables including inputs and farm characteristics, and z_{ki} $(k = m+1, m+2, ..., n)$ is now the set of all other predictor variables including categorical and dummy variables. These two equations will yield slightly different estimates of the effect of fertilizer use on yield, with slightly different interpretations.

Equation 4.2 will require a "starting point" to determine the impact of adjusting fertilizer application from a current level of fertilizer use and production, whereas equation 4.1 will predict constant returns to fertilizer use. Since fertilizer usually has decreasing marginal returns, a model that predicts fertilizer's impact given current input and output levels should give a more accurate picture of the value of adding additional fertilizer, while a model that predicts constant returns will provide a simpler picture of the value of fertilizer on average. To ensure accurate measures of significance for the fertilizer application variable and the other predictor variables in the model, I use robust standard errors clustered at the district level to control for heteroskedasticity of errors in both of these models. Additionally, while I constructed these models to control for the differences in farmer and farm characteristics throughout Ghana, given the large variations between

these characteristics in the North and South, I also consider each of these models separately for farmers in the North and South.

Quantile Regressions

The above regressions present a good overall picture of the effects of fertilizer use on maize yield, but I also use quantile regressions at the 0.25, 0.5, and 0.75 levels to estimate the effects of fertilizer at different yield quantiles. I consider quantile regressions for two reasons: (1) with a skewed distribution, the median may become the more appropriate measure of central tendency, and (2) examining the marginal effects of fertilizer use at different quantiles of yield can provide a better picture of the benefits of fertilizer use for farmers with varying unobserved characteristics that may impact yield. The quantile regression model is similar to the ordinary least squares model discussed above, but approximates the quantile value of yield rather than the mean. Following Hao and Naiman (2007), the quantile regression model is expressed as:

$$y_i = \beta_0^{(p)} + \beta_1^{(p)} x_i + \sum_{j=2}^{n} \beta^{(p)} z_{ji} + \epsilon_i^{(p)}. \tag{4.3}$$

Where $0 < p < 1$ indicates the proportion of the holders having maize yields below the quantile at p. For this equation, z_{ij} $(j = 2, 3, ..., n)$ is the same set of predictor variables from the OLS yield model, equation 4.1, but also includes a set of dummy variables to control for district and soil characteristics.

Similarly, the quantile-regression model using the variables from the production model can be expressed as:

$$ln(P_i) = \beta_0^{(p)} + \beta_1^{(p)} ln(x_i) + \beta_2^{(p)} ln(x_i)^2 + \sum_{j=2}^{m} \beta_j^{(p)} ln(w_{ji}) + \sum_{k=m+1}^{n} \beta_k^{(p)} z_{ki} + \varepsilon_i^{(p)}. \tag{4.4}$$

The Value-Cost Ratio

The price ratio used to calculate the value-cost ratio depends on (1) the market price of maize, (2) the market price of inorganic fertilizer (I use NPK), and (3) the subsidized price of inorganic fertilizer. I obtain these values from the Ministry of Food and Agriculture in Ghana for the 2011/2012 major growing season. The output-nutrient ratio depends on β_1, the coefficient of fertilizer in equations 4.1 and 4.2. In equation 4.1, the application of β_1 in the output-nutrient ratio is relatively straightforward: an additional kilogram of fertilizer is associated with an increase of β_1 metric tons (or 1,000*β_1 kg) in yield. So, the output-nutrient ratio in kilograms using equation 4.1 is defined as:

$$O/N = (1000 * \beta_1)/1. \tag{4.5}$$

Similarly, following the above methods but using the fertilizer elasticity of output, for equation 4.2 the ratio is:

$$O/N = (1000 * \Delta P)/\Delta F. \tag{4.6}$$

Where the increase in production associated with a ten percent increase in fertilizer use is given by $\Delta P = (1 + .10 * \beta_1 + \beta_2) * P - P$ and the increase in fertilizer use by ten percent is given by $\Delta F = 1.10 * F - F$.

The Farmer's Decision

A farmer's decision to apply fertilizer is a binary outcome dependent on the factors that determine fertilizer profitability, the factors that contribute to the farmer's knowledge of effective fertilizer application practices and knowledge of its true profitability, and the factors that impact the farmer's ability to access fertilizer; while these are reasonable expectations of what factors impact the fertilizer-use decision of farmers in Ghana, the actual factors are unknown. To begin to determine what factors are significant and how they impact the farmer's decision, I use a linear probability model with fertilizer use as the outcome variable, taking on 1 if the farmer applied any fertilizer and 0 if they did not. I use a linear probability model instead of a nonlinear model because it is easy to interpret, because the odds ratio is not very close to 0 or 1, and because the farmer's decision to apply fertilizer most likely does not follow a standard normal distribution. So to determine the effects of various factors on the farmer's decision to apply fertilizer (F), I use the equation:

$$P(F = 1|X) = x'\beta. \tag{4.7}$$

Where X is the vector of chosen regressors, and the parameters β are estimated using least squares. The vector of X's that I chose consists of variables that could influence any of the factors in the farmer's decision function (discussed in the conceptual framework). Because those factors are functions of a large number of variables, examining the impact of those variables on the farmer's decision could provide insight as to how farmers in Ghana make this decision. To strengthen these results, I also include a probit model with fertilizer use as the outcome variable, using the same set of regressors as in the linear probability model, and including indicator variables to control for district.

5 Maize Response to Fertilizer

In this chapter I first discuss the specific variables included in my model for determining maize yield response to fertilizer, next I discuss the results from the OLS regressions modeling maize yield and logged production, then I discuss the results of my quantile regressions, and finally I discuss the implications of each of the models.

5.1 Variables

Yield

I calculated maize yield by dividing total production by the total area that maize was planted on; however, the mean maize yield in my sample (2.99 mT/Ha) is significantly above the mean calculated by the FAO (1.8 mT/Ha). Additionally, the median yield in my sample is well below the mean indicating that reports of yield in my sample are skewed to the right, and I have a few larger reported yields that are causing the high mean value. This is typical when dealing with yield data and does not necessarily indicate a problem, but some of the very large yield values seem unlikely, and probably indicate either an overestimate of production or an underestimate of field area. To handle these large values as well as some very small values, I drop the top and bottom 5-percent of yield values— yields above 7 mT/Ha and below 0.30 mT/Ha. Additionally, since some of these large yield values are the result of very small reports of field area, I remove all observations with reported field areas below 0.01 Hectares (100 square meters). My alternate method for handling these outliers is to use the logged production model, which decreases the impact of outliers.

Table 5.1: Summary statistics for maize yield and production

	Mean	Median	# Observations	Min	Max
Yield (mT/Ha)	1.53	1.10	802	0.10	8.31
Production (mT)	0.97	0.60	802	0.02	9.10
Field Area (Ha)	0.75	0.54	802	0.02	5.43

note: outliers removed

Table 5.2: Summary statistics for maize yield, production, and area for farmers in the North and South

	Northern Ghana			Southern Ghana		
	Mean	Median	# Observations	Mean	Median	# Observations
Yield (mT/Ha)	1.22	0.98	326	1.75	1.30	476
Production (mT)	0.99	0.80	326	0.96	0.52	476
Field Area (Ha)	0.91	0.71	326	0.64	0.41	476

Table 5.1 shows the adjusted mean and median of yield and production after removing outliers. These results still indicate that the yield and production distributions from my sample are right skewed,

however the mean estimates have decreased significantly after removing just a few outliers. Table 5.2 shows the mean and median of yield, production, and area for farmers in Northern and Southern Ghana in my sample. These estimates agree with the literature, indicating that field sizes tend to increase from the South to the North, while yields tend to decrease.

Inputs

The farm inputs I include in my model of maize yield are the amounts spent on: inorganic fertilizer, certified seeds, labor for tending and harvesting, pesticides, selective herbicides, machinery for ploughing and tilling, and whether or not the farmer used certified seeds. Similar to the yield data, however, for all of the input variables the median is always less than the mean indicating that the distributions of amounts spent on these inputs are skewed right. Closer examination of the data reveals some unrealistic values that are likely the culprits of the very high means in the data. Table 5.3 summarizes these variables after removing outliers in each category. With the removal of just a few observations, the means of all of these variables decrease significantly, drawing the mean values closer to the median. This table shows that farmers in Ghana, on average, spend more on fertilizer than other inputs. Additionally, this table reveals that the median for a majority of these inputs are zero, indicating that more than half of the farmers did not spend any money on that input.

Table 5.4 summarizes these input variables separately for farmers in my sample in Northern and Southern Ghana. These estimates reveal that, on average, farmers in the North spend more on fertilizer per hectare, labor for tending per hectare, and machinery for ploughing and tilling than farmers in the South; while farmers in the South tend to spend more per hectare on certified seeds, labor for harvesting, pesticides, and selective herbicides.

The amount spent on certified seeds and whether the farmer used certified seeds at all are very important for examining the effects of fertilizer, since non-certified seeds may not be responsive to fertilizer. Out of my sample of holders, after removing outliers, about 31-percent of holders use certified seeds. There is a large difference in the proportions of farmers in the North and South using certified seeds; in my sample, only 10-percent of farmers in the North use certified seeds, while 44-percent of farmers in the South report using them, which may contribute to the higher average amount spent on certified seeds in the South than North. Since farmers in the North tend to use more fertilizer than those in the South, the lower prevalence of certified seeds seems illogical, however, farmers may still be using seed varieties which are responsive to fertilizer if they are not purchasing certified seeds.

Finally, because I am interested in the amount of fertilizer applied rather than the amount spent on fertilizer, I calculate an estimate of the amount of inorganic fertilizer applied using the amount spent and

Table 5.3: Summary statistics of inputs

	Mean	Median	# Observations	Min	Max
Fertilizer	77.55	0	802	0	424.33
Seeds	12.33	0	802	0	320.37
Labor-Tending	22.87	0	802	0	998.57
Labor-Harvesting	34.64	17.94	802	0	457.14
Pesticides	2.51	0	802	0	276.32
Herbicides	10.20	0	802	0	324.18
Plough/Till (GH¢)	21.90	0	802	0	500

note: outliers removed

note: units in GH¢/Ha unless otherwise noted

Table 5.4: Summary statistics of inputs for farmers in the North and South

	Northern Ghana			Southern Ghana		
	Mean	Median	# Observations	Mean	Median	# Observations
Fertilizer	136.76	137.30	326	37.00	0	476
Certified Seeds	3.28	0	326	18.52	0	476
Labor-Tending	28.40	0	326	19.08	0	476
Labor-Harvesting	17.67	0	326	46.27	30.78	476
Pesticides	1.11	0	326	3.47	0	476
Herbicides	3.90	0	326	14.52	0	476
Plough/Till (GH¢)	30.36	10	326	16.11	0	476

note: units in GH¢/Ha unless otherwise noted

the price paid for NPK (the most widely used fertilizer in my sample and generally in Ghana). I do this by dividing the total amount the farmer paid for fertilizer on maize fields by the district average price of a 50kg bag of NPK. To produce the amount of fertilizer applied in kilograms, I multiply this value by 50.

Table 5.5 summarizes this new variable on total fertilizer application in kilograms and kilograms per hectare. The mean value for fertilizer application seems high, but these values are not impossible or unfathomable considering this accounts for all inorganic fertilizers applied to maize fields. Table 5.6 shows these estimates separately for farmers in the North and South; the results indicate that farmers in the North tend to apply more total inorganic fertilizer and inorganic fertilizer per hectare than farmers in the South. Given the lower rainfalls and generally worse growing conditions in the North, these farmers may be applying more fertilizer simply to combat their adverse growing conditions. Despite the higher fertilizer use in the North, only about 12-percent of the farmers in the North who are applying fertilizer are also using certified seeds, while in the South roughly 74-percent of the farmers applying fertilizer are also using certified seeds. Since fertilizer is likely to be more effective when used with high quality seeds, this discrepancy in the use

Table 5.5: Summary statistics of inorganic fertilizer use

	Mean	Median	# Observations	Min	Max
Inorganic Fertilizer (kg/Ha)	124.76	0	802	0	581.58
Total Inorganic Fertilizer (kg)	94.19	0	802	0	638.79

Table 5.6: Summary statistics of inorganic fertilizer use in North and South

	North		South	
	Mean	Median	Mean	Median
Inorganic Fertilizer (kg/Ha)	226.02	226.81	55.41	0
Total Inorganic Fertilizer (kg)	188.20	180.17	29.80	0

Table 5.7: Summary statistics of binary farmer and household characteristics

	Percent	# Observations
Able to Sell	33.54	802
Farmer	88.15	802
Household Head Male	77.93	802
No Education	55.61	802
≤Kindergarten	0	802
Kindergarten–Primary	8.73	802
Primary–Middle	11.22	802
Middle–Secondary	21.07	802
>Secondary	3.37	802

of certified seeds between farmers in the North and South could largely impact the effectiveness of fertilizer for farmers in those areas.

To strengthen my results, in addition to a regression model including all observations summarized above, I also consider a model including only farmers who report using some fertilizer. I do so because including farmers with zero fertilizer application rates reduces the fit of my model due to large fluctuations in yield responses from farmers who did not apply fertilizer. My purpose is to determine how maize yields respond to additional fertilizer use, and my model appears to analyze that relationship more precisely conditional on positive fertilizer use.

Farmer and Household Characteristics

I control for the following farmer and household characteristics: the land tenure status of the maize plot, whether the household head is male, indicators of household development, whether the holder's primary occupation is farming, the holder's education and age, the household size, the heads of chicken owned by the holder, total farm area, and the number of years the farmer has been cultivating on the field.

Table 5.7 shows that a majority of holders are not able to sell their fields (usually meaning the farmer has limited rights over the land), that a majority of holders' primary occupation is farming, that males head a majority of households, and a majority of holders have no formal education. The education levels are treated as categories, where kindergarten indicates that the farmer had no higher than a kindergarten education, primary indicates that the farmer had more than a kindergarten education, but no more than primary, and so on. Table 5.8 presents these same descriptive statistics separately for farmers in Northern and Southern

Table 5.8: Summary statistics of binary farmer and household characteristics for North and South

	North		South	
	Percent	# Observations	Percent	# Observations
Able to Sell	41.10	326	28.36	476
Farmer	88.96	326	87.61	476
Household Head Male	93.87	326	67.02	476
No Education	67.79	326	40.97	476
≤Kindergarten	0	326	0	476
Kindergarten–Primary	3.99	326	11.97	476
Primary–Middle	4.60	326	15.76	476
Middle–Secondary	10.43	326	28.36	476
>Secondary	3.99	326	2.94	476

Table 5.9: Summary statistics of household development indicators

Floor Type:	Proportion	Electricity Type:	Proportion	Drinking Water:	Proportion	Cooking Fuel:	Proportion	Sanitation	Proportion
Earth/Mud	21.82	Electricity (Mains)	48.13	Pipe, Inside	4.61	None	1.12	None	43.27
Cement/Concrete	77.06	Private Generator	0.75	Pipe, Outside	28.93	Wood	67.96	Water Closet	2.12
Stone	0	Kerosene Lamp	32.54	Bore Hole/Pump	44.14	Gas	2.00	Pit Latrine	15.21
Burnt Bricks	0	Gas Lamp	0.12	Protected Well	4.24	Electricity	0	KVIP	10.60
Wood	0	Solar Energy	0.37	Rain	1.25	Kerosene	0.12	Bucket	0.87
Vinyl Tiles	0.12	Candle	0.12	Protected Spring	0.25	Charcoal	16.71	Public Toilet	27.18
Ceramic/Porcelain	0.25	Flashlight	17.33	Bottled Water	0.12	Crop Residue	11.97	Other	0.75
Terrazo	0.37	Firewood	0.12	Sachet Water	2.37	Saw Dust	0		
Other	0.37	Crop Residue	0.25	Tanker/Vendor	1.37	Animal Waste	0.12		
		Other	0.25	Unprotected Well	3.87	Other	0		
				Unprotected Spring	0.12				
				River	7.86				
				Dugout	0.75				
				Other	0.12				
# Observations	802		802		802		802		802

Table 5.10: Summary statistics of household development indicators for North

Floor Type:	Proportion	Electricity Type:	Proportion	Drinking Water:	Proportion	Cooking Fuel:	Proportion	Sanitation	Proportion
Earth/Mud	21.82	Electricity (Mains)	48.13	Pipe, Inside	4.61	None	1.12	None	43.27
Cement/Concrete	77.06	Private Generator	0.75	Pipe, Outside	28.93	Wood	67.96	Water Closet	2.12
Stone	0	Kerosene Lamp	32.54	Bore Hole/Pump	44.14	Gas	2.00	Pit Latrine	15.21
Burnt Bricks	0	Gas Lamp	0.12	Protected Well	4.24	Electricity	0	KVIP	10.60
Wood	0	Solar Energy	0.37	Rain	1.25	Kerosene	0.12	Bucket	0.87
Vinyl Tiles	0.12	Candle	0.12	Protected Spring	0.25	Charcoal	16.71	Public Toilet	27.18
Ceramic/Porcelain	0.25	Flashlight	17.33	Bottled Water	0.12	Crop Residue	11.97	Other	0.75
Terrazo	0.37	Firewood	0.12	Sachet Water	2.37	Saw Dust	0		
Other	0.37	Crop Residue	0.25	Tanker/Vendor	1.37	Animal Waste	0.12		
		Other	0.25	Unprotected Well	3.87	Other	0		
				Unprotected Spring	0.12				
				River	7.86				
				Dugout	0.75				
				Other	0.12				
# Observations	326		326		326		326		326

Table 5.11: Summary statistics of household development indicators for South

Floor Type:	Proportion	Electricity Type:	Proportion	Drinking Water:	Proportion	Cooking Fuel:	Proportion	Sanitation	Proportion
Earth/Mud	21.43	Electricity (Mains)	62.18	Pipe, Inside	3.99	None	1.47	None	15.76
Cement/Concrete	77.31	Private Generator	0.84	Pipe, Outside	39.92	Wood	74.37	Water Closet	3.15
Stone	0	Kerosene Lamp	19.96	Bore Hole/Pump	27.52	Gas	3.15	Pit Latrine	23.11
Burnt Bricks	0	Gas Lamp	0	Protected Well	4.20	Electricity	0	KVIP	11.97
Wood	0	Solar Energy	0	Rain	2.10	Kerosene	0	Bucket	1.47
Vinyl Tiles	0.21	Candle	0.21	Protected Spring	0.42	Charcoal	20.80	Public Toilet	43.91
Ceramic/Porcelain	0.42	Flashlight	16.60	Bottled Water	0.21	Crop Residue	0.21	Other	0.63
Terrazo	0.42	Firewood	0	Sachet Water	3.99	Saw Dust	0		
Other	0.21	Crop Residue	0.21	Tanker/Vendor	2.31	Animal Waste	0		
		Other	0	Unprotected Well	2.73	Other	0		
				Unprotected Spring	0.21				
				River	11.13				
				Dugout	1.05				
				Other	0				
# Observations	476		476		476		476		476

Table 5.12: Summary statistics of farmer and household continuous characteristics

	Mean	Median	Observations	Min	Max
Age (years)	46.90	45	802	13	90
Household Size	6.59	6	802	1	30
Heads Chicken	7.63	0	802	0	65
Years Cultivating	20.34	7	802	1	112
Total Area (Ha)	1.65	1.17	802	0.02	11.60

Table 5.13: Summary statistics of farmer and household continuous characteristics for North and South

	North			South		
	Mean	Median	# Observations	Mean	Median	# Observations
Age (years)	45.83	44.5	326	47.64	46	476
Household Size	8.41	7	326	5.35	5	476
Heads Chicken	12.02	9	326	4.62	0	476
Years Cultivating	36.63	16	326	9.18	5	476
Total Area (Ha)	1.95	1.48	326	1.45	0.97	476

Ghana. These results indicate that farmers in the North are more likely to be able to sell their land, more likely to be in a house headed by a male, and more likely to have no formal education than farmers in the South.

In table 5.9, each variable is an indicator of development from the living standard indicator of poverty in the multidimensional poverty index (MPI). I include these variables as additional control variables for the household's income/level of development. I chose to only discuss the most frequent responses of these variables because they are categorical, so I am mainly interested in noting the most prevalent household conditions. The floor variable has nine response options; in the MPI a response of 'mud/earth' indicates the household is deprived, and the other eight options indicate it is not deprived. The electricity variable has ten response options; in the MPI a response of 'electricity' indicates the household is not deprived, while the other options indicate it is deprived. The drinking water variable has 14 response options where options 1 through 8 (ranging from 'pipe-bourne' to 'satchet water', and including 'bore hole/pump') indicate a form of safe drinking water according to the Millennium Development Goals (MDG) guidelines and thus indicate not deprived in the MPI. The cooking fuel variable has 10 response options where responses of 'gas', 'electricity', or 'kerosene' indicate that the household is not deprived according to the MPI. Finally, the sanitation variable has 7 response options for toilet facilities, of which 'water closet' and 'pit latrine' indicate that the facilities are improved according to the MDG guidelines and thus indicate not deprived in the MPI. Table 5.10 and 5.11 reveal that these development indicators are similar for farmers in the North and South, with two exceptions— farmers in the North tend to be considered deprived in electricity and sanitation, whereas most farmers in the South are not considered deprived in any category.

Table 5.12 shows the average farm and farmer characteristics in the sample; the average farmer

in the sample is in his or her 40s, lives in a household with six members, and has been cultivating their current maize field for roughly 20 years. Table 5.13 shows that these average farm and farmer characteristics vary slightly between the North and South; specifically, farmers in the North tend to have more household members, tend to have more chickens, tend to have been cultivating the field for longer, and their total farm sizes tend to be larger than farmers in the South. The largest difference between farmers in the North and South in table 5.12 is the number of years they have been cultivating their fields; farmers in the North, on average have been cultivating their fields for over four times as long as farmers in the South. This may suggest that farmers in the North have higher rates of soil nutrient deficiency, and thus lower soil quality, than those in the South. The median years of cultivation for farmers in the North, however, is drastically lower than the mean, indicating a heavily right skewed distribution; the median years cultivating are still higher for farmers in the North than South.

I chose to include each of these variables because of their relation to the farmer or the farm. The farmer's ability to sell the land may impact how much the farmer is willing to invest in the land since he may not be able to fully realize all the benefits. Whether or not the holder's primary occupation is farming may impact the holder's motivation to increase yield and may result in lower yields due to the holder dividing their time. Male household heads are found, on average, to have higher yields than female-headed households, and this has generally been attributed to males using higher input quantities than females. The farmer's education level could potentially indicate information on fertilizer application and profitability, however the direction of this relationship is unclear. An education could provide the farmer with additional knowledge on farming or it could take the farmer away from the farm and away from gaining information through on farm experience.

The development indicators of the farmer's household serve as indicators of social status and income, which could impact knowledge and access to inputs. The farmer's age could impact knowledge about farming, since the farmer should gain knowledge with age. The household size can serve as an indicator of free labor available to the farmer, and thus serves as a measure of labor in addition to the labor they reported paying. Generally heads of animals on a farm can serve as an indicator of wealth, but the primary animal on farms that grew maize in this survey were chickens, which are not a great indicator of wealth, but are included as an animal headcount measure. The number of years the farmer has been cultivating the field could indicate the farmer's knowledge of the field and crop, but could also indicate land degradation if the farmer has been cultivating on the field for a long period of time. Finally, I include the total farm area because of the literature on the inverse farm size-productivity relationship.

Farm and Field Characteristics

In my model I control for soil color and soil type, weather shocks, and district fixed effects. I include indicator variables for each of six main soil colors, six main soil types, and interaction terms for soil color and type in my model. The GAPS survey provides information on weather shocks at the enumeration area level that affected crop production such as droughts, floods, burning, early/late rains, and wind storms; using this, I include indicator variables for droughts and floods, because these would likely affect maize yields in most of the enumeration area. Since I do not have local weather data I cannot control for the amount of rainfall or temperatures, but these weather conditions are also likely to be similar within small areas in Ghana, so to account for this missing information I include district fixed effects. Along with controlling for variation in weather throughout Ghana, district fixed effects control for unobserved farmer, farm, and soil characteristics common to the district.

5.2 Results

OLS regressions

The results from the OLS regression modeling the relationship between fertilizer application and maize yield are presented in table 5.14. (The full regression results for this model for farmers who report applying fertilizer are shown in Appendix B.) This regression shows that fertilizer application has a positive and significant relationship with maize yield, holding other factors constant. The results in the first column of table 5.14 show the regression results for all farmers in my sample, after removing outliers, including all control variables, and using district fixed effects. These results indicate that applying an additional 1 kg/Ha of inorganic fertilizer is associated with an increase of 1.23 kg/Ha in maize yields. The results in the second column show the same regression results, restricted to the sample of farmers who report applying fertilizer in some amount. These results indicate that increasing fertilizer application by 1 kg/Ha is associated with a 2.75 kg/Ha increase in maize yields. The results of the second model indicate that fertilizer has a larger impact on maize yields when restricting the sample to farmers that are applying it; this is likely an effect of the large variation in reported yields of farmers who report applying no fertilizer, since some report very high yields. I include a lot of control variables in the final model, but I believe that there are still many unobserved factors that should be included in this model to better determine the effects of fertilizer.

In the summary statistics for my sample I found large differences in the characteristics of farmers in the North and farmers in the South, which suggests that there may also be large differences in unobserved characteristics of farmers in these areas. In table 5.15 I present the results of my OLS regression, including all control variables, separately examining farmers in the North and South. In both regression samples, the

Table 5.14: Regression results for OLS yield model

Dependent Variable: Yield (mT/Ha)	All Farmers	Farmers Applying Fertilizer
Fertilizer (kg/Ha)	0.00123***	0.00275***
	(0.000276)	(0.000448)
Observations	802	394
R-squared	0.249	0.502

***Significant at the 1 percent level

Table 5.15: Regression results for OLS yield model-Separate North and South

Dependent Variable: Yield (mT/Ha)	Northern Ghana		Southern Ghana	
	All Farmers	Farmers Applying Fertilizer	All Farmers	Farmers Applying Fertilizer
Fertilizer (kg/Ha)	0.000790**	0.00222***	0.00173**	0.00380**
	(0.000238)	(0.000497)	(0.000533)	(0.00157)
Observations	326	275	476	119
R-squared	0.343	0.495	0.314	0.729

***Significant at the 1 percent level
**Significant at the 5 percent level

full sample and the sample applying fertilizer, For farmers in Northern Ghana, these results reveal a fairly large difference in the effectiveness of fertilizer for maize farmers in these two zones. The overall sample results implicate that for farmers in the North, an increase of 1 kg/Ha in fertilizer correlates with a 0.79 kg/Ha increase in maize yields; while for farmers in the South, the same increase in fertilizer correlates with a 1.73 kg/Ha increase in maize yields. The regression results for the restricted sample similarly reveal a higher response rate for farmers in the South, but both coefficients are also larger; for these farmers in the North, and increase of 1 kg/Ha in fertilizer correlates with a 2.22 kg/Ha increase in maize yields; for these farmers in the South, the same increase correlates with a 3.80 kg/Ha increase in maize yields. These results are consistent with what I would expect given the higher annual rainfalls and higher prevalence of certified seeds in the South, however, since fertilizer use in my sample is concentrated in the North, these results stress the importance of increasing fertilizer use in the South.

These results provide insight into the effects of per hectare fertilizer application on maize yields for farmers in Ghana, but I am also interested in the effects of total inorganic fertilizer use on total maize production. This relationship is modeled in my second OLS regression, equation 4.2, and the results are shown in table 5.16. (The full regression results for this model for farmers who report applying fertilizer are shown in Appendix C.) These coefficients for fertilizer use are interpreted differently from the previous regression in two ways; first, since the outcome and predictor variables are logged, the coefficients are interpreted as percent changes; second, this model additionally requires interpretation of the squared term. Similar to the previous model, the first column of table 5.16 shows the results from the regression including all control variables and considering the entire sample; these results implicate that a 10-percent increase in total

Table 5.16: Regression results from OLS production model

Dependent Variable: Logged Production (mT)	All Farmers	Farmers Applying Fertilizer
Logged Fertilizer (kg)	0.00958**	0.148***
	(0.00433)	(0.0301)
(Log Fertilizer)^2 (kg)	0.0187***	0.0309**
	(0.00432)	(0.0126)
Observations	802	394
R-squared	0.620	0.673

***Significant at the 1 percent level
**Significant at the 5 percent level

fertilizer application is associated with a 0.12-percent increase (a 0.10-percent increase from the linear term, and a 0.02-percent increase from the squared term) in total production (mT). The second column shows the regression results for only the sample of farmers who report applying fertilizer; these results implicate that a 10-percent increase in total fertilizer application correlates with a 1.51-percent increase in total production. Since the squared terms in both regressions are positive and significant, they further reveal that farmers in my sample see increasing returns to fertilizer (there is a convex relationship between fertilizer and maize yields).

Again, as with my yield model, I repeated this OLS regression separately for farmers in the North and South of Ghana; the results are shown in table 5.17 and they reveal very different trends depending on the sample that was included. The results in table 5.17 suggest that for all farmers in Northern Ghana in my sample, a 10-percent increase in total inorganic fertilizer application on maize fields is associated with a 0.84-percent increase in total maize production, while for all farmers in the South in my sample, at low percentage increases in fertilizer application they actually see negative returns to fertilizer, a 10-percent increase in fertilizer application is associated with a 0.59-percent decrease in total maize production. From examining a scatterplot of this data, this negative correlation appears to be a result of the relatively high reported yields of farmers who did not apply any fertilizer, however when those observations are removed the correlation returns to positive. The results in table 5.17 for the regressions including only farmers who apply fertilizers reveal that for these farmers in Northern Ghana, a 10-percent increase in total inorganic fertilizer application on maize fields is associated with a 1.29-percent increase in total maize production, and for these farmers in Southern Ghana, a 10-percent increase in fertilizer application is associated with a 2.32-percent increase in total maize production. Again, all of these regressions have positive squared terms, indicating that a larger percentage increase in fertilizer application increases the magnitude of the effects on production. These regression results have several interesting implications; first, in both the South and North the effects of fertilizer on yields are much larger for the sample of farmers that are applying fertilizer, which may indicate that farmers who aren't applying inorganic fertilizer have found other ways to increase

Table 5.17: Regression results from OLS production model- Separate North and South

Variable: Logged Production (mT)	Northern Ghana		Southern Ghana	
	All Farmers	Farmers Applying Fertilizer	All Farmers	Farmers Applying Fertilizer
Logged Fertilizer (kg)	0.0821***	0.127***	-0.0619**	0.220**
	(0.0112)	(0.0247)	(0.0226)	(0.0705)
(Log Fertilizer)^2 (kg)	0.0197***	0.0233	0.0285***	0.123***
	(0.00307)	(0.0119)	(0.00776)	(0.0316)
Observations	326	275	476	119
R-squared	0.693	0.724	0.644	0.799

***Significant at the 1 percent level
**Significant at the 5 percent level

their yields, which farmers applying fertilizer do not employ. Second, the comparison between farmers in the South and North for the full and conditional samples reveal interesting differences between the groups. For the model of all farmers in my sample, farmers in the North have higher yield responses to fertilizer, while for the conditional sample, farmers in the South have higher responses; this may be indicative of the characteristics of farmers not applying fertilizer, since farmers in the South who don't apply fertilizer still tend to achieve very high yields, while for farmers in the North this is less prevalent.

Quantile regressions

I show the results from the quantile regression modeling the effects of per hectare inorganic fertilizer application on maize yields in table 5.18. Figure 5.1 presents a plot of the coefficients of the fertilizer variable compared with the OLS coefficient. The regression results and the graph indicate that increasing fertilizer application has a positive and significant influence on maize yield at all levels of yield. Observing the relationship between fertilizer and yield at different levels of yield is very useful for interpreting the effects of fertilizer use given other unobserved factors. Figure 5.1 shows that farmers with relatively low yield levels see lower benefits from fertilizer use, while for farmers with higher relative yields, increasing fertilizer application has higher returns to yield. This suggests that the unobserved factors that cause farmers to have relatively low yields decrease the effectiveness of fertilizer, while the factors that cause farmers to have relatively high yields increase the effectiveness of fertilizer. The figure also shows that the OLS regression is most closely representing the returns to fertilizer use in the upper quantile of maize yield. More explicitly, the results in the first column of table 5.18 show that for farmers with yields near the twenty-fifth percentile, an additional 1 kg/Ha of fertilizer correlates with an increase of 1.19 kg/Ha in maize yields. The results in the second column show that for the farmers with yields around the median level, a 1 kg/Ha increase in fertilizer use is associated with a 1.22 kg/Ha increase in maize yields. Finally, the third column shows that for farmers with yields near the seventy-fifth percentile, an additional 1 kg/Ha of fertilizer use correlates with a 1.25 kg/Ha increase in maize yields. For the farmers in my sample who report applying fertilizer, there is a similar but

Table 5.18: Regression results from quantile yield model

Dependent Variable:	All Farmers			Farmers Applying Fertilizer		
Yield (mT/Ha)	$Y_{.25}$	$Y_{.5}$	$Y_{.75}$	$Y_{.25}$	$Y_{.5}$	$Y_{.75}$
Fertilizer (kg/Ha)	0.00119***	0.00122***	0.00125**	0.00159***	0.00253***	0.00310***
	(0.000203)	(0.000329)	(0.000555)	(0.000297)	(0.000359)	(0.000491)
Observations	802	802	802	394	394	394

***Significant at the 1 percent level
**Significant at the 5 percent level

larger increase in yield response to fertilizer across quantiles; the results in the fourth column show that for these farmers with yields around the twenty-fifth percentile, an additional 1 kg/Ha increase in fertilizer use is associated with a 1.59 kg/Ha increase in maize yields. For these farmers around the median level, an additional 1 kg/Ha increase in fertilizer use is associated with a 2.53 kg/Ha increase in yields. Finally, for these farmers in the seventy-fifth percentile, an additional 1 kg/Ha of fertilizer is associated with a 3.10 kg/Ha increase in yields. These results suggest that the unobserved factors that affect farmers' yields also alter the yield returns to fertilizer for all farmers in my sample and even more so for only the farmers in my sample who apply fertilizer, so next I examine whether these factors similarly affect the farmer's returns to fertilizer in terms of total production.

In table 5.19, I show the results from the quantile regression modeling the effects of total inorganic fertilizer application on total maize production. Figure 5.4 presents a plot of the coefficients of the logged fertilizer variable compared with the OLS coefficient. Similarly to the previous quantile regression, the results indicate that increasing fertilizer application has a positive and significant relationship with maize production at all relative levels of production, but this quantile regression reveals a completely different trend in the coefficients of fertilizer use. Figure 5.4 shows that farmers with relatively low maize production levels see the highest benefits from fertilizer, while farmers between the sixtieth and eightieth percentiles of the production distribution see the lowest production returns to fertilizer. More precisely, the first column of table 5.19 shows that for all farmers in my sample with total maize productions near the twenty-fifth percentile relative to their fertilizer use, a 10-percent increase in fertilizer use correlates with a 0.26-percent increase in total production. The second column shows that for farmers with median production levels, a 10-percent increase in fertilizer application is associated with a 0.16-percent increase in total production. Finally, the third column reveals that for farmers near the seventy-fifth percentile of maize production, a 10-percent increase in fertilizer application correlates with a 0.12-percent increase in total production. The regression results for only the farmers in my sample who apply fertilizer reveal similar trends; for these farmers near the twenty-fifth percentile of total maize production, a 10-percent increase in fertilizer use is associated with a 1.86-percent increase in total maize production. For these farmers near the median of

Table 5.19: Regression results from quantile production model

Dependent Variable:	All Farmers			Farmers Applying Fertilizer		
Logged Production (mT)	$P_{.25}$	$P_{.5}$	$P_{.75}$	$P_{.25}$	$P_{.5}$	$P_{.75}$
Logged Fertilizer (kg)	0.0230***	0.0139**	0.00959	0.182***	0.161***	0.110***
	(0.00514)	(0.00551)	(0.00620)	(0.0360)	(0.0265)	(0.0356)
(Log Fertilizer)^2 (kg)	0.0272***	0.0205***	0.0165***	0.0358**	0.0346***	0.0139
	(0.00439)	(0.00470)	(0.00529)	(0.0143)	(0.0105)	(0.0141)
Observations	802	802	802	394	394	394

***Significant at the 1 percent level
**Significant at the 5 percent level
*Significant at the 10 percent level

maize production, a 10-percent increase in fertilizer use is associated with a 1.65-percent increase in total maize production. Finally, for these farmers near the seventy-fifth percentile of production, a 10-percent increase in fertilizer use is associated with a 1.11-percent increase in maize production. Again, the squared term coefficients indicate a convex relationship between fertilizer and production such that as fertilizer use increases by a larger percent, production increases at a higher rate. In the discussion section below I address the implications of these results and the differences between the results of all my models.

5.3 Discussion

The results presented in the previous section generally show that fertilizer use has a positive and significant impact on maize production/yield, but the results indicate several different coefficients for fertilizer use. In this section I compare and contrast the OLS models with their quantile counterpart, compare the trends of the coefficients in the quantile regressions, compare the OLS models for farmers in the North and South, and discuss the implications of these results. In the next chapter I translate the regression results into value-cost ratios for fertilizer application which simplifies comparing across all the models. Identifying the similarities and differences between these results helps to answer the questions posed in this paper and raises new questions as to what is occurring in the sample.

Figure 5.1 shows the fertilizer use coefficients from the OLS and quantile regressions modeling the effect of per hectare fertilizer use on yield for my entire sample. This figure indicates that fertilizer use per hectare has relatively constant returns to yield for farmers at most relative yield levels, however the returns plummet for farmers with the highest relative yields. Figure 5.2 shows the fertilizer use coefficients from the OLS and quantile yield regressions for only the sample that reports applying fertilizer. This figure reveals very different trends in the quantile coefficient than the results from modeling the entire sample; this figure shows that farmers producing at relatively high levels of yield see the highest returns to fertilizer, and farmers producing at lower relative yields see the lowest returns to fertilizer. The quantile coefficients

Figure 5.1: Coefficients from OLS and quantile yield models for entire sample

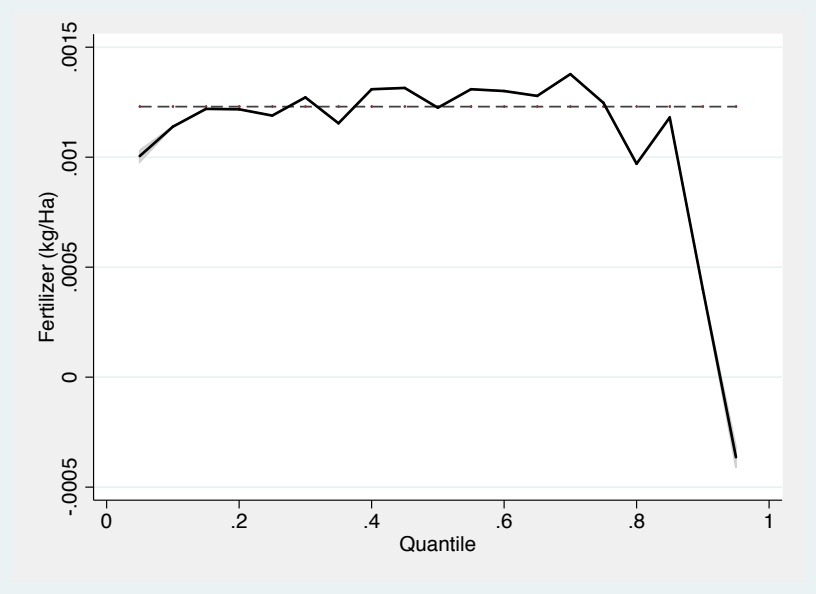


Figure 5.2: Coefficients from OLS and quantile yield models for sample applying fertilizer

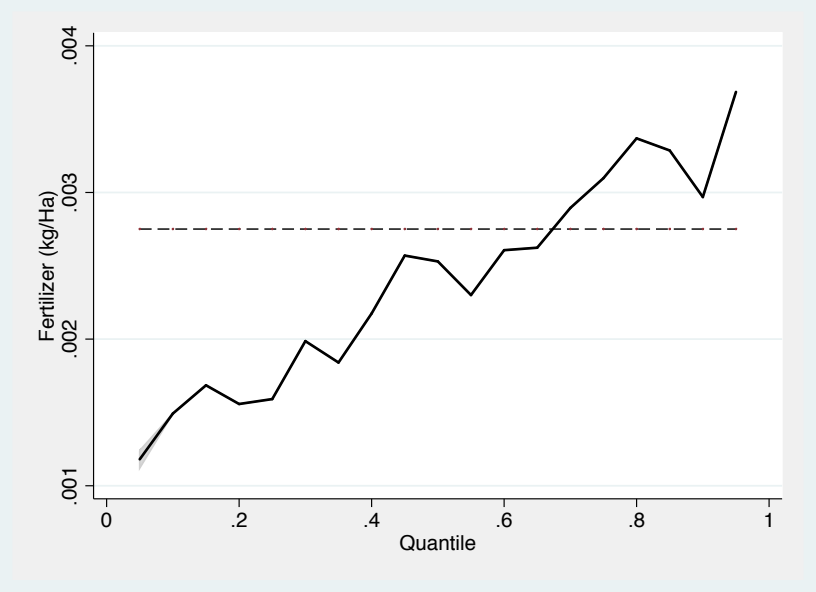
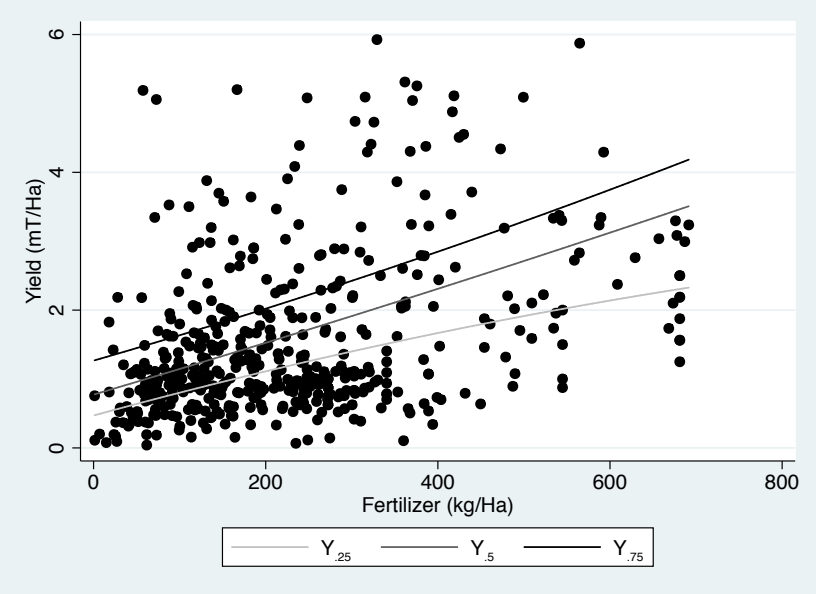


Figure 5.3: Scatterplot of maize yield and per-hectare fertilizer use with quantile predictions



from this restricted sample show that the unobserved characteristics that increase yields also increase the effectiveness of fertilizer. Figure 5.3 demonstrates the yield predictions for farmers at the 0.25, 0.5, and 0.75 quantiles of maize yield in this restricted sample; the varying slopes of the quantile regressions reflect the differences in how responsive maize yields are to fertilizer at relative yield levels. The lowest line shows that farmers at the lowest yields use fertilizer least efficiently, which is likely why their yields are so low, while the top lines show that farmers with higher yields use fertilizer more efficiently.

Figure 5.4 shows the fertilizer use coefficients from the equations modeling the effect of total fertilizer application on total maize production for the entire sample. This figure implicates that as farmers move to relatively higher levels of production, the production returns to fertilizer are generally decreasing; this implies that the smallest relative producers use fertilizer most effectively. Figure 5.5 shows these fertilizer use coefficients for the reduced sample production model, only including farmers who apply fertilizer. This figure reveals a similar trend in the fertilizer coefficients, with fertilizer use having maximum returns for farmers around the 25th percentile of production; however, this model indicates that fertilizer has a much larger impact on production at all levels. Figure 5.6 shows the production predictions for farmers at the 0.25, 0.5, and 0.75 quantiles of production in the reduced sample; while this figure should help conceptualize the quantile regressions, it is not very easy to see the differences in the slopes of these lines. In both the production and yield model, removing farmers who do not report applying fertilizer greatly strengthens the regression results. Farmers who reported not applying any fertilizer also report largely variating yield and production levels, which seem to greatly reduce the correlation that is obvious when those farmers are

Figure 5.4: Coefficients from OLS and quantile total production models for entire sample

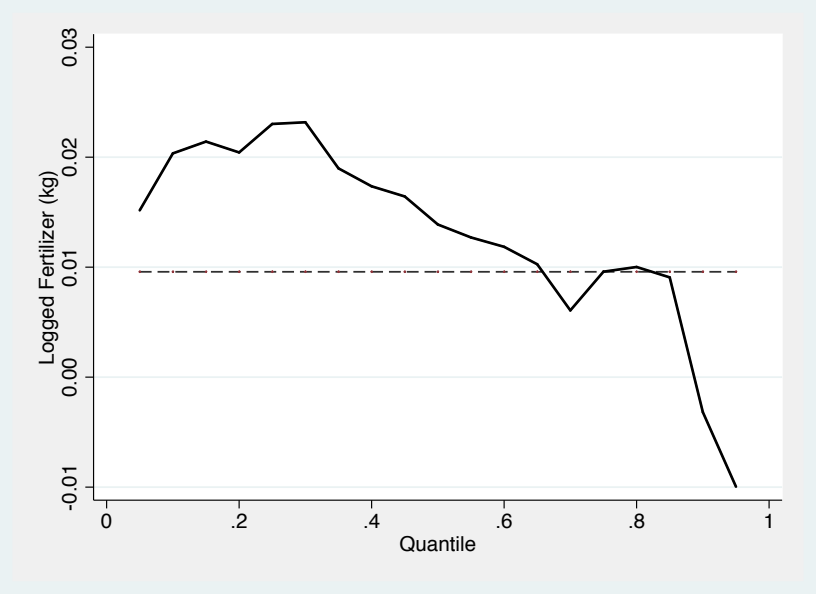


Figure 5.5: Coefficients from OLS and quantile total production models for sample applying fertilizer

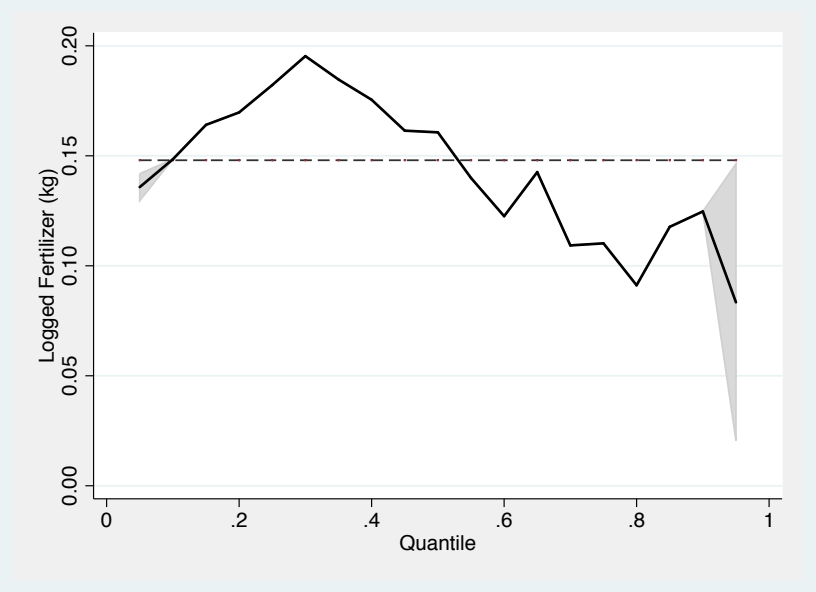
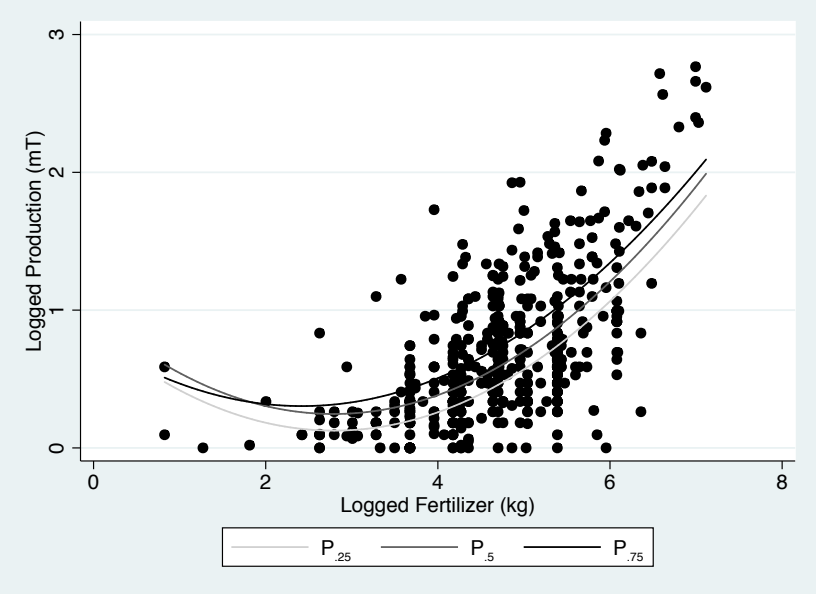


Figure 5.6: Scatterplot of maize production and total fertilizer use with quantile predictions



removed from the sample. Despite the large variations in reported yields and production, however, the regressions containing the entire sample still indicate that fertilizer has a positive and significant correlation with maize yields and production. Given the greatly reduced coefficients in those regressions, to calculate the value cost ratios I only use the regression results from the restricted sample; so, the value cost ratios reflect the benefits of increasing fertilizer usage for farmers who are already applying fertilizer in some amount.

Figure 5.7 shows the OLS yield predictions for farmers in the North and South in the reduced sample. This figure shows that farmers in the South tend to have higher yields at all levels of fertilizer use. Further, this figure shows that the slope of the predicted line for farmers in the South has a larger slope than the line for farmers in the North; this indicates that farmers in the South get higher yield returns to fertilizer than those in the North. Figure 5.8 shows the OLS production predictions for farmers in the North and South in the reduced sample. This figure shows that farmers in the South tend to produce more than farmers in the North in general, and since the slope of the predicted line for farmers in the South is steeper than the one for those in the North, this figure also reveals that farmers in the South get higher fertilizer returns to production than those in the North.

These two figures show that among the farmers in the sample who apply fertilizer, farmers in the South utilize fertilizer more efficiently to increase maize yields and production. Comparing the two pictures, however, reveals that while the slope for fertilizer use in the yield model is near zero for farmers in the North, the slope for fertilizer use in the production model is much steeper. While still less than the returns to fertilizer for farmers in the South, this large increase in fertilizer effectiveness when modeling total

production rather than yields indicates to some extent that farmers in the North better utilize fertilizer to increase total production than they do to increase yields. Considering that a majority of reported fertilizer use in the sample is in the North, these results have significant implications for fertilizer use in Ghana. In the South, where relatively little inorganic fertilizer is applied, farmers see much higher maize returns to fertilizer than farmers in the North, implicating that the current fertilizer use distribution is not the most productive.

The basic implications from the models are obvious: fertilizer use increases yields and production for the average farmers in my sample. Comparing the results for farmers at different quantiles of the yield and production distributions and famers in the North and South, however, has further implications. The quantile regressions show that different groups of farmers in my sample (groups defined by farmers with similar yields or production levels) achieve varying marginal returns to fertilizer. These quantile regressions suggest that understanding the unobserved characteristics that impact yield and production could be very useful for maximizing fertilizer productivity. The OLS regressions for farmers in the North and South reveal that farmers in the South are best at utilizing fertilizer to maximize maize yields and production.

The models demonstrate that fertilizer use does increase maize output for farmers in Ghana, however, these results do not provide insight on whether increasing fertilizer use is the best way to increase yields. More specifically, these models reveal that fertilizer increases yields but does not indicate whether fertilizer generates profits. In the following chapter I employ the value-cost ratio to assess the profitability of fertilizer according to the results from these models. The value-cost ratio will provide practical interpretations of these regression coefficients and insight into whether fertilizer use should be incentivized for farmers in Ghana.

Figure 5.7: Scatterplot of maize yield and per hectare fertilizer use with OLS predictions for farmers in the North and South

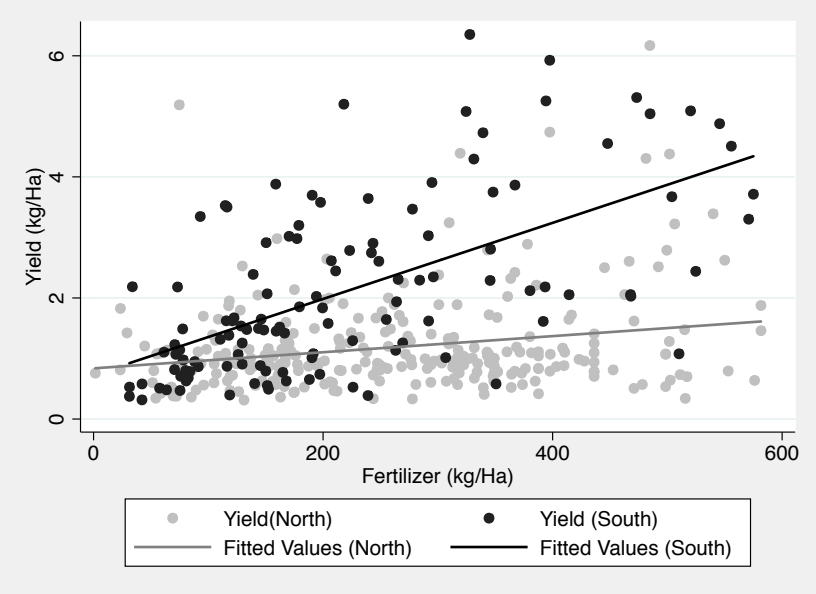
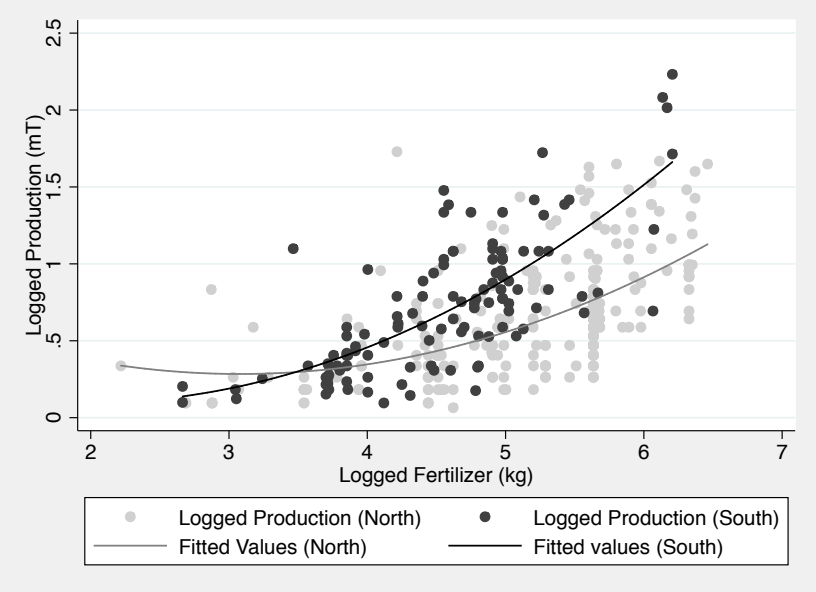


Figure 5.8: Scatterplot of maize production and total fertilizer use with OLS predictions for farmers in the North and South



6 The Value-Cost Ratio

In this chapter I use the regression results from the previous chapter to examine the profitability of fertilizer using different models and considering various starting farm conditions. I begin with determining the nutrient-output price ratio, and then calculate the value-cost ratios using the OLS and quantile regression results.

6.1 The Nutrient-Output Price Ratio

The nutrient-output price ratio is simply defined as the price per unit of nutrient divided by the price per unit of output. The prices per 50kg bag of NPK fertilizer in the 2011/2012 and 2012/2013 seasons are in table 6.1; the table shows the fertilizer costs at the government mandated subsidy and at the estimated market price. For the season that this survey covers (2011/2012 major season), the price of NPK to farmers should have been 39 GH¢. In the remainder of this chapter, when I calculate the value-cost ratio using the OLS and quantile regressions outputs, I will consider (1) whether additional fertilizer application is profitable without subsidized fertilizer, (2) whether it is profitable with subsidized fertilizer, and (3) whether it will be profitable at the following year's subsidized price. So I will consider the nutrient-output price ratio at three levels of fertilizer price per 50kg bag: (1) unsubsidized [76 GH¢], (2) subsidized 2011 [39 GH¢], and (3) subsidized 2012 [51 GH¢].

Table 6.1: NPK Prices (GH¢/50kg)

	Subsidized	Unsubsidized
2011/2012	39	76
2012/2013	51	71.5

Source: MoFA

The sale prices of a 100kg bag of maize for the 2011/2012 season, according to the Ministry of Food and Agriculture in Ghana, are in table 6.2; these sale prices represent the government mandated buying (farm gate) price and government recommended selling (licensed buying company) price. Since these prices likely varied throughout the year, I also look at monthly market maize prices in Ghana for the 2011/2012 season as calculated by Amanor-Boadu (2012) in table 6.3. Since these are the market prices of maize, I would expect them to be similar to the licensed buying company-selling price, and table 6.3 shows that the mean market price is very close to the sales price according to the MoFA. The farm gate price is the price guaranteed to the farmer by the government each year and should be considered the minimum price a farmer will receive for maize; however, this is also a reasonable estimate of the price farmers receive for maize, since a majority of farmers cannot provide their own transportation, storage, or processing and rely on licensed

Table 6.2: Government determined maize prices for 2012 (GH¢/100kg)

	Price
Farm Gate	45
Licensed Buying Company	70

Source: MoFA

Table 6.3: Observed maize prices (GH¢/100kg)

	Minimum	Maximum	Mean
2011/2012	58.12	80.54	71.05

Source: Amanor-Boadu, 2012

buying companies to handle the maize after harvest. So, for simplicity I only consider the nutrient-output price ratio at one level of maize price per 100kg bag: 45 GH¢.

Using this price information, I determine three nutrient-output price ratios that I will use in examining the value-cost ratio by calculating the ratio of the cost of 1 kg of fertilizer (at the 2011/12 unsubsidized, 2011/12 subsidized, and 2012/13 subsidized prices) to the value of 1 kg of maize; the nutrient-output price ratios calculated at each of the fertilizer prices are:

Unsubsidized Fertilizer Price:

$$\frac{76GH¢/50kg}{45GH¢/100kg} = 3.38GH¢/kg, \tag{6.1}$$

2011/2012 Subsidized Fertilizer Price:

$$\frac{39GH¢/50kg}{45GH¢/100kg} = 1.73GH¢/kg, \tag{6.2}$$

2012/2013 Subsidized Fertilizer Price:

$$\frac{51GH¢/50kg}{45GH¢/100kg} = 2.27GH¢/\text{kg}. \tag{6.3}$$

6.2 The VCR

The VCR calculated from the OLS yield model results

In this section I calculate the output-nutrient ratio using the results from the OLS regression modeling yield in the methods section, and then, using the price ratios from the previous section, I calculate the VCR. The coefficient of fertilizer application from the OLS yield model is given in table 5.14 as β_1=0.00275; so, following the equation for the output-nutrient ratio in my methods section, equation 4.5, the output-nutrient

Table 6.4: VCR using the OLS yield model

Output-Nutrient Price Ratio Used	VCR
Unsubsidized	0.81
2011/2012 Subsidy	1.59
2012/2013 Subsidy	1.21

Table 6.5: The VCR for farmers in the North and South using the OLS yield model

Output-Nutrient Price Ratio Used	VCR: North	VCR: South
Unsubsidized	0.66	1.12
2011/2012 Subsidy	1.28	2.20
2012/2013 Subsidy	0.98	1.67

ratio is 2.75.

Table 6.4 shows the corresponding value-cost ratios for this output-nutrient ratio. The results indicate that fertilizer use is not incentivized at any fertilizer price. At the 2011/12 and 2012/13 subsidized prices, the VCRs are greater than 1, implying that additional fertilizer use is profitable, but as I discussed in section 4.1, for this paper I only consider a VCR>2 to provide sufficient incentive.

Further, because I am interested in the profitability of fertilizer for farmers in different areas of Ghana, I also calculate VCRs using the yield regression results for farmers in the South and North. The coefficients of fertilizer application for these models are in table 5.15; for farmers in the North β_1=0.00222, while for farmers in the South β_1=0.00380. These coefficients indicate that the output-nutrient ratios are 2.22 and 3.80 for the North and South respectively.

Table 6.5 shows the VCRs for farmers in the North and South of Ghana calculated using the results of my OLS yield model. These VCRs indicate that for farmers in the South, fertilizer use is sufficiently profitable only at the 2011/2012 subsidized price, while for farmers in the North, additional fertilizer is not incentivized at any price. As noted in the regression results, the fertilizer use coefficient is much lower for farmers in the North than in the South; these VCRs demonstrate that for farmers in the North, fertilizer is not effective enough to incentivize additional use even at the subsidized fertilizer prices.

The VCR calculated from the OLS production model results

Next, I calculate the value-cost ratios using the regression results from my OLS equation modeling logged total maize production. The coefficients of logged fertilizer application and the squared term in the final regression are shown in table 5.16 as β_1=0.148 β_2=0.031. Following the output-nutrient ratio equation from my methods section, equation 4.6, and starting from the mean fertilizer application (F=94.19 kg) and mean production (P=0.97 mT), the output-nutrient ratio is 1.56.

Table 6.6 shows the corresponding value-cost ratios for this model; the results indicate that addi-

Table 6.6: VCR using the OLS production model

Output-Nutrient Price Ratio Used	VCR
Unsubsidized	0.46
2011/2012 Subsidy	0.90
2012/2013 Subsidy	0.69

Table 6.7: VCR for farmers in the North and South using OLS production model

Output-Nutrient Price Ratio Used	VCR-North	VCR-South
Unsubsidized	0.23	3.24
2011/2012 Subsidy	0.46	6.33
2012/2013 Subsidy	0.35	4.82

tional fertilizer use is likely incentivized at the 2011/2012 subsidized fertilizer price, but not at the other fertilizer prices. These results are consistent with the VCRs for the yield model, and since a farmer who is already applying 89 kg of fertilizer should be already applying sufficient fertilizer (depending on their field area), the lower VCRs in this equation seem reasonable; a farmer applying that quantity of fertilizer is not the intended target of the subsidy program.

Next, I again calculate the VCRs for farmers in the North and South, this time using this OLS production model and starting from the mean fertilizer application and mean production for farmers in the North (F=188.20 kg and P=0.99 mT) and the South (F=29.80 kg and P=0.96 mT). The coefficients for fertilizer use from these models are in table 5.17; for farmers in the North β_1=0.13 and β_2=0.02 and for farmers in the South β_1=0.22 and β_2=0.12, so the output-nutrient ratios are 0.79 and 10.95 for the North and South respectively. Before examining the VCRs for farmers in the North and South, I would first like to address the large difference in the output-nutrient ratios for farmers in the two areas; this large difference results from (1) the lower estimated responsiveness to fertilizer for farmers in the North and (2) the higher fertilizer use rates for farmers in the North. If these farmers in the North are actually applying the amount of fertilizer they are reporting, then they are likely over applying, particularly considering the low maize response rates.

The VCRs using the OLS production model results for farmers in the North and South are in table 6.7. This table shows that additional fertilizer use is not profitable for the average farmer in the North at any fertilizer price; this is likely because on average farmers in the North apply 188 kg of inorganic fertilizer, which should be more than sufficient fertilizer use and due to the low coefficient for fertilizer use. On the other hand, farmers in the South have a higher fertilizer use coefficient and have lower mean fertilizer application rates and the VCRs indicate that additional fertilizer use is incentivized for the average farmer in the South at all fertilizer prices; this may be due to the much lower average fertilizer application rate in the South of 30 kg. These results demonstrate the importance of the initial fertilizer use and production

amounts for determining fertilizer profitability using this model; so when looking at the quantile regression results, I will consider the effects of increasing fertilizer application for farmers at different production levels, applying different amounts of fertilizer.

The VCR calculated from the quantile yield model results

Next, I calculate the value-cost ratios using the quantile regression results from my yield model, equation 4.3. This time, however, I will consider three different coefficients of fertilizer application, one for estimating the effects on yield at 0.25, 0.5, and 0.75 quantiles. These coefficients are in table 5.18 as: ($Y_{.25}$) β_1=0.00159, ($Y_{.5}$) β_1=0.00253, and ($Y_{.75}$) β_1=0.00310. So, the output-nutrient ratios are:

$(Y_{.25}) : 1.59$,

$(Y_{.5}) : 2.53$, and

$(Y_{.75}) : 3.10$.

Table 6.8: VCR using the quantile yield model

Output-Nutrient Price Ratio Used	VCR Using $Y_{.25}$	VCR Using $Y_{.5}$	VCR Using $Y_{.75}$
Unsubsidized	0.47	0.75	0.92
2011/2012 Subsidy	0.92	1.46	1.79
2012/2013 Subsidy	0.70	1.11	1.37

Table 6.8 shows the corresponding value-cost ratios using the results from the quantile regression modeling yield. These results reveal that by my standard of fertilizer profitability, at all relative yield levels and all considered fertilizer prices, fertilizer is not profitable. This may indicate that farmers producing at these yield levels are facing challenges with production that cannot be solved with additional fertilizer application. These farmers likely need interventions to address the other causes of their low yields before the fertilizer subsidy program will be useful for them. Despite that fertilizer does not appear profitable for farmers at any of these quantiles, the returns to fertilizer (the output-nutrient ratios) are increasing with the yield quantiles considered. This indicates that as farmers move to higher relative yield levels, they obtain higher returns to fertilizer. These results provide a good overall picture of farmers that produce at these different levels, but it may be more useful to examine the profitability of fertilizer given current fertilizer use and current yields. So, next I examine the profitability of fertilizer for farmers with different fertilizer-use rates and production levels.

The VCR calculated from the quantile production model results

Finally, I calculate the value-cost ratios using the results from the quantile regression modeling logged production. Again, I will consider three different coefficients of fertilizer at the 0.25, 0.5, and 0.75 quantiles

of production, but this time I will additionally consider farmers at three different levels of production and fertilizer use. The coefficients are in table 5.19 as: ($P_{.25}$) β_1=0.182 and β_2=0.04; ($P_{.5}$) β_1=0.161 and β_2=0.035; and ($P_{.75}$) β_1=0.110 and β_2=0.01. I will determine the levels of maize production and fertilizer application by using the quantile values for each. For ($P_{.25}$) I use a starting point of F=5.13 and P=0.30, for ($P_{.5}$) I use a starting point of F= 12.82 and P=0.62, and for ($P_{.75}$) I use a starting point of F=128.21 and P=1.3. So, following equation 4.6, the output-nutrient ratios are:

$(P_{.25}) : 12.87$,

$(P_{.5}) : 9.67$, and

$(P_{.75}) : 1.92$.

The corresponding VCRs in table 6.9 show that at the lower and middle quantiles of production and fertilizer application, fertilizer use is incentivized at all prices, while for farmers producing around the seventy-fifth percentile, additional fertilizer use is not incentivized at any price. These results suggest that smaller and mid-level producers see very high returns to fertilizer, while the larger producers do not use fertilizer as effectively. These results likely occur (1) due to the higher fertilizer use coefficients for farmers in the lower quantiles of the production distribution and (2) because to calculate the VCRs for farmers in those quantiles I use the 25^{th} and 50^{th} fertilizer use estimates for the sample, which are much lower than the estimates for the 75^{th} percentile. The VCRs using the quantile production model produce the most malleable results, and since the utility from increasing fertilizer usage likely varies based on the amount farmers are currently applying as well as their current yields and production levels, these results are likely the most relevant. Rather than examining only central tendency, these VCRs examine the profitability of increasing fertilizer usage for farmers at varying starting fertilizer application and production levels. In the following section I discuss the implications of the VCRs that I calculated in this section using my various regression models.

Table 6.9: VCR using quantile production model

Output-Nutrient Price Ratio Used	VCR Using $P_{.25}$	VCR Using $P_{.5}$	VCR Using $P_{.75}$
Unsubsidized	3.81	2.86	0.57
2011/2012 Subsidy	7.44	5.59	1.11
2012/2013 Subsidy	5.67	4.26	0.85

6.3 Discussion

The value-cost ratios in section 6.2 vary based on the nutrient-output ratio, but generally reveal that additional fertilizer is not incentivized for the average farmers in my sample. The VCRs calculated using the OLS regressions reveal that the average farmer in my sample should not be incentivized to apply fertilizer

at any of the fertilizer prices, implicating that the subsidy program is not an efficient mechanism for raising yields in Ghana. Further, the results of the yield model imply that fertilizer is profitable for farmers in the South only at the 2011/12 subsidized fertilizer price, while it is not profitable for those in the North at any of the considered prices. The results from the production model indicate that additional fertilizer is profitable for the average farmer in the South at all considered fertilizer prices, while fertilizer is again, not profitable for the average maize farmer in the South at any of the prices; this is likely because farmers in the North are already applying large quantities of fertilizer.

While considering fertilizer profitability for the average farmers in the North and South enables me to examine some variation in profitability, I am more interested in the VCRs from the quantile regressions; the quantile regressions allow me to assess fertilizer profitability for farmers at different points on the yield distribution. Since these farmers may have different unobservable characteristics that affect their relative yield levels and their fertilizer profitability, determining the yield levels where fertilizer use is profitable could reveal the groups who the subsidy program is effective for and the groups that may require different policy solutions to increase their yields.

Figure 6.1: VCRs for quantile yield equation using subsidized fertilizer prices

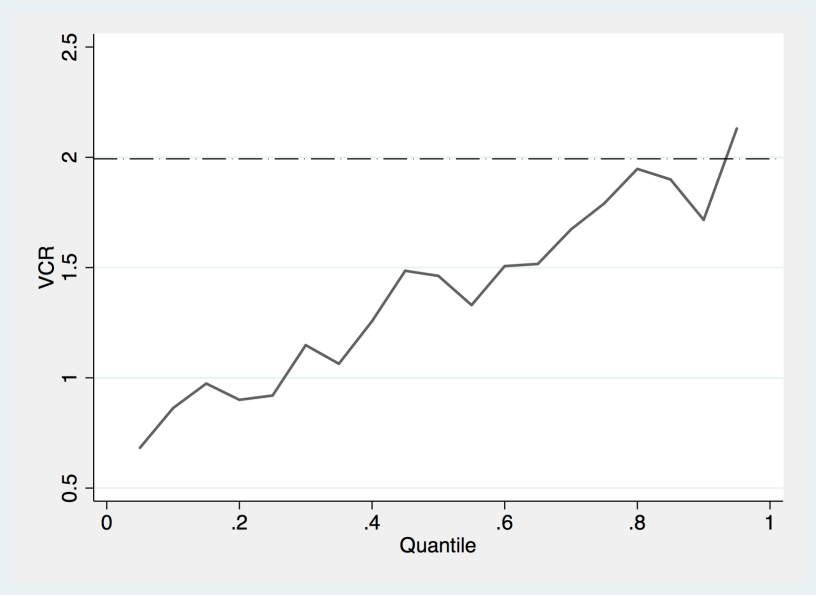


Figure 6.1 shows the VCRs for farmers producing at different quantiles of yield using the results from the quantile yield model at the 2011/2012 subsidized fertilizer price. This shows that using the quantile yield regression results, only the farmers at the very top of the maize yield distribution should have sufficient incentive to apply fertilizer at the subsidized price, while for all other farmers, the subsidy program still does not incentivize fertilizer use; for farmers with VCRs below the dashed line (where VCR=2), either a larger

subsidy or a different policy solution is necessary to increase their yields. Increasing fertilizer use should be a viable option for increasing yields for all farmers currently applying fertilizer at sub-optimal rates, but using alternate policies designed to increase fertilizer use or policies targeting other yield-increasing practices may be more cost-effective.

The 2011/2012 subsidy program absorbed half the costs of fertilizer, while further increasing the subsidy amount would be effective at increasing fertilizer profitability, this would be a very expensive solution and there are likely better options for increasing yields. The primary tool for increasing fertilizer use should be increasing fertilizer profitability, which can be done by either decreasing costs or increasing revenues. The primary policy tool for decreasing costs is the use of subsidies, but there are many ways to increase revenues, mainly through maximizing the returns to fertilizer.

For this paper, I concentrate on increasing yields through increasing fertilizer use in Ghana, but there are many other inputs and practices that could increase yields. In general, in Ghana the use of inputs are low, farmers are highly dependent on rainfall, and farmers face very risky growing conditions. Future work on increasing yields in Ghana should examine other policies which could impact some of these other yield-increasing practices or which could increase the effects of fertilizer on yields. In this paper, I contribute to this purpose in the following chapter; having addressed how the subsidy program impacts fertilizer use, I examine other farm and farmer characteristics that influence whether the farmer uses fertilizer.

7 The Farmer's Decision

In this chapter I discuss the farmer's decision to apply fertilizer. In the previous chapter I found that inorganic fertilizer use was profitable for the average maize farmer at the 2011/2012 subsidized fertilizer price, yet only about one third of the farmers in my sample reported applying inorganic fertilizer. I would expect farmers to apply fertilizer if it is profitable, but the farmers in my sample do not appear to behave this way. In this chapter I examine what variables impact whether or not the farmer applies fertilizer to determine what other factors are motivating farmers in my sample to apply fertilizer. Identifying these variables may reveal new policies to increase fertilizer use in Ghana.

7.1 Variables

Fertilizer application

Since I am only attempting to find factors that significantly affect the farmer's decision to apply fertilizer, I create a dummy variable for fertilizer application to use as the dependent variable. This variable is equal to one if the farmer reports applying inorganic fertilizer to maize during the 2011/2012 major season and is equal to zero otherwise.

Table 7.1: Percent of farmers applying inorganic fertilizer

	Percent	Total #
Farmers in Northern Ghana	56.79	243
Farmers in Southern Ghana	13.34	757
Farmers in all of Ghana	23.90	1000

Table 7.1 shows the percentage of farmers in my sample that report applying fertilizer in some amount. The majority of farmers in my sample did not apply any fertilizer, however, there is a considerable difference between the percent of farmers in the North applying fertilizer and the percent in the South. In the previous chapter I found that additional fertilizer should be incentivized for the average farmer in the South at the 2011/2012 subsidized fertilizer price, yet less than one-fifth of them report applying fertilizer in any amount, while more than one-half of farmers in the North report applying at least some fertilizer. Due to this disparity in fertilizer application rates, as well as the differences in weather, soil quality, and farm and farmer characteristics between farmers in the North and South, I include separate regressions for these farmers in addition to my overall model.

Table 7.2: Summary statistics of fertilizer profitability variables

	Farmers Applying Fertilizer			Farmers Not Applying Fertilizer		
	Mean	Median	# Observations	Mean	Median	#Observations
District Price NPK	32.89	30.45	239	41.91	35	761
Total Area (Ha)	1.68	1.21	239	1.19	0.49	761
Holder has Property Rights (%)	41. 00	−−	239	24.97	−−	761
Seeds	8.75	0	239	9.06	0	761
Plough/Till	21.05	0	239	32.25	0	761
Pesticides	0.56	0	239	1.81	0	761
Herbicides	4.49	0	239	15.69	2	761
Labor-Tending	3.41	0	239	9.21	0	761

note: units are in GH¢ unless otherwise indicated

Profitability of fertilizer application

I am mainly interested in finding factors other than fertilizer profitability that affect the farmer's decision to apply fertilizer, but I also have to include measures of fertilizer profitability as control variables to ensure that I am isolating the effects of the other variables. The variables for profitability that I control for are the district price of fertilizer, the total farm area, whether the holder has the ability to sell the land, the other inputs, and the color and type of the soil. I only include variables that impact the profitability of fertilizer at the time of purchase; for example, while weather shocks can impact fertilizer profitability, the farmer does not usually have information on the shocks at the time of fertilizer application, so I do not include weather shocks in this model. The summary statistics for the variables I include in the model to control for fertilizer profitability are in table 7.2. This table reveals that farmers who reported applying fertilizer tended to have a lower district average price of NPK fertilizer and were more likely to be able to sell their land than farmers who did not apply fertilizer, but does not indicate very large differences in the other fertilizer profitability variables.

I chose to include each of these variables because they in some way affect fertilizer profitability. The price of fertilizer is directly linked to fertilizer profitability, since an increase in the price without a change in the sale price of maize will result in an increase in the nutrient-output price ratio. Unfortunately, I only have fertilizer price data for farmers who purchase fertilizer, so I can only construct fertilizer prices by averaging these reported prices at the district level. I provide summary statistics for the district price of NPK, however, I do not include it in the final regression because I include district fixed effects in the model which already account for varying fertilizer prices by district. A larger total farm area may cause the farmer to spread his limited resources across a larger area, potentially resulting in the farmer not being able to afford applying fertilizer to maize fields because its allocation may be more profitable on other crops. Whether the holder has the ability to sell their land may impact the farmer's willingness to make investments in the property, such as apply fertilizer to increase soil fertility, because they may not be able to reap future benefits of that

Table 7.3: Summary statistics of farmer's information variables

	Farmers Applying Fertilizer		Farmers Not Applying Fertilizer	
	Mean	# Observations	Mean	# Observations
Years Cultivating (Years)	26.78	239	9.96	761
Extension Visits	0	239	0	761
Age (Years)	46.32	239	47.50	761
Distance Extension Agent (km)	67.46	239	47.00	761
	Percent	#Observations	Percent	#Observations
No Education	63.60	239	50.33	761
Kindergarten	0	239	0	761
Primary	7.53	239	9.99	761
Middle	9.21	239	12.61	761
Secondary	15.48	239	24.57	761
Beyond	4.18	239	2.50	761
Farmer	89.54	239	89.22	761

behavior. The use of other inputs and their quality may impact the effectiveness of fertilizer, thus impacting the profitability. Finally, the soil quality may impact the extent to which applying fertilizer will increase output, and thus impact the profitability.

Information

Policies and interventions that increase the farmer's knowledge about how to apply fertilizer and the benefits of doing so are frequently employed in conjunction with fertilizer subsidy programs. This can be a very effective policy to increase farmers' knowledge about fertilizer profitability and profit-maximizing application procedures. Farmers with more information should be more likely to apply fertilizer if it is profitable, so I include several variables in my model that are associated with the farmer's information. I include variables for how long the holder has been farming on the field, the holder's education level, whether the holder's primary occupation is farming, whether any extension agents visited the farmer, the holder's age, and the distance to the nearest extension agent office. The summary statistics for these variables are in table 7.3. This table shows that farmers who apply fertilizer tend to have been cultivating their maize fields for longer, tend to be further from an extension office, and tend to have less formal education than those who do not apply fertilizer.

Each of these variables indicates the farmer's overall knowledge and some are more directly related to the farmer's information on fertilizer use. How long the holder has been farming on the field could indicate the farmer's knowledge of fertilizer profitability on that field. Whether or not the holder's primary occupation is farming may impact the holder's knowledge about profitable farming practices and may also impact the farmer's motivation and time available for applying fertilizer. The holder's education level and

Table 7.4: Summary statistics of variables for access to fertilizer

	Applying Fert.	Not Applying
	Mean	Mean
Time to Weekly Market (min)	42.83	54.64
Heads of Chicken	13.38	6.26
Heads of Goats	1.23	1.42
	Percent	Percent
Access Credit	0.84	4.60
Household Head Male	89.12	72.54
Pre-Harvest Contract	0.84	1.31

age both have the potential to increase the farmer's knowledge about applying fertilizer and the profitability of applying it. A farmer's access to extension agent services could directly influence the holder's knowledge of fertilizer profitability, so I use the distance from the farm to the nearest extension office and the number of visits from extension agents to determine the effects of this increased knowledge. Unfortunately, despite the potential usefulness of a question in the survey about extension agent visits, no one in my sample of maize producers reported having any visits from MoFA extension agents in the past 12 months, so I could not include that variable. Also, because the extension offices are in larger cities throughout Ghana, the farm's distance from the nearest extension office variable also (generally) represents the distance from the nearest large city.

Access to fertilizer

Whether or not a farmer can physically and financially access fertilizer is an obvious determinant of whether the farmer will purchase fertilizer. I am interested in examining what barriers to access significantly deter farmers from purchasing fertilizer. The variables I include in my model as indicators of fertilizer access are the distance to the weekly market, the farmer's heads of livestock, whether the farmer had access to credit, the household head's gender, the farmer's household characteristics, and whether the farmer had a pre-harvest contract. Table 7.4 contains summary statistics for these variables. These tables reveal that farmers who apply fertilizer tend be closer to the weekly market, tend to have more chickens, are less likely to access credit, and are more likely to live in a male headed household than farmers who do not apply fertilizer.

Each of these variables signals either financial or physical ability to access fertilizer and may influence the farmer's decision to apply fertilizer. The distance from the farm to the nearest weekly market could represent the distance the farmer has to travel to purchase fertilizer, but that may not always be the case. Unfortunately I do not have any information on that specific distance, so I use the distance to the weekly

market, calculated in travel time, as an estimate. The holder's heads of chicken and goats as well as the household characteristics serve as indicators of the farmer's level of income and development. Whether the holder accesses credit may influence their ability to purchase fertilizer at the time it is needed. I include a variable for the gender of the household head because the literature indicates that this may impact the ability of the holder to access/purchase inputs such as fertilizer. Finally, whether the holder had a pre-harvest contract could indicate that there were agreed upon inputs, that the contractor helped pay for inputs, or simply that the farmer had less uncertainty in their post-harvest profits.

Variables of interest

The above sections introduce all the variables I include in my final model, but I would like to highlight a few variables that I am particularly interested in. The main purpose of this model is to determine policies that could increase fertilizer use in Ghana. Therefore, I am mainly interested in variables that suggest policy solutions. So, the variables that I focus on in my analysis are the distance to the extension office, the distance to weekly market, the farmer's access to credit, the farmer's primary occupation, whether or not the farmer has property rights to the land, and whether the farmer had a pre-harvest contract. Among the variables I include in my model, these are the most relevant to consider for policy intervention.

7.2 Results

I include all of these variables in my linear probability model for fertilizer application, equation 4.7, to determine which variables are significantly correlated with fertilizer application. I find significant results for most of my variables of interest and further find reasonable directions of correlation among these variables and my control variables.

Table 7.5 shows that among my variables of interest the farmer's decision to apply fertilizer is significantly correlated with the distance from the nearest weekly market and whether the farmer had a pre-harvest contract. The first column shows the regression results for the linear probability model including all control variables, using district fixed effects, and using robust standard errors clustered at the district level. The second column shows the results for the probit model including all control variables, using indicator variables for each district, and using robust standard errors clustered at the district level. In both models, the only variables that are significant at at least the 10-percent level are the farmer's distance from the weekly market and whether the farmer has property rights over the field. Both regressions reveal that an increase in the time it takes the farmer to get to the weekly market decreases the probability that the farmer applies fertilizer and that having a pre-harvest contract increases the probability that the farmer applies

Table 7.5: Farmer's decision linear probability model results

Dependent Variable: Fertilizer Dummy	Linear Probability Model	Probit Model
Distance from Extension Office	0.000350	0.00319
	(0.000965)	(0.00525)
Minutes from Weekly Market	-0.00110**	-0.00791**
	(0.000492)	(0.00373)
Holder Farmer	-0.0148	-0.0810
	(0.0291)	(0.184)
Accessed Credit	-0.0451	-0.365
	(0.0633)	(0.435)
Pre-Harvest Contract	0.141*	0.971***
	(0.0719)	(0.146)
Holder Has Property Rights	0.0194	0.137
	(0.0621)	(0.289)
Observations	1000	1000
R-Squared	0.100	0.479

***Significant at the 1 percent level
**Significant at the 5 percent level
*Significant at the 10 percent level

fertilizer. The linear probability model is simply interpreted as an increase of 1 minute to the distance from the weekly market decreases the probability of the farmer applying fertilizer by 0.0011 and the farmer having a pre-harvest contract increases the probability by 0.141. The results of the probit model are not as straightforward, and the coefficients are interpreted as changes to the z-score, however I mainly include the probit model as a check for the linear probability model, and since the results appear similar I only address the linear probability model.

Given the disparity between fertilizer use rates and maize response to fertilizer between the North and South, I also examine the significant factors in the fertilizer-use decision separately for farmers in these areas. These results are shown in table 7.6; these results show that for farmers in the North, the only significant variables of interest are the distance from the weekly market and whether the holder has property rights, while for farmers in the South, whether the holder's primary occupation is farming and whether the farmer had a pre-harvest contract. Specifically, for farmers in the North, an additional 1 minute to the weekly market decreases the probability that the farmer will apply fertilizer by 0.00141 and the holder having property rights on the field increases the probability they will apply fertilizer by 0.217; for farmers in the South, the holder's primary occupation being farming reduces the probability of applying fertilizer by 0.0524 and having a pre-harvest contract increases the probability by 0.204. I discuss the implications of these regression results in the following discussion section.

Table 7.6: Farmer's decision linear probability model results for North and South

Dependent Variable: Fertilizer Dummy	North	South
Distance from Extension Office	0.00437	-0.00121
	(0.00635)	(0.00108)
Distance from Weekly Market	-0.00141***	-0.000317
	(0.000295)	(0.000513)
Holder Farmer	0.108	-0.0524*
	(0.0911)	(0.0243)
Accessed Credit	-0.0460	-0.0172
	(0.297)	(0.0132)
Pre-Harvest Contract	0.172	0.204**
	(0.220)	(0.0697)
Holder Has Property Rights	0.217*	-0.00373
	(0.106)	(0.0732)
Observations	243	757
R-Squared	0.302	0.108

***Significant at the 1 percent level
**Significant at the 5 percent level

7.3 Discussion

In these results, the coefficients for the significant variables in the overall model seem logical; being further from the market decreases the probability of applying fertilizer and having a pre-harvest contract increases the probability. The coefficients of some of the other variables, however, are not as logical. The coefficient for whether the farmer accessed credit, for example, is negative in all models and is negative and significant in the linear probability model for farmers in the South. This suggests that farmers who obtain loans (these loans are specifically for their crops) are not allocating this money toward fertilizer for maize; these farmers may be spending the loans on inputs for other crops, more likely cash crops, or they may be spending it on inputs or practices besides fertilizer. Another surprising result among these variables of interest, although it is not significant in any of the models, is that the distance from the nearest extension office positively correlates with fertilizer application. I expected that a farmer who is further from an extension office would acquire less information on farming activities through extension agents, but the positive coefficient implies the opposite; farmers are more likely to apply fertilizer as they get further from extension offices. In the previous section, I discussed that the distance from extension agent variable also encapsulates the distance from nearest large city, so I assume that this alternate interpretation of the variable evokes the positive correlation. Another complication in this variable results because I calculate it using the distance from the farm to the extension office, however the farmer does not necessarily live near the farm, so this variable may not accurately represent the farmer's distance from the extension office.

As a farm's distance from the nearest weekly market increases, the probability of the farmer applying fertilizer decreases. This is the relationship I expected for this variable and it could be caused by several

factors. Mainly, I assume that the distance from the nearest weekly market captures the difficultly of transporting fertilizer to the farm. While farmers cannot change the location of their farm (with ease) or the location of the weekly market, improvements in road infrastructure and modes of transportation could dissipate difficulties in transporting fertilizer.

Whether the holder's primary occupation is farming is only significant in the linear probability model for farmers in the South, but in most of the models the coefficient is negative. While this is not the correlation I expected, this result is not unreasonable. I anticipated the holder's primary occupation to, at least to some extent, represent how knowledgable they are about farming and profitable farming practices; however, this is likely better captured by the number of years the holder has been cultivating the field. This variable may also be indicative of wealth, since holders who are not primarily farmers, particularly in the South where there are more off-farm work opportunities, may be able to earn more money in other jobs and use that to help pay for inputs.

I find that farmers who have a pre-harvest contract are more likely to apply fertilizer, which goes along with what I would expect. Some pre-harvest contracts specify agreed upon inputs which can include fertilizer, but even without those specifications, pre-harvest contracts provide farmers with more knowledge of their future revenues, so they may be more willing and able to invest in inputs. This variable is significant and positively correlated with fertilizer use in all models except the linear probability model for farmers in the North, where it is not significant but remains positive.

Finally, I find that the holder having property rights and the ability to sell the land tends to be positively correlated with fertilizer use, but is only significant in the linear probability model for farmers in the North. This goes along with what I would expect, since the ability to sell the land suggests that the farmer has more to gain in the long run from properly maintaining the soils. This variable, however, is only significant in one of the models, indicating that having property rights is not necessarily indicative of fertilizer use.

These results generally indicate that the distance from the weekly market and having a pre-harvest contract are significant factors in the farmer's fertilizer-use decision. These indicate that effective policy solutions for increasing fertilizer use would be policies aimed at reducing the impacts of the farmer's physical distance from fertilizer and increasing the use of pre-harvest contracts. Further, for farmers in the North, providing long-term incentives to farmers without property rights to encourage soil maintenance should increase the probability of the farmer applying fertilizer. I further discuss the policy implications of these results and the results of my other equations in the concluding chapter.

8 Conclusion

The Ghana Ministry of Food and Agriculture determined the maize yield potential in Ghana to be 6 mT/Ha, but average observed maize yields remain below 2 mT/Ha. This implies that on average maize yields in Ghana are less than a third of their potential, which suggests that some changes in farming practices must be made to close this yield gap. My main objective in this paper was to determine policy mechanisms to increase yields and decrease the yield gap for farmers in Ghana. Due to the recent enactment of the fertilizer subsidy program and the prevalence and importance of maize in Ghanaian agriculture, I chose to concentrate on increasing maize yields through increasing fertilizer use. To do this I first assessed whether increasing fertilizer use would increase maize yields, to determine whether fertilizer is an effective mechanism to fuel growth in yield. Using OLS and quantile regressions I found that fertilizer application has a positive and significant impact on maize yields and total maize production. Having established fertilizer as a viable instrument for increasing yields, I next turned to determining policies that will increase fertilizer use rates in Ghana.

In chapter 6 I calculated the value-cost ratios using the estimated fertilizer coefficients from the OLS and quantile regressions. These value-cost ratios evaluate the profitability of fertilizer based on the cost of fertilizer and the estimated value in maize generated. The value-cost ratios suggest that in the 2011/2012 growing season, fertilizer application on maize fields was profitable for farmers in the South at the subsidized fertilizer price, but not at the market price; for farmers in the North, additional fertilizer use was not incentivized at any fertilizer price. These results indicate that the fertilizer subsidy program is a viable option for encouraging fertilizer use for farmers in the South, however, it is not a good option for increasing the maize yields and production levels of farmers in the North.

The 2011/2012 subsidy program was very costly, and in the following growing season the government reduced the subsidy amount; at the new subsidy rate, fertilizer use does not appear to be incentivized for the average farmers in Ghana. By reducing the subsidy, the Ghana government greatly reduced the costs associated with maintaining the program, but also appear to have reduced the incentives for farmers to apply fertilizer. Despite this decrease in the subsidy rate, the costs associated with the program are still high, and while, with additional funding, the program could prove to be an effective means to increase fertilizer use, there may be a more cost-efficient policy option.

To determine other policies that may increase fertilizer use, in chapter 7 I analyzed the factors that are significantly correlated with the farmer's binary fertilizer application decision. Determining these factors could identify new policies to increase yields through impacting farmer or farm characteristics that encourage fertilizer use. I found that fertilizer use is significantly correlated with the distance from the nearest weekly

market and whether the farmer had a pre-harvest contract. These variables indicate that policies focused on increasing physical and financial access to fertilizer should be viable policy options for increasing fertilizer use and thus yields in Ghana.

The results of my OLS and quantile regressions confirm the expected; despite the poor growing conditions in Ghana, fertilizer use has a significant and positive effect on maize yields and production. The quantile regressions, however, have further implications; I include quantile regressions in my analysis because I assume I am not controlling for all possible yield-impacting factors, so using the quantile regressions allows me to look at the marginal effects of fertilizer given farmers at certain relative levels of yield or production. Farmers that fall into different groups likely have some different unobserved characteristic that I was unable to control for, but by examining the marginal effects of fertilizer for the different groups of farmers, I can make inferences about how those unobserved yield-impacting characteristics affect fertilizer efficiency. The results of my quantile regressions suggest that these unobserved characteristics largely impact the effectiveness of fertilizer. So, future work on increasing maize yields in Ghana should attempt to identify some of these unobserved characteristics that were not included in the GAPS as they appear to not only influence yields, but also fertilizer productivity.

The value-cost ratios calculated from the OLS and quantile regressions indicate that increasing fertilizer use was not profitable for the average farmer in Ghana in the 2011/2012 major growing season, even at the subsidized price, however, increasing fertilizer should have been incentivized for the average farmer in the South. Farmers in the North appear to be applying fertilizer in more than sufficient quantities, while farmers in the South should be applying more; there are several possible causes for these apparent discrepancies in farmer behavior. Recent work in behavioral economics suggests that farmers in developing countries, who tend to have very little money left by planting season, have a reduced ability to plan ahead because they are focused on their current financial scarcity (Mullainathan and Shafir, 2013). More conventional explanations for this perplexing behavior indicate that lack of access to money at the time it is needed for purchasing inputs could prevent farmers from purchasing fertilizer, that farmers do not have accurate information on the profitability of fertilizer, or that farmers do not know how to correctly apply fertilizer or are not using modern seed varieties, which reduce fertilizer's effectiveness and profitability. Determining the true reasons for this illogical farmer behavior would reveal some ways to correct this behavior and increase fertilizer use in Ghana.

Finally, in an attempt to reveal some potential causes of these farmer behaviors, in this paper I determine some of the observable characteristics that contribute to the farmer's fertilizer use decision using a linear probability model with a binary outcome variable for fertilizer application. This model suggested that farmers who are further from weekly markets, where they would likely be able to purchase fertilizer,

have a significantly lower probability of applying fertilizer than those who live closer. These results reveal that a policy solution to increase fertilizer use for average farmers in Ghana should be aimed at reducing this distance. While a policy that reduces the distance between farms and fertilizer retailers is not particularly reasonable, improving road infrastructure, increasing access to transportation capable of hauling fertilizer, and/or establishing a delivery service are reasonable policy solutions that would reduce the impact of being further from fertilizer retailers. The overall model and the model for farmers in the South also suggest that farmers who have a pre-harvest contract have a significantly higher probability of applying fertilizer. This suggests that a policy that encourages purchasing companies to arrange pre-harvest contracts may be an effective method for increasing fertilizer use. Further, for farmers in the North, whether the holder has property rights is significant and positively correlated with fertilizer application, indicating that policies which encourage soil fertility by providing incentives to farmers without land rights may increase the long-run incentives for these farmers to apply fertilizer. These linear probability models only provide a limited look at the factors that contribute to whether or not farmers apply fertilizer; if the government of Ghana remains motivated to increasing fertilizer use, there are many other factors and policy mechanisms they should consider.

The purpose of this paper was to contribute to the understanding of yield-increasing practices for farmers in Ghana. Because of the recent Government investments in increasing fertilizer use, I chose to concentrate on determining factors to increase fertilizer application. From looking at my OLS and quantile regressions, I know that there are many other factors that could raise yields in Ghana, and future work should expand on this paper by more thoroughly examining the effects of these other variables. Particularly, future work should examine yield-impacting inputs, characteristics, and practices that have the potential to be influenced by policy. Further, my work suggests that farmers in Ghana are not necessarily profit-maximizing with their current fertilizer application, so future work should examine whether they are profit-maximizing with other inputs. Finally, in this paper I included a limited and brief analysis of the factors that impact fertilizer use for farmers, but future work could expand on this idea by considering additional variables, by using a panel dataset, or through behavioral analysis.

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Appendix A: The GAPS I Survey

GHANA GOVERNMENT

Ministry of Food and Agriculture
Statistics, Research and Information Directorate
Accra, Ghana

Ghana Agriculture Production Survey

Form 1

1a: Household & Holders Listing Form
1b: General Characteristics of the Community

REGION	CODE

DISTRICT	CODE

EA	CODE

LOCALITY NAME

EA TYPE	RURAL 1 / URBAN / SEMI-URBAN 2	

DASA	CODE

SIGNATURE

ENUMERATION COMPLETED ON: DD | MM | YY

DASO	CODE

SIGNATURE

DATA ENTERED ON: DD | MM | YY

NO. OF HOUSEHOLDS	NO. OF HOLDERS

District: |_|_|_|_| EA: |_|_|_|_|_|_|

Form 1a **Major Season** **Pre-harvest** **Listing of households and holders**

(1) House / Compound No.	(2) Household Serial No.	(3) NAME OF HOUSEHOLD HEAD	(4) AGE (YEARS)	(5) GEN-DER (Male 1, Female 2)	(6) PRIMARY OCCUPATION		(7) House-hold size	(8) Holder Serial No.	(9) NAME OF HOLDER	(10) AGE (YEARS)	(11) GEN-DER (Male 1, Female 2)
					Farmer	1					
					Farm hand	2					
					Fishing	3					
					Agro-processing	4					
					Trader	5					
					Artisan	6					
					Civil / Public servant	7					
					Unskilled	8					
					Other	9					
					Student	10					
					None	11					

District: |_|_|_| EA: |_|_|_|_|_|

Form 1b | Major Season | Pre-harvest — General characteristics of the community

(12) POPULATION OF THE COMMUNITY

(13) What are the principal ethnic groups in this community?

LIST UP TO THREE

Akan	1
Ewe	2
Ga-Dangme	3
Grusi	4
Guan	5
Gruma	6
Hausa	7
Mande-Busanga	8
Mole-Dagbani	9
Other (specify)	10

(14) What are the principal religions in this community?

LIST UP TO THREE

Pentecostal	1
Protestant	2
Catholic	3
Other Christians	4
Islamic	5
Other (specify)	6

(15) What are the principal languages in this community?

LIST UP TO THREE

Akan	1
Daagare-Wale	2
Dagbani	3
Dangme	4
Ewe	5
Ga	6
Gonja	7
Kasem	8
Hausa	9
Other (specify)	10

(16) When are the main crops typically grown in this community?

CROSS THE MONTHS WHEN CROP IS GROWN

CROP NAME	CODE	January	February	March	April	May	June	July	August	Septembe	October	November	December

(17) When does it rain?

TYPICALLY													
LAST YEAR													

(18) Were the crops affected by any shock last year?

DESCRIBE THE SHOCK IN WORDS

(19) What is the most common form of transport?

Foot	1	Animal/Animal-drawn cart	4
Bycicle	2	Taxi / Bus	5
Motorbike	3	Other	6

(20) FOR EACH FACILITY IN THE LIST Is there a ___ in this community?

CROSS ALL THAT APPLIES ▼

IF THE FACILITY IS NOT IN THE COMMUNITY

		How far is the nearest ___?	How long does it take to get there?			
			DRY SEASON		WET SEASON	
		KM	HRS	MIN	HRS	MIN
Clinic / Heath post						
Family planning clinic						
Maternity						
Hospital						
Drugstore / Chemical store / Pharmacy						
Traditional herbal clinic						
Elementary school						
Junior high school						
Secondary school						
Bank						
Post office						
Restaurant / Drinking bar / Chop bar						
Daily market						
Weekly market						
Public telephone						
Electric grid						
Cell phone signal						
All-weather motorable road						

(21) For how many years has this community existed?

IF MORE THAN 50, WRITE 50+

(22) Are there people who permanently move away from this community?

Yes	1	
No	2 ►	(26)

(23) Why do they move away?

CROSS ALL THAT APPLIES ▼

Work in agriculture		
Work, not in agriculture		
Study		
Family reasons		
Other (Specify)		

CROSS THE MOST IMPORTANT ▲

(24) Where do they go?

CROSS ALL THAT APPLIES ▼

Elsewhere in this district		
Other district in the region		
Other region in Ghana		
Abroad		

CROSS THE MOST IMPORTANT ▲

(25) Are their remittances important for their relatives in this community?

No one sends remittances	0
Not very important	1
Somewhat important	2
Very important	3

(26) Are there people who permanently move into this community?

Yes	1	
No	2 ►	(29)

(27) Why do they move in?

CROSS ALL THAT APPLIES ▼

Work in agriculture		
Work, not in agriculture		
Study		
Family reasons		
Other (Specify)		

CROSS THE MOST IMPORTANT ▲

(28) Where do they come from?

CROSS ALL THAT APPLIES ▼

Elsewhere in this district		
Other district in the region		
Other region in Ghana		
Abroad		

CROSS THE MOST IMPORTANT ▲

(29) In the past 10 years, have more people moved away or into this community?

More people have moved away	1
More people have moved into	2
No significant difference / change	3

(30) DATE OF THE INTERVIEW — DAY | MONTH | YEAR

(31) RESPONDENTS

NAME	TITLE	CELL PHONE

GHANA GOVERNMENT

Ministry of Food and Agriculture
Statistics, Research and Information Directorate
Accra, Ghana

Ghana Agriculture Production Survey

Household and Holding Enquiry - Pre-Harvest - Major Season

Form 2a - General characteristics of the household and holding/s

REGION	CODE	DISTRICT	CODE	EA	CODE	HOUSEHOLD NO.

LOCALITY NAME

EA TYPE	RURAL 1 / URBAN / SEMI-URBAN 2	

DASA	CODE

SIGNATURE

ENUMERATION COMPLETED ON: DD | MM | YY

DASO	CODE

SIGNATURE

DATA ENTERED ON: DD | MM | YY

NAME OF HOUSEHOLD HEAD	HOUSEHOLD SIZE	SERIAL NO. OF HOLDER 1	NAME OF HOLDER 1	SERIAL NO. OF HOLDER 2	NAME OF HOLDER 2

District: |_|_|_| EA: |_|_|_|_|_| HH: |_|_|

Form 2a **Major Season** **Pre-harvest** **Household members**

ID CODE	(1) LIST ALL HOUSEHOLD MEMBERS, BEGINNING WITH THE HEAD	(2) RELATIONSHIP TO HEAD	(3) GENDER	(4) AGE	(5) MARITAL STATUS	(6) OCCUPATION	(7) Is this person literate?	(8) ENGLISH PROFI-CIENCY	(9) HIGHEST LEVEL OF FORMAL EDUCATION COMPLETED	(10) YEARS OF FORMAL EDUCATION COMPLETED	(11) In the past 12 months, how many months in total has this person been absent from the household?	(12) FOR EACH HOLDING IN THE HOUSEHOLD			(13) PHONE NUMBER
												SERIAL NUMBERFROM THE LIST OF HOUSEHOLDS AND HOLDERS	NUMBER OF FARMS	APPROXIMATE AREA OF ALL FARMS	(10 DIGITS)
		Head 1 Spouse 2 Son / Daughter 3 Grandchild 4 Brother / Sister 5 Other 6	Male 1 Female 2	YEARS	Married 1 Single 2 Divorced 3 Widowed 4	Farmer 1 Farm hand 2 Fishing 3 Agro-processing 4 Trader 5 Artisan 6 Civil / Public servant 7 Unskilled 8 Other 9 Student 10 None 11 PRIMARY : SECONDARY	Yes 1 No 2	None 0 Speak 1 Read 2 Write 3	None 1 Kindergarten 2 Primary 3 Middle/ Junior High 4 Secondary 5 Beyond secondary 6	DO NOT COUNT KINDER-GARTEN YEARS	MONTHS			ACRES	
01															
02															
03															
04															
05															
06															
07															
08															
09															
10															
11															
12															
13															
14															
15															

Form 2a | Major Season | Pre-harvest | Holdings

Holding Number	(14) Who controls / owns this holding? ID CODES	(15) What kind of agriculture is carried on in this holding?	(16) Do you participate in any of these?	(17) FARM RECORDS	(18) Have you changed any of your farming practices or adopted new farming practices during the past 12 months?	(19) Why did you make this change?	(20) How did you learn about these practices?	(21) How many extension visits (crop or veterinary) did you receive during the past season	(22) NUMBER OF FARMS IN THIS HOLDING
1	MAIN HOLDER OTHER HH MEMBERS WHO SHARE CONTROL / OWNERSHIP Is control / ownership shared with anyone who is not a household member? Yes 1 No 2	CROSS ALL THAT APPLIES ▼ TREE CROP FOOD CROP INDUSTRIAL CROP LIVESTOCK / POULTRY AQUA-CULTURE HORTI-CULTURE	CROSS ALL THAT APPLIES ▼ CO-OPERATIVE COLLECTIVE FARM BLOCK FARMING FBO CROSS IF REGISTERED ▲	Do you keep farm records? Yes 1 No 2 Why do you keep farm records? CROSS ALL THAT APPLIES ▼ To keep track of expenditures To keep track of revenues To seek bank loan Other What method do you use to keep farm records? CROSS ALL THAT APPLIES ▼ Simple book keeping Recording figures on the wall Counting of pebbles Other	Yes 1 No 2 ► (21) CROSS ALL THAT APPLIES ▼ MULCHING CROP ROTATION COMPOSTING WATER HARVESTING USE OF FERTILIZER ZERO TILLAGE ROW PLANTING AGROCHEMICAL USE SPECIFY: SUPPLEMENTARY FEEDING HOUSING LIVESTOCK VACCINES OTHER SPECIFY:	CROSS ALL THAT APPLIES ▼ TO INCREASE PRODUCTION TO REDUCE THE USE OF INPUTS TO REDUCE EXPENSES TO WORK LESS TO REDUCE MORTALITY TO COMBAT THEFT & ACCIDENTS OTHER (SPECIFY):	CROSS ALL THAT APPLIES ▼ FARMER-BASED ORGANIZTION FRIENDS OR RELATIVES RADIO / TV / NEWSPAPER EXTENSION (MoFA) OTHER (SPECIFY):		
2	MAIN HOLDER OTHER HH MEMBERS WHO SHARE CONTROL / OWNERSHIP Is control / ownership shared with anyone who is not a household member? Yes 1 No 2	CROSS ALL THAT APPLIES ▼ TREE CROP FOOD CROP INDUSTRIAL CROP LIVESTOCK / POULTRY AQUA-CULTURE HORTI-CULTURE	CROSS ALL THAT APPLIES ▼ CO-OPERATIVE COLLECTIVE FARM BLOCK FARMING FBO CROSS IF REGISTERED ▲	Do you keep farm records? Yes 1 No 2 Why do you keep farm records? CROSS ALL THAT APPLIES ▼ To keep track of expenditures To keep track of revenues To seek bank loan Other What method do you use to keep farm records? CROSS ALL THAT APPLIES ▼ Simple book keeping Recording figures on the wall Counting of pebbles Other	Yes 1 No 2 ► (21) CROSS ALL THAT APPLIES ▼ MULCHING CROP ROTATION COMPOSTING WATER HARVESTING USE OF FERTILIZER ZERO TILLAGE ROW PLANTING AGROCHEMICAL USE SPECIFY: SUPPLEMENTARY FEEDING HOUSING LIVESTOCK VACCINES OTHER SPECIFY:	CROSS ALL THAT APPLIES ▼ TO INCREASE PRODUCTION TO REDUCE THE USE OF INPUTS TO REDUCE EXPENSES TO WORK LESS TO REDUCE MORTALITY TO COMBAT THEFT & ACCIDENTS OTHER (SPECIFY):	CROSS ALL THAT APPLIES ▼ FARMER-BASED ORGANIZTION FRIENDS OR RELATIVES RADIO / TV / NEWSPAPER EXTENSION (MoFA) OTHER (SPECIFY):		

Form 2a **Major Season** **Pre-harvest** **Farms**

Holding Number	Farm Number	(23) What is the approxi-mate area of the farm? ACRES	(24) Could you sell this farm if you wanted? Yes 1 ► (26) No 2	(25) Why not? CROSS ALL THAT APPLIES: Family owned	Too young	Used as col-lateral	Need spou-se's permi-sion	Does not own the land	Other	(26) Under which tenure is this farm held? Owner / Owner-like 1; Rented in 2; Share-cropped in 3; Rented out 4 ► (28); Share-cropped out 5 ► (28); Squatter basis 6; Communal 7; Other 8	(27) Number of fields in this farm
1	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
2	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										

Form 2a **Major Season** **Pre-harvest** **Livestock / poultry / other animals**

Holding Number	(28) Do you rear livestock / poultry / other animals in this holding? YES 1 / NO 2 ► (32)	(29) Which livestock / poultry / other animals do you have now? ANIMAL NAME	ANIMAL CODE	(30) How many heads do you have now? (NUMBERS) MALE: LESS THAN 1 YEAR	MALE: 1 OR 2 YEARS OLD	MALE: 3 YEARS AND MORE	FEMALE: LESS THAN 1 YEAR	FEMALE: 1 OR 2 YEARS OLD	FEMALE: 3 YEARS AND MORE	TOTAL	(31) Do you vaccinate them? Yes 1 / No 2
1											
2											

Form 2a **Major Season** **Pre-harvest** **Tree crops**

Holding Number	(32) Do you have perennial trees in this holding? YES 1 NO 2 ► (35)	(33) Which perennial trees do you have now? TREE NAME	TREE CODE	(34) How many trees do you have now? LESS THAN 3 YEARS	3 TO 5 YEARS	6 TO 10 YEARS	11 TO 20 YEARS	21 TO 30 YEARS	MORE THAN 30 YEARS	TOTAL
1	☐									
2	☐									

Form 2a | Major Season | Pre-harvest | Housing

IF MORE THAN ONE CATEGORY APPLIES, REPORT THE MOST IMPORTANT

GPS COORDINATES

		°	'	"
LATITUDE	N			
LONGITUDE				

(35) TYPE OF DWELLING

Separate house	1
Semi-detached house	2
Flat / Apartment	3
Compound house (rooms)	4
Huts / Buildings (same compound)	5
Huts / Buildings (different compound)	6
Hotel / Hostel	7
Tent	8
Improvised house (kiosk, container)	9
Living quarters attached to office / shop	10
Uncompleted building	11
Other (specify)	12

(36) OUTER WALL

No wall	0
Mud brick / Earth	1
Wood	2
Metal sheet or Slate / Asbestos	3
Stone	4
Burnt bricks	5
Cement blocks / Concrete	6
Landcrete	7
Bamboo	8
Palm leaves / thatch (grass) / raffia	9
Other (specify)	10

(37) FLOOR (FINISHED)

Earth / Mud	1
Cement / Concrete	2
Stone	3
Burnt bricks	4
Wood	5
Vinyl tiles	6
Ceramic / Porcelain / Granite / Marble tiles	7
Terrazo / Terrazzo tiles	8
Other (specify)	9

(38) ROOF

Earth / Mud	1
Cement / Concrete	2
Stone	3
Burnt bricks	4
Wood	5
Vinyl tiles	6
Ceramic / Porcelain / Granite / Marble tiles	7
Terrazo / Terrazzo tiles	8
Aluminum sheets	9
Other (specify)	10

(39) TENURE

Owner occupied	1
Renting	2
Rent-free	3
Perching	4
Squatting	5
Other (specify)	6

(40) OWNERSHIP TYPE

Owned by household member	1
Being purchased (eg Mortgage)	2
Relative not household member	3
Other private individual	4
Private employer	5
Other private agency	6
Public / Government ownership	7
Other (specify)	8

(41) A NUMBER OF ROOMS

B NUMBER OF SLEEPING ROOMS

(42) LIGHTING SOURCE

Electricity (mains)	1
Electricity (private generator)	2
Kerosene lamp	3
Gas lamp	4
Solar energy	5
Candle	6
Flashlight / torch	7
Firewood	8
Crop residue	9
Other (specify)	10

(43) A DRINKING WATER

Pipe-borne inside	1
Pipe-borne outside (incl. public tap)	2
Bore hole / pump	3
Protected well	4
Rain water	5
Protected spring	6
Bottled water	7
Satchet water	8
Tanker supply / vendor-provided	9
Unprotected well	10
Unprotected spring	11
River / stream	12
Dugout / pond / lake / dam / canal	13
Other (specify)	14

(43) B WATER FOR COOKING, WASHING, ETC.

Piped into dwelling	1
Piped to yard / plot	2
Public tap / standpipe	3
Tube-well / borehole	4
Protected dug well	5
Unprotected dug well	6
Protected spring	7
Unprotected spring	8
Rainwater collection	9
Cart with small tank / drum	10
Tanker-truck	11
River / pond / lake / dam / canal	12
Other (specify)	13

(44) COOKING FUEL

None, no cooking	1
Wood	2
Gas	3
Electricity	4
Kerosene	5
Charcoal	6
Crop residue	7
Saw dust	8
Animal waste	9
Other (specify)	10

(45) COOKING SPACE (KITCHEN)

No cooking space	1
Separate room for exclusive use of the household	2
Separate room shared with other households	3
Enclosure without roof	4
Structure with roof but without walls	5
Bedroom / hall (living room)	6
Verandah	7
Open space in compound	8
Other (specify)	9

(46) BATHING FACILITIES

Own bathroom for exclusive use	1
Shared separate bathroom in the same house	2
Private open cubicle	3
Shared open cubicle	4
Public bath house	5
Bathroom in another house	6
Open space around house	7
River / pond / lake / dam	8
Other (specify)	9

(47) A TOILET FACILITIES

No facility	1 ►	(48)
W.C.	2	
Pit latrine	3	
KVIP	4	
Bucket / pan	5	
Public toilet	6 ►	(48)
Other (specify)	7 ►	(48)

(47) B Do you share this toilet facility with other households?

Yes, with other household/s in the same house	1	
Yes, with other household/s in different house	2	
No	3 ►	(48)

(47) C How many households use this toilet facility?

(48) SOLID WASTE DISPOSAL

Collected	1
Burned by household	2
Public dump	3
Dumped indiscriminately	4
Buried by household	5
Other (specify)	6

(49) LIQUID WASTE DISPOSAL

Through the sewerage system	1
Through pumping system into a gutter	2
Through plumbing into a pit (soak away)	3
Thrown onto the street (outside)	4
Thrown into gutter	5
Thrown onto compound	6
Other (specify)	7

Form 2a **Major Season** **Pre-harvest** **Farm and household assets**

		(50) FOR EACH ITEM ON THE LIST How many functioning ___s do you have in this household? (IF NONE, WRITE 0)	No.	IF ONE ITEM OR MORE (51) Who owns this ___? ID CODES		IF ONE ITEM OR MORE (52) What is the current total value of these ___s? GH¢
SIMPLE FARM EQUIPMENT	1	Hoe				
	2	Axe				
	3	Rake				
	4	Shovel				
	5	Pick(-axe)				
	6	Sickle / Reaping hook				
	7	Cutlass				
	8	Dibbler				
	9	Wheelbarrow				
	10	Cart				
	11	Other animal drawn equipment (specify_____)				
	12	Cocoa harvester (go-to-hell)				
	13	Pots for storage				
	14	Cribs / Barns				
	15	Room Storage				
	16	Baskets				
	17	Headpans				
	18	Sacks				
	19	Knapsack				
	20	Gun				
FARM MACHINERY	21	Cane crusher				
	22	Harrow				
	23	Tiller				
	24	Motorized spraying machine				
	25	Water pump				
	26	Plough				
	27	Trailer				
	28	Tractor				
	29	Harvester				
	30	Planter				
	31	Thresher				
	32	Cassava grater (commercial)				
	33	Other tractor drawn equipment (specify_____)				
	34	Feed mixer				
	35	Dryer				
	36	Rice mill				
	37	Corn mill				
	38	Palm oil extractor				
	39	Silo				
	40	Granary				

		(50) FOR EACH ITEM ON THE LIST How many functioning ___s do you have in this household?	No.	IF ONE ITEM OR MORE (51) Who owns this ___? ID CODES		IF ONE ITEM OR MORE (52) What is the current total value of these ___s? GH¢
FISHING GEAR	41	Outboard motor				
	42	Canoe				
	43	Fishing net				
	44	Baskets				
	45	Other (specify)				
HOUSEHOLD ASSETS	46	Sewing machine				
	47	Kerosene stove				
	48	Electric / gas stove				
	49	Refrigerator / Freezer				
	50	Blender				
	51	Air conditioner				
	52	Fan				
	53	Radio				
	54	Radio cassette player				
	55	CD player				
	56	Video player				
	57	Desktop computer				
	58	Laptop computer				
	59	Printer				
	60	Camcorder / video camera				
	61	Camera				
	62	Cell (mobile) phone				
	63	Telephone (fixed line)				
	64	Television (CRT)				
	65	Television (flat screen)				
	66	Parabolic satellite antenna				
	67	DVD player				
	68	Washing / drying machine				
	69	Lanterns / gas lights				
	70	Buckets				
	71	Electric power generator				
	72	Bicycle				
	73	Motorcycle				
	74	Car				
	75	Truck / bus				
	76	Non-agricultural land				
	77	Other buildings / dwellings				
	78	Other (specify)				

(53) Is this the household's main dwelling owned?

Yes	1
No	2
►	END

(54) What is the current total value of this owned main dwelling?

GHANA GOVERNMENT

Ministry of Food and Agriculture
Statistics, Research and Information Directorate
Accra, Ghana

Ghana Agriculture Production Survey

Household and Holding Enquiry - Pre-Harvest - Major Season

Form 3 - Field Measures

REGION	CODE	DISTRICT	CODE	EA	CODE	HOUSEHOLD NO.

LOCALITY NAME

EA TYPE	RURAL 1 / URBAN / SEMI-URBAN 2	

DASA	CODE

SIGNATURE

ENUMERATION COMPLETED ON | DD | MM | YY |

DASO	CODE

SIGNATURE

DATA ENTERED ON | DD | MM | YY |

NAME OF HOUSEHOLD HEAD	HOUSEHOLD SIZE	SERIAL NO. OF HOLDER 1	NAME OF HOLDER 1	SERIAL NO. OF HOLDER 2	NAME OF HOLDER 2

District: |_|_|_|_| EA: |_|_|_|_|_|_| HH: |_|_|_|

Form 3 **Major Season** **Pre-harvest** **Fields**

Holding Number	Farm Number	Field Number	DASA OBSERVATIONS (1) MAIN COLOR OF THE SOIL		(2) MAIN SOIL TYPE		(3) MAIN WEED TYPE		(4) What year did you start cultivation of this land?	(5) PART OF THE FIELD UNDER PERENNIAL VEGETATION		(6) What sources of water for irrigation are available in this field? CROSS ALL THAT APPLIES							(7) Which crops have you planted or do you intend to plant in this field during this season?
										WHEN CULTIVATION STARTED	NOW								
			Red	RE	Sand	SA	Acheampong	1		None 0	None 0								IF LAND IN FALLOW, CODE "FA"
			Black	BL	Loam	LO	Sensitive	2		Less than 1/2 1	Less than 1/2 1								IF VIRGIN LAND, CODE "VL"
			Grey	GR	Light Clay	LC	Centrocema	3		About 1/2 2	About 1/2 2								
			Yellow	YE	Heavy Clay	HC	Nut grass	4		More than 1/2 3	More than 1/2 3								
			Brown	BR	Gravel	GR	Striga weed	5		All 4	All 4								
			White	WH	Mixed	MI	Other	6				River / Stream	Well / Tube well	Dam / Pond	Temp-orarily shal-low well	Custo-marilly flooded area	Other	None	
							None	7	YEAR										CROP CODES
1																			
2																			

District: |_|_|_|_| EA: |_|_|_|_|_|_| HH: |_|_|_|

Form 3 **Major Season** **Pre-harvest** **Fields - GPS measures**

Holding Number	Farm Number	Field Number	(8) PERIMETER	(9) AREA	(10) ALTITUDE	(11) COORDINATES OF THE START / END POINT							
						LATITUDE				LONGITUDE			
			METRES	SQUARE METRES	METRES	N	o	'	"	E / W	o	'	"
1			m	m²	m	N							
			m	m²	m	N							
			m	m²	m	N							
			m	m²	m	N							
			m	m²	m	N							
			m	m²	m	N							
			m	m²	m	N							
			m	m²	m	N							
			m	m²	m	N							
			m	m²	m	N							
			m	m²	m	N							
			m	m²	m	N							
			m	m²	m	N							
			m	m²	m	N							
			m	m²	m	N							
			m	m²	m	N							
			m	m²	m	N							
2			m	m²	m	N							
			m	m²	m	N							
			m	m²	m	N							
			m	m²	m	N							
			m	m²	m	N							
			m	m²	m	N							
			m	m²	m	N							
			m	m²	m	N							
			m	m²	m	N							
			m	m²	m	N							
			m	m²	m	N							
			m	m²	m	N							
			m	m²	m	N							
			m	m²	m	N							
			m	m²	m	N							
			m	m²	m	N							

GHANA GOVERNMENT

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Household and Holding Enquiry - Post-Harvest - Major Season

Form 2b - Practices, Inputs and Outputs

REGION	CODE	DISTRICT	CODE	EA	CODE	HOUSEHOLD NO.

LOCALITY NAME

EA TYPE	RURAL 1 / URBAN / SEMI-URBAN 2	

DASA	CODE

SIGNATURE

ENUMERATION COMPLETED ON: DD | MM | YY

DASO	CODE

SIGNATURE

DATA ENTERED ON: DD | MM | YY

NAME OF HOUSEHOLD HEAD	HOUSEHOLD SIZE	SERIAL NO. OF HOLDER 1	NAME OF HOLDER 1	SERIAL NO. OF HOLDER 2	NAME OF HOLDER 2

District: |_|_|_|_| EA: |_|_|_|_|_|_| HH: |_|_|_|

Form 2b **Major Season** **Post-harvest** **Fields - Practices, inputs and expenses**

ASK ABOUT THE SEASON JUST ENDED
INCLUDE IN CASH AND IN-KIND PAYMENTS
IF NOTHING OR NONE, WRITE 0

Holding Number	Farm Number	Field Number	(1) Which crops were grown in this field during the season just ended? IF LAND IN FALLOW, CODE "FA" IF VIRGIN LAND, CODE "VL" CROP CODES	(2) What sources of water for irrigation were used in this field? CROSS ALL THAT APPLIES: River / Stream	Well / Tube well	Dam / Pond	Temporarily shallow well	Customarily flooded area	Other	None	(3) LAND CLEARING How many times did you clear the land? Slashing	Stumping	Hoeing	Burning	Non-selective weeding	Non-selective weedicide GH¢	Equipment rental GH¢	Labor (in cash or in-kind) GH¢	(4) PLOUGHING / TILLING How many times did you ... ? Plough	Till	Harrow	Mound / Ridge	With tractor	With animals	How much did it cost to undertake this operations? Tractor rental GH¢	Rental of other equipment GH¢	Rental of animals GH¢
1																												
2																												

District: |_|_|_|_| EA: |_|_|_|_|_|_| HH: |_|_|_|

Form 2b **Major Season** **Post-harvest** **Fields - Practices, inputs and expenses**

ASK ABOUT THE SEASON JUST ENDED
INCLUDE IN CASH AND IN-KIND PAYMENTS
IF NOTHING OR NONE, WRITE 0

Holding Number	Farm Number	Field Number	(5) SOWING: How many times did you use / do? Certified seeds	Improved planting material	Seed dribbling	Broadcasting	Row planting	Transplanting	How much did you pay for: Certified seeds GH¢	Other seeds GH¢	Planting material GH¢	Equipment rental GH¢	Labor (in cash or in-kind) GH¢	(6) FERTILIZING: How many times did you use fertilizer? Manure	Other organic	Inorganic	How much did you pay for: Manure GH¢	Other organic fertilizer GH¢	Inorganic fertilizer GH¢	Equipment rental GH¢	Labor (in cash or in kind) GH¢
1																					
2																					

District: |_|_|_|_| EA: |_|_|_|_|_|_| HH: |_|_|_|

Form 2b **Major Season** **Post-harvest** **Fields - Practices, inputs and expenses**

ASK ABOUT THE SEASON JUST ENDED
INCLUDE IN CASH AND IN-KIND PAYMENTS
IF NOTHING OR NONE, WRITE 0

Holding Number	Farm Number	Field Number	(7) PEST CONTROL How many times did you apply pesticide?					(8) WEED CONTROL How many times did you use / do?					(9) OTHER ACTIVITIES How much did you pay for? IN CASH OR IN-KIND				
			Holder's initiative	Govt campaign	How much did you pay for: Pesticide GH¢	Equipment rental GH¢	Labor (in cash or in kind) GH¢	Selective herbicic	Hand weeding	How much did you pay for: Selective herbicide GH¢	Equipment rental GH¢	Labor (in cash or in kind) GH¢	Labor for tending the field (scaring birds, etc.) GH¢	Labor for harvesting GH¢	Equipment rental for harvesting GH¢	Labor for post-harvesting / processing GH¢	Equipment rental for post-harvesting / processing GH¢
1																	
2																	

District: |_|_|_| EA: |_|_|_|_|_| HH: |_|_|

Form 2b **Major Season** **Post-harvest** **Fields - Practices, inputs and expenses**

ASK ABOUT THE SEASON JUST ENDED
INCLUDE IN CASH AND IN-KIND PAYMENTS
IF NOTHING OR NONE, WRITE 0

Holding Number	Farm Number	Field Number	(10) Which household members worked in this field during the season just ended? IF THE HOLDER WORKED, INCLUDE HIM / HER — ID CODES		(11) How much shared labor/ labor exchange did you use in your fields? — PERSON-DAYS	
			PERMANENT	CASUAL	MALE	FEMALE
1						
2						

District: |_|_|_| EA: |_|_|_|_|_| HH: |_|_|

Form 2b **Major Season** **Post-harvest** **Crops - Production and marketing**

ASK ABOUT THE SEASON JUST ENDED
INCLUDE IN CASH AND IN-KIND PAYMENTS
IF NOTHING OR NONE, WRITE 0

Holding Number	(12) Which crops did you grow during the season just ended?	(13) HARVEST CONDITION	(14) Was the harvest green or mature?	(15) When did you harvest?				(16) When did you sell?				(17) Was sale based on a pre-harvest contract?	(18) Who did you sign the contract with?	(19) What were the agreed upon inputs? CROSS ALL THAT APPLIES				(20) Which part of the harvest was covered by the contract?	(21) Was the price settled before or after the harvest?
						IF NOT FINISHED, WRITE		IF NOT STARTED, WRITE		IF NOT FINISHED, WRITE									
						99	99	99	99	99	99								
				APPROXIMATE DATES				► (22) APPROXIMATE DATES											
	CROP CODE	Not harvested yet 1 ► (35)	Green 1	FROM		TO		FROM		TO		Yes 1	Wholesaler 1					None 0	Before 1
		Partially harvested 2	Mature 2	DD	MM	DD	MM	DD	MM	DD	MM	No 2	Industry 2					Less than 1/2 1	
		Completely harvested 3											Market queen 3					About 1/2 2	
		Sold standing 4 ► (29)										► (22)	Other 4	Money	Ferti-lizer	Seeds	Other	More than 1/2 3	
																		All 4	After 2
1																			
2																			

District: |_|_|_|_| EA: |_|_|_|_|_|_| HH: |_|_|_|

Form 2b **Post-harvest** **Crops - Production and marketing**

ASK ABOUT THE SEASON JUST ENDED
INCLUDE IN CASH AND IN-KIND PAYMENTS
IF NOTHING OR NONE, WRITE 0

Holding Number	DASA Transcribe crop codes from (12) CROP CODE	(22) DASA: WRITE THE NAME OF THE UNIT USED TO REPORT QUANTITIES FOR THIS CROP (e.g. bag, basket, bucket, bunch, etc) UNIT NAME	(23) How many UNITS of each crop did you produce during the season just ended? UNITS	(24) How many UNITS did you keep for home consumption? UNITS	(25) How many UNITS did you use to pay for labor in kind? UNITS	(26) How many UNITS did you sell? UNITS	(27) DASA: WHAT IS THE WEIGHT OF EACH UNIT? SHOW PICTURES KILOS / UNIT	(28) What was the value of each unit at the time you sold this crop? GH¢ / UNIT	(29) What was your revenue for sales of these crops during the season just ended? GH¢
1									
2									

Form 2b | **Major Season** | **Post-harvest** | **Crops - Production and marketing**

ASK ABOUT THE SEASON JUST ENDED
INCLUDE IN CASH AND IN-KIND PAYMENTS
IF NOTHING OR NONE, WRITE 0

Holding Number	DASA Transcribe crop codes from (12)	(30) What storage facilities did you use? CROSS ALL THAT APPLIES							(31) How much did you pay for storage of these crops during the season just ended?	(32) To whom did you sell?									(33) Where did you sell the larger part of your production?		How far from your farm is that place?
	CROP CODE	Silos	Grana-ries	Pots for sto-rage	Cribs / Barns	Room sto-rage	Hea-ped on the ground	Other	IN CASH OR IN-KIND GH¢	Fac-tory / can-nery / mill	Poultry / live-stock station	Govt agency / COCO BOD / etc.	Insti-tution / school / etc.	Whole-saler	Other private enter-prise	Retai-ler / market	Other	None ► ###	Farm 1 ► (35) Holder's residence 2 ► (35) Local market 3 ► (35) Market in other town 4 Assembling, wholesale mkt 5 Other 6	KM
1																					
2																					

Form 2b **Major Season** **Post-harvest** **Holding**

Holding Number	(34) IF PRODUCE WAS SOLD AWAY FROM FARM: What form of transportation to the market did you use during the season just ended?	(34) How much did you pay for transportation?	(35) Did you try to access credit from any of these sources during the season just ended? For which kind of crop? CROSS ALL THAT APPLIES / IF NEVER TRIED ► (39)	Food crop	Cash crop	(36) Did you succeed? Yes 1 / No 2 ► (38)	(37) How much credit did you access? (in cash or in-kind) ► (39)	(38) Why were you not able to access credit? CROSS ALL THAT APPLIES: High interest rates	Delay in procedures	Lender too distant	No collateral	Other	(39) Did you buy any ... during the season just ended? Yes 1 / No 2 ► NEXT	(40) What was the unit price of … during the season just ended? GH¢ /
1														
2														

	CROSS ALL THAT APPLIES ▼		GH¢
1	HEADLOADING		
	BICYCLE / MOTORCYCLE		
	TRACTOR		
	PUSH TRUCK		
	MOTOR CAR / TRUCKS		
	BOAT / RIVER TRANSPORTATION		
	ANIMAL DRAWN CART		
	POWER TILLER		
	RAIL		
	OTHER FORMS		
	TOTAL		
2	HEADLOADING		
	BICYCLE / MOTORCYCLE		
	TRACTOR		
	PUSH TRUCK		
	MOTOR CAR / TRUCKS		
	BOAT / RIVER TRANSPORTATION		
	ANIMAL DRAWN CART		
	POWER TILLER		
	RAIL		
	OTHER FORMS		
	TOTAL		

	FORMAL FINANCIAL SYSTEM									
1	CO-OPERATIVE SOCIETY									
	RELATIVES									
	PRE-FINANCE									
	MONEYLENDER									
	SUSU CLUBS									
	ROTATING SAVING									
	WOMEN-TARGETTED SCHEME									
	OTHER									
	TOTAL									
2	CO-OPERATIVE SOCIETY									
	RELATIVES									
	PRE-FINANCE									
	MONEYLENDER									
	SUSU CLUBS									
	ROTATING SAVING									
	WOMEN-TARGETTED SCHEME									
	OTHER									
	TOTAL									

1	NPK		/ 50 kg
	Sulp of Amo		/ 50 kg
	Urea		/ 50 kg
	Actelic		/ 1 lt
	Karate		/ 1 lt
	Roundup		/ 1 lt
	Dusban		/ 1 lt
	Atrazine		/ 1 lt
	Champion		/ 1 lt
	Gramazone		/ 1 lt
	Pawa		/ 1 lt
	Tractor rent		/ 1 day
	Labor (male)		/ 1 day
	Labor (female)		/ 1 day
2	NPK		/ 50 kg
	Sulp of Amo		/ 50 kg
	Urea		/ 50 kg
	Actelic		/ 1 lt
	Karate		/ 1 lt
	Roundup		/ 1 lt
	Dusban		/ 1 lt
	Atrazine		/ 1 lt
	Champion		/ 1 lt
	Gramazone		/ 1 lt
	Pawa		/ 1 lt
	Tractor rent		/ 1 day
	Labor (male)		/ 1 day
	Labor (female)		/ 1 day

Crop and animal codes

STARCH STAPLE CROPS	CV	Cassava
	CY	Cocoyam
	MZ	Maize
	ML	Millet
	PL	Plantain
	RC	Rice
	SG	Sorghum
	SP	Sweet potato
	TR	Taro
	YM	Yam
TREE CROPS	AV	Avocado
	BN	Banana
	CS	Cashew
	CO	Cocoa
	CN	Coconut
	CF	Coffee
	CL	Cola
	LM	Lime
	MG	Mango
	OP	Oil-palm
	OG	Oranges
	PW	Paw-paw
	SN	Shea-nut

INDUS-TRIAL	CI	Citronella
	CT	Cotton
	JT	Jute
	KF	Kenaf
	RB	Rubber
	SS	Sissal
	SB	Sweet Berry
	SC	Sugar Cane
	TB	Tobacco
HORTI-CULTURE	FL	Flowers
	PN	Pineapples
	WM	Watermelon
VEGE-TABLES	AS	Asian vegetables
	CG	Cabbage
	CR	Carrots
	GE	Garden eggs
	LT	Lettuce
	ME	Melon (agusi)
	OK	Okro
	PE	Pepper (Sweet)
	PK	Pumpkin leaves
	CU	Cucumber
	TL	Talinum leaves
	TO	Tomato

SPICES	BP	Black pepper
	GI	Ginger
	NM	Nutmeg
	ON	Onions
	PH	Pepper (Hot)
	SH	Shallots
PULSES / LEGUMES	BB	Bambara beans
	CP	Cow peas
	GN	Ground nuts
	PP	Pigeon peas
	SY	Soya bean
OTHER	OT	Other Crops

	FA	Fallow
	VL	Virgin Land

LIVE-STOCK	GS	Ghana West African shorthorn (WASH)
	SA	Sanga
	ND	N'Dama
	ZE	Zebu
	OC	Other cattle
	HO	Horse
	DO	Donkey
	MU	Mule
	LP	Local pig
	EP	Exotic pig
	GO	Shahalian Goat
	WG	West African Dwarf Goat (WAD)
	SE	Sahalian Sheep
	DS	Djallonke Sheep
	OA	Other
POULTRY AND BARN-YARD	LC	Local chicken
	CC	Cross chicken
	EC	Exotic chicken
	GF	Guinea fowl
	DU	Duck
	OS	Ostrich
	TU	Turkey
	PI	Pigeon
	RA	Rabbit
	SL	Snail
	BH	Beehives
	GC	Grasscutter
	OB	Other
AQUA-CULTURE	TI	Tilapia
	CA	Catfish
	SR	Shrimp
	OF	Other

Event	Year	Difference
Yaa Asantewaa War	1900	111
Capture of Yaa Asantewaa	1901	110
First World War	1914	97
West African Currency Notes introduced	1918	93
Armistice Day (End of 1st World War)	1918	93
Prince of Wales visited Gold Coast	1925	86
First Aeroplane arrived in Accra	1926	85
Dr. J.E. Kwagyir Aggrey died	1927	84
Takoradi Harbour opened	1928	83
Introduction of Basic Rate	1936	75
Cocoa Hold-up	1938	73
Second World War Started	1939	72
Eclipse of the sun	1947	64
Founding of CCP by Kwame Nkrumah	1949	62
Positive Action declared	1950	61
Kwame Nkrumah made Leader of Government Business	1951	60
Kwame Nkrumah made first Prime Minister of the Gold Coast	1952	59
Ghana's Independence declared	1957	54
Ghana became a Republic	1960	51
Queen Elizabeth II visited Ghana	1961	50
The Kulungugu bomb explosion	1962	49
Flagstaff House shooting incident involving Ametewee	1964	47
Formal opening of Akosombo Dam	1965	46
President Nkrumah overthrown by the Army & Police	1966	45
Introduction of the New Cedis & New Pesewas	1967	44
Dr. K.A. Busia made Prime Minister of Ghana	1969	42
Death of Asantehene Nana Sir Osei Agyeman Prempeh II	1970	41
Ghana broke Diplomatic Relations with Israel	1973	38
Introduction of Right H& Traffic	1974	37
Creation of Supreme Military Council (SMC I)	1975	36
Referendum on Union Government	1978	33
Uprising in which Flt. Lt. J.J. Rawlings was arrested	1979	32
Pope John Paul II visited Ghana	1980	31
Draught, bush fires & hunger (Rawlings chain)	1983	28
Voters registration exercise	1987	24
District level elections	1989	22
Constitution of 4th Republic	1991	20
Election of J.J. Rawlings as President of Ghana	1992	19
J.J. Rawlings elected President for a second term	1996	15
Visit of the American President (Bill Clinton)	1998	13
Election of President John Agyekum Kufour	2000	11
Accra sports stadium disaster (May 9th)	2001	10
Eclipse of the sun	2006	5
Ghana celebrates 50 years of independence	2007	4
Election of President John Evans Atta Mills (December)	2008	3
US President Barack Obama visits Ghana (July)	2009	2

Code	Ethnicity
01	*Akan*
	Agona
	Ahafo
	Ahanta
	Akuapem
	Akwamu
	Aowin
	Asante
	Asen (Assin)
	Boron (Brong)
	Evalue
	Fante
02	*Ewe*
03	*Ga-Dangme*
	Dangme (Ada, Shai, etc.)
	Ga
04	*Grusi*
	Kasena (Paga)
	Mole-Dagbani
	Sisala
	Vagala
05	*Guan*
	Akapafu, Lolobi, etc.
	Avatime, Nyongbo, etc.
	Awutu, Efutu, etc.
	Cherepong, Larteh, etc.
	Gonja
	Nkonya
	Yeji, Nchumuru, etc.
06	*Gurma*
	Bimoba
	Kokomba
	Basare (Kyamba)
	Pilapila
	Salfalba (Sabulaba)
07	*Housa*
08	*M&e-Busanga*
	Busanga
	Wangara
09	*Mole-Dagbani*
	Builsa\
	Dagarte (Dagaba), Lobi, etc.
	Dagomba
	Kusasi
	Mamprusi
	Nankansi, Talensi, etc.

Appendix B: The Full OLS Yield Regression Results

Dependent Variable: Yield (mT/Ha)	Coefficient
Fertilizer (kg/Ha)	0.00275***
	(0.00)
Certified Seeds	0.335**
	(0.15)
Labor-Tending (GH¢/Ha)	0.00
	(0.00)
Labor-Harvesting (GH¢/Ha)	0.00635**
	(0.00)
Pesticides (GH¢/Ha)	0.00
	(0.00)
Herbicides (GH¢/Ha)	0.00828**
	(0.00)
Plough/Till (GH¢)	0.00
	(0.00)
Able to Sell	0.23
	(0.15)
Primary Occupation: Farming	0.08
	(0.15)
Household Head Male	0.19
	(0.11)
Household Floor Type:	
Concrete/Cement	-0.352**
	(0.13)
Terrazo	-0.70
	(0.68)
Other	-0.989**
	(0.42)
Household Electricity Type:	
Private Generator	-0.20
	(0.54)
Kerosene Lamp	0.02
	(0.11)
Gas Lamp	-0.472*
	(0.27)
Solar Energy	-0.19
	(0.30)
Candle	0.05
	(0.17)
Firewood	0.55
	(0.60)
Crop Residue	-0.60
	(0.36)
Other	-0.523**
	(0.25)
Household Drinking Water Type:	
Pipe, Outside	-0.16
	(0.30)
Bore Hole/Pump	-0.37
	(0.34)
Protected Well	-0.32
	(0.34)
Protected Spring	-0.95
	(0.58)
Bottled Water	-2.936**
	(1.25)
Sachet Water	-0.10
	(0.23)
Tanker/Vendor	0.53
	(0.81)
Unprotected Well	-0.14
	(0.33)
River	-0.19
	(0.37)

(Cont.)	
Outcome Variable: Yield (mT/Ha)	Coefficient
Household Cooking Fuel Type:	
Wood	0.19
	(0.31)
Gas	-0.52
	(0.32)
Kerosene	0.22
	(0.38)
Charcoal	0.17
	(0.37)
Crop Residue	0.12
	(0.35)
Household Sanitation Facility Type:	
Water Closet	0.78
	(0.47)
Pit Latrine	-0.02
	(0.13)
KVIP	-0.234*
	(0.13)
Bucket	0.45
	(0.36)
Public Toilet	-0.343**
	(0.16)
Other	0.81
	(0.46)
Holder's Education Level	0.02
	(0.04)
Holder's Age	0.00337*
	(0.00)
Household Size	0.01
	(0.01)
Heads of Chicken	0.00
	(0.00)
Total Area (Ha)	0.01
	(0.02)
Holder's Years Farming	-0.00497*
	(0.00)
Flood	-0.09
	(0.08)
Soil Color:	
Red	0.03
	(0.69)
Black	-2.847**
	(1.07)
Grey	-0.05
	(0.40)
Yellow	-2.264**
	(0.86)
Brown	1.339**
	(0.47)
White	-0.07
	(0.75)
Soil Type:	
Sand	3.256**
	(1.27)
Loam	1.134**
	(0.43)
Light Clay	2.843**
	(1.10)
Gravel	0.21
	(0.45)
Mixed	0.02
	(0.56)
Constant	0.11
	(0.62)
Observations	394
Number of Districts	16
R-squared	0.50

Appendix C: The Full OLS Logged Production Regression Results

Dependent Variable: Logged Production (mT)	Coefficient
Fertilizer (kg)	0.148***
	(0.03)
Fertilizer (kg)	0.0309**
	(0.01)
Area (Ha)	0.515***
	(0.09)
Certified Seeds	0.112**
	(0.04)
Labor-Tending (GH¢)	-0.0172**
	(0.01)
Labor-Harvesting (GH¢)	0.01
	(0.01)
Pesticides (GH¢)	-0.0231**
	(0.01)
Herbicides (GH¢)	0.0629***
	(0.02)
Plough/Till (GH¢)	0.01
	(0.01)
Able to Sell	0.04
	(0.03)
Primary Occupation: Farming	0.00
	(0.02)
Household Head Male	0.02
	(0.04)
Household Floor Type:	
Cement/Concrete	-0.0511***
	(0.01)
Terrazo	-0.14
	(0.24)
Other	-0.0794**
	(0.03)
Household Electricity Type:	
Private Generator	0.03
	(0.24)
Kerosene Lamp	0.00
	(0.04)
Gas Lamp	-0.21
	(0.12)
Solar Energy	0.0790**
	(0.03)
Flashlight	0.01
	(0.05)
Firewood	0.17
	(0.15)
Crop Residue	-0.06
	(0.14)
Other	-0.228**
	(0.08)
Household Drinking Water Type:	
Pipe, Outside	-0.01
	(0.07)
Bore Hole/Pump	-0.05
	(0.07)
Protected Well	-0.03
	(0.07)
Protected Spring	-0.18
	(0.17)
Bottled Water	-0.420**
	(0.17)
Sachet Water	-0.02
	(0.06)
Tanker/Vendor	-0.01
	(0.20)
Unprotected Well	-0.03
	(0.07)
River	-0.04
	(0.12)

(Cont.) Dependent Variable: Logged Production (mT)	Coefficient
Household Cooking Fuel Type:	
Wood	0.225*
	(0.11)
Gas	0.15
	(0.13)
Kerosene	0.415***
	(0.14)
Charcoal	0.208*
	(0.11)
Crop Residue	0.222*
	(0.11)
Household Sanitation Facility Type:	
Water Closet	0.21
	(0.16)
Pit Latrine	-0.01
	(0.03)
KVIP	-0.01
	(0.04)
Bucket	0.09
	(0.05)
Public Toilet	-0.05
	(0.05)
Other	0.11
	(0.11)
Holder's Education Level	0.00
	(0.01)
Holder's Age	0.00
	(0.00)
Household Size	0.03
	(0.03)
Heads of Chicken	0.01
	(0.01)
Total Area (Ha)	0.03
	(0.03)
Holder's Years Farming	-0.0308*
	(0.02)
Flood	0.00
	(0.02)
Soil Color:	
Red	-0.05
	(0.14)
Black	-0.715**
	(0.26)
Grey	-0.02
	(0.08)
Yellow	-0.573**
	(0.22)
Brown	0.12
	(0.12)
White	-0.06
	(0.18)
Soil Type:	
Sand	0.771**
	(0.33)
Loam	0.308**
	(0.13)
Light Clay	0.754**
	(0.26)
Gravel	0.11
	(0.13)
Mixed	0.07
	(0.11)
Constant	-0.06
	(0.15)
Observations	394
Number of Districts	16
R-squared	0.67