FACTORS AFFECTING THE USE OF FERTILIZER BY SMALL- AND MEDIUM-SIZED FARMING HOUSEHOLDS IN ZAMBIA, 1997 TO 2000

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ABSTRACT

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Agriculture represents the main form of income for many families in rural Zambia and increasing incomes of the majority of the population is a crucial goal. The use of fertilizer is seen as an important way to improve agricultural output and productivity, and therefore incomes of rural households. Identifying characteristics of households that currently use fertilizer may lead to a better understanding of the constraints and opportunities to increasing fertilizer use. This paper uses three, nation-wide surveys to identify the factors that affect a household's use of fertilizer. The factors analyzed include market-characteristics, household-level characteristics, and geographical-level characteristics. The paper also analyzes factors that affect the total quantity of fertilizer a household uses. The factors found to significantly increase a household's likelihood of using fertilizer include total cropped area, ownership of farming assets, and proximity to a fertilizer depot. However, the most influential factors identified were transportation assets and level of district transportation infrastructure. These findings imply a straightforward policy response for government: improvements in transportation infrastructure may be among the most effective methods of increasing levels of fertilizer use and by extension the incomes of rural farming households.

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CHAPTER 1
INTRODUCTION

In Zambia, increasing incomes of the majority of the population is a crucial goal because approximately 86 percent of the population lives on less than $1 per day purchasing power parity (Pletcher 2000). Until other options arise, agriculture represents the main form of income for many families in rural Zambia. For these farming households, the use of inorganic fertilizer is seen as one important way to potentially improve productivity and increase agricultural output, and therefore bring substantial improvements to their incomes, lives, and well-being (Feder *et al.* 1985). Some social scientists go so far as to insist that economic development in less developed countries will not occur unless preceded by the adoption of new technologies such as fertilizer and hybrid seed varieties (Nkonya *et al.* 1997).

Use of fertilizer can improve the nutrient balance of soils, which may lead to increases in crop yields. Higher rates of fertilizer use may be of significant importance in Sub-Saharan Africa because some authors and researchers suggest soil nutrient depletion in Africa is occurring at an alarming rate and represents the primary cause of declining per capita food production in this region (Sanchez *et al.* 1997). Other authors' views are less pessimistic and recommend that better interpretation of current research is warranted because of the limitations of that research (Scoones and Toulmin 1999).

Whether or not the nutrient balance in Sub-Saharan Africa is declining or not, the region has the lowest mineral fertilizer consumption compared to the world average and other regional averages (Greenland and Nabhan 2001). Few small-holder households use fertilizer in Zambia and the reasons for this infrequent use are not clearly understood. Responding to this situation, current and historical government policies have been designed to increase the use of fertilizer by expanding the distribution of fertilizer and providing it at below market costs (Pletcher 2000).

These policies, no matter how well intentioned, may not necessarily enhance national welfare. Research conducted by the Food Security Research Project in Zambia suggests that, while fertilizer use can be quite profitable under the proper conditions, promoting its use throughout the country may be difficult and counter-productive because it may not be profitable to use at market prices, given prevailing seed types, management practices, market infrastructure, and output price distributions. Continuing fertilizer use where it is unprofitable will negatively affect national income and welfare by misallocating resources (FSRP 2001). Additionally, because of low loan recovery rates, the government loses millions of dollars each year in distributing fertilizer to farmers.

Many policy makers contend that current input market liberalization in Zambia is to blame for low levels of fertilizer use. On one side, there is a widespread perception that market liberalization has been a failure because the private sector has been unable or unwilling to service rural farmers in remote areas of the country. On the other side, there is a perception that government continues to directly or indirectly participate in input markets and therefore affects private traders' behavior in unintended ways. As a result of these conflicting views, fertilizer-marketing policy is at a crossroads. Some donors and policy makers favor the return to direct state involvement in distribution of fertilizer to small farmers. Others want the country to adhere to a more market-oriented approach to input and credit disbursement (Pletcher 2000). A better understanding of households' decision to use, or not use, fertilizer could help inform policy decision-making at this crossroads.

Studies of fertilizer adoption and use have been performed for decades. However, few studies have utilized large, nationwide datasets; most analyze small, geographically homogenous samples. This data limitation prevents analysis of the decision to adopt and use a technology such as fertilizer across multiple ecological regions or across an entire nation. In contrast, three annual, nation-wide surveys of Zambian households provide the basis for the research conducted in this thesis. The current study utilizes household and geographic characteristics across a wide range of ecological zones, similarly to Kaliba *et al.* 2000, to analyze household use of fertilizer.

Few previous analyses look at the decision to use a new technology over multiple years of data. Consequently, the results obtained in most studies stand in isolation and cannot be shown to be consistent and robust over time. By utilizing three years of community-level, panel survey data, this paper also overcomes this drawback. Unfortunately, since the same households were not interviewed each of the three years, the data is not household-level panel data. However, the data is panel data at the village level because households were chosen from the same Standard Enumeration Areas for each of the three survey periods. It is hoped that this quality of the data provides insights not available in other studies.

This thesis will address the following areas of research. First, it will determine how household characteristics affect the use of fertilizer by small- and medium-sized farming households in Zambia. These include the gender of household head, number of family members, ownership of productive assets, and area cropped. Second, this paper will determine how the physical location and geographic characteristics of a household affect its use of fertilizer. Levels of rainfall and other natural phenomenon will affect a household's use of fertilizer. Other geographical factors such as proximity to fertilizer distribution centers and the level of infrastructure influence a household's ability to purchase and transport fertilizer and therefore its use of fertilizer.

Thirdly, this paper will econometrically test how these household and geographic characteristics interact, and evaluate which of these factors has the most significant impact on the decision to use fertilizer among households in Zambia. The most significant factors to household use of fertilizer are hypothesized to be total cropped area and access to fertilizer distribution centers. A fourth analysis utilizes an additional econometric test to explore the factors that influence the quantity of fertilizer a household uses.

The thesis is organized as follows. The first three chapters following the introduction provide the framework for the analyses conducted in later chapters. Chapter 2 presents the conceptual framework utilized as the foundation for the econometric work. Chapter 3 describes the data employed in the analyses. Chapter 4 follows with detailed descriptions of the variables gathered and models formulated to answer the research questions.

Chapter 5 provides a descriptive analysis of the data and characterizes the different types of households that grew crops during the agricultural seasons included in this paper. Econometric measurement of the interactions and magnitudes of the household and geographic characteristics that influence the use of fertilizer is addressed in Chapter 6.

Chapter 7 explores the market system, overall use, and prices of fertilizer in Zambia. An econometric test of factors that contribute to the total quantity of fertilizer a household uses is presented in Chapter 8. This chapter explores household characteristics and geographical characteristics that affect the quantity of fertilizer a household chooses to use.

The conclusions and implications of the findings appear in Chapter 9. At this point, the findings of this research are summarized and an evaluation of the trends presented. This research may assist Zambian policy makers in deciding how to continue their involvement in the fertilizer market.

CHAPTER 2
LITERATURE REVIEW

Modeling a household's decision to use a new technology is a difficult process. There is substantial variation in the methods and specifications of empirical studies of technology use. This chapter introduces some of the related work from previous studies. The types of models used in other empirical work as well as the types of variables employed in other models will provide a foundation from which the current study departs.

The demand for and use of fertilizer in Zambia does not follow traditional demand as described by standard economic theory. In the textbook case, product price is the mechanism that clears the market. For reasons described below, some fertilizer in Zambia is rationed, and it is likely that effective demand exceeds supply. In this market environment, the purchase of fertilizer depends upon many other factors, price being but one of them. Some of the other factors include household characteristics (i.e. family size, education, wealth) and location characteristics (i.e. proximity to markets, ease of transporting the fertilizer). For some households, fertilizer is simply not available. It is for these reasons that adjustments need to be made to standard models and sample sizes adjusted to incorporate these exceptions to standard economic theory.

Defining use of technology

Adoption of a new technology at the household level has been defined as "the degree of use of a new technology in long-run equilibrium when the farmer has full information about the new technology and its potential" (Feder *et al.* 1985). This definition implies that adoption has two separate components: a time component indicating length of time the technology has been used, and an intensity of use component indicating the appropriateness of its use. Such long-run information is seldom obtained, however, and the "adoption" of a technology is generally reduced to a binary variable indicating use of the technology or not (Kaliba *et al.* 2000).

In most cases, the binary variable definition is based on whether a household used or did not use the technology. The current paper follows this pattern. In the first econometric analysis the binary variable approach is used and the sample is divided into two categories: households that used fertilizer and those that did not. This approach, however, is not perfect; a major shortcoming is that households utilizing an inappropriate level of the technology are treated the same as those using an appropriate amount (Rauniyar and Goode 1992 and Feder *et al.* 1985). Despite this shortcoming, the binary variable approach of modeling the use of a new technology is widely used.

The second econometric analysis performed in this thesis employs the quantity of fertilizer used as the dependent variable. The results of this second analysis will indicate the household and geographic factors that affect the quantity of fertilizer a household uses.

Variables influencing fertilizer use

Empirical studies identify numerous variables as being important to a household's decision to use a new technology. The underlying characteristic of these variables is that they are hypothesized to affect the demand for the technology. Overall, the factors that affect a household's decision to use a new technology such as fertilizer fall into three broad categories: market price and economic profitability-level variables, household-level variables, and physical and geographical-level variables.

Market price and economic profitability-level factors

Kherallah *et al.* 2001 report that market price of fertilizer had a negative effect, as economic theory would suggest, on fertilizer use in Benin. This result suggested that household use of fertilizer decreased as its price increased and its use increased as price decreased. Interestingly, the corresponding variable for fertilizer use in their study in Malawi was not found to be significant.

A draft report by the Food Security Research Project in Zambia concludes the profitability of fertilizer use throughout the country is far from clear (FSRP 2001). Factors identified as deleterious to profitable fertilizer use included high variability in response rates of maize to fertilizer, climatic conditions, proper timing and quantity of application of fertilizer, existing soil fertility, and crop management practices. The variability of the price of fertilizer and indicators of the profitability of its use will be addressed in this analysis.

Household-level factors

Different rates of fertilizer and other technology use are typically observed between male and female heads of household (Doss and Morris 2001). The gender of the head of household may influence the use of a new technology for various reasons. Male and female heads of households may have different levels of access to credit or to transportation assets. They may also differ in the types of crops they grow and as a result in their preferences for using fertilizer. Often when included in econometric analyses, however, the coefficient estimates of gender of the head of household variable indicates this variable to be insignificant. Results from studies in Ethiopia by Croppenstedt and Demeke 1996 indicate gender of the head of household not to be significant. Doss and

Morris 2001 also found no significant influence of gender upon use of modern varieties of maize or fertilizer use among farming households in Ghana. Despite results to the contrary, Doss and Morris 2001 do suggest that gender may play a role through other institutional constraints such as access to extension visits and other resources.

Age of the head of household has been found to be a significant factor affecting the use of new technologies, but of contradictory impact in some research; and even insignificant in others. Kaliba *et al.* 2000 found that older heads of household were more likely to use fertilizer in Tanzania. Khanna 2001 found similar results: higher levels of education and experience (both only attainable through increased years of farming) led to higher rates of use of new technologies in high-input agriculture. Sain and Martinez 1999 found the opposite affect for households in Guatemala using improved maize seeds. Several other studies of fertilizer use in Sub-Saharan Africa found age of the head of household to be insignificant (Green and Ng'ong'ola 1993, Croppenstedt and Demeke 1996, Nkonya *et al.* 1997, Kaliba *et al.* 2000).

Education of the household head is assumed to have an important, positive impact upon the adoption and use of new technologies. The results of research by Nkonya *et al.* 1997 showed education to be an important factor in the household's decision to use improved seeds. Proximity to neighbors utilizing a new technology may increase use by other households by increasing the non-user's understanding of the technology, and therefore reducing the uncertainty of the technology (Ghadim and Pannell 1999). Sain and Martinez 1999 found a contradictory result for households in Guatemala, while the level of education of the household head was found to have a negative effect, participation in associations (another form of education) had a positive effect upon improved maize seed use. Visits by agricultural extension workers, another form of farmer learning, have been found to be significant as well (Nkonya *et al.* 1997, Demeke *et al.* 1998). However, both participation in associations and visits by extension workers are arguably endogenous to the use of new technology, which may compromise the validity of the studies' conclusions.

Labor constraints may also affect a household's ability and willingness to adopt and use a new technology (Feder *et al.* 1985). It is for this reason that family size of households is typically hypothesized to have a positive effect upon a household's decision to use new technologies; larger families would theoretically have more family members available to work on the household crops. Croppenstedt and Demeke 1996 and Green and Ng'ong'ola 1993 suggest this to be the case. Doss and Morris 2001 reported the number of adult males to significantly affect use of improved varieties of maize in Ghana. However, family size was not found to be significant by Nkonya *et al.* 1997 and Kaliba *et al.* 2000. Interestingly, Sain and Martinez 1999 hypothesized that larger families would be less likely to use improved maize seeds because the increased financial strain of larger families led to budget constraints.

Farm size will generally have a positive impact on a household's decision to adopt and use a new technology such as fertilizer (Nkonya *et al.* 1997, Kherallah *et al.* 2001). Households with larger cultivated areas will tend to have more productive assets and fewer credit constraints than smaller ones. Doss and Morris 2001 reported larger farm sizes to positively affect the use of both modern varieties of maize as well as fertilizer in Ghana. Land area cropped positively affected the results observed by Sain and Martinez 1999 who entered the land size variable as the natural logarithm for their study of the use of improved maize seed in Guatemala. On the other hand, farm size may be negatively correlated with the *intensity* of use of fertilizer; smaller households that use fertilizer tend to use it more intensively than larger households (Feder *et al.* 1985). Nkonya *et al.* 1997 found farm size to be significant, but negatively related to improved maize seed use, indicating that households with smaller cropped areas used improved maize seed more intensively than did larger farms in Tanzania.

Asset ownership has been incorporated into these studies with mixed results. Croppenstedt and Demeke 1996 used oxen ownership as a proxy for wealth and found it to be positively related to use of fertilizer in Ethiopia. Interestingly, Demeke *et al.* 1998 did not find livestock assets to be a significant factor in their study of fertilizer use in Ethiopia.

Off-farm income is typically seen as significant in the decision of households to use new technologies. Households with lower levels of off-farm income or poor access to credit are less likely to be able to afford newer, potentially riskier, technologies (Feder *et al.* 1985). However, since household income is likely to be endogenous to the household decision to use fertilizer, incorporating these types of variables in econometric models must be interpreted with caution.

Access to credit was significantly associated with fertilizer use in Nepal (Shakya and Flinn 1985). Green and Ng'ong'ola 1993 found access to credit to be significant, and off-farm income to be insignificant, in the use of fertilizer in Malawi. Similarly, availability of external financing for Guatemalan households was not a significant determinant of the use of improved maize seed (Sain and Martinez 1999).

Interesting work has been pursued in analyzing farmers' perceptions and how they influence decisions. Adesina and Zinnah 1993 and Adesina and Baidu-Forson 1995 found perceptions of yield, seed quality, tolerance to weeds, adaptability to poor soil types, tillering capacity, threshing, and tolerance to drought to be significantly related to a households' use of modern seed varieties. Even perceptions of the ease of cooking the varities of maize were found to significantly impact a decision to use new maize varieties (Adesina and Zinnah 1993, Adesina and Baidu-Forson 1995).

Physical and geographical-level factors

Location of the household farm and its surrounding environment will have a significant impact on the use of new technologies such as fertilizer. Soil type and quality, levels of rainfall and other weather and natural phenomena affect crop yields and therefore the profitability of fertilizer (Feder *et al.* 1985). Farmers with better soil quality were found to more likely to use new soil fertility and fertilizer application technologies by Khanna 2001. In that study, regional dummy variables were created to represent the four states in the survey. Kaliba *et al.* 2000 incorporated a dummy variable representing households located in the low lands region.

Supply constraints, in the form of poor timing of delivery, may hinder such decisions to use new technologies (Feder *et al.* 1985). It is for this reason that the relative level of infrastructure is typically hypothesized to affect the use of new technologies. Croppenstedt and Demeke 1996 found that fertilizer use was affected significantly by access to all-weather roads in Ethiopia. Access to fertilizer had a positive impact on fertilizer use in Ethiopia (Demeke *et al.* 1998). Transportation costs may also significantly affect fertilizer use (Shakya and Flinn 1985). Khanna 2001 found that a “major factor” affecting the participation in soil testing was proximity to markets. Khanna 2001 also found that as the frequency of soil tests increased, testing was not restricted to more innovative or educated farmers, but rather to the ease of use as measured by the distance to the test service.

Estimator models used

Previous adoption and use of new technology studies have utilized a variety of econometric models. Production functions have been used to examine adoption and levels of fertilizer use (Hiebert 1974). Feder *et al.* 1985 present additional studies that analyzed the use of fertilizer or other new technologies utilizing similar ordinary least squares (OLS) methods. A newer method in this area of study is to incorporate a Bayesian learning model. Applied to a household’s decision to adopt fertilizer, Bayes’ theorem states that the household will try the new technology, in small trials or on specific fields for instance, to see whether or not its performance, in output or return on investment criteria, meets their expectations. The household may perform trials, watch neighbors’ performance, or gain information from extension workers before more widely adopting or entirely rejecting the use of the new input (Feder *et al.* 1985, Shampine 1998, Ghadim and Pannell 1999).

The majority of these adoption and use papers have incorporated maximum likelihood estimation techniques. Among the more commonly used estimation techniques are tobit (Adesina and Zinnah 1993, Adesina and Baidu-Forson 1995, Nkonya *et al.* 1997), logit (Green and Ng'ong'ola 1993, Sain and Martinez 1999), and probit (Negatu and Parikh 1999, Kaliba *et al.* 2000). These models are more appropriate than OLS for analyzing the decision to use a new technology (Feder *et al.* 1985). Because of the underlying specifications of these maximum likelihood models, they have a more discrete range of values. The dependent variable is constrained to values between zero and one in the case of the logit and probit models; and for the tobit model, the dependent variable can be defined to have a lower bound of zero (as would be appropriate for a fertilizer use study) but may take any positive value (Kennedy 1998).

CHAPTER 3
DATA AND MODEL USED

Using prior research as a guide, this chapter outlines the data utilized in the current study. A description of the source of the data is followed by the statistical and econometric procedures utilized in addressing the research questions.

Data utilized for the current study

The data used in this paper comes from household surveys conducted in the Republic of Zambia, through the Central Statistical Office and Ministry of Agriculture, Food and Fisheries. Annually, a sample of small- and medium-scale farming households from across the entire country are surveyed in the Post-Harvest Survey (PHS). Government employees train enumerators who administer the PHS. Upon completion of the surveys, the results are entered into computer files and analyzed to find potential data entry errors. Once identified, potential errors are fixed by referencing the original survey and entering corrected values. The data utilized in the current analysis is from the PHS of the 1997/1998, 1998/1999, and 1999/2000 agricultural seasons.

The structure of the PHS follows a "stratified three-stage sample design" (Megill 2000). The three stages are stratification by district, by Census Supervisory Area (CSA), and by Standard Enumeration Area (SEAs are smaller divisions within CSAs). Each of Zambia's seventy-two districts is represented in the survey (with the exceptions of two entirely urban districts: Lusaka Urban and Ndola Urban). The process of selecting CSAs and SEAs was not random. They were selected using a probability proportional to their population.

Deciding which households to interview within the selected CSAs and SEAs was not based on strictly random probabilities either. All households were divided into two groups based upon total farmed area: households farming areas less than five hectares (category "A" households), and larger households farming areas between five and twenty hectares (category "B" households). Since smaller households vastly outnumber the larger ones, the survey oversampled the larger households in order to ensure adequate inclusion of these larger households in the survey. This oversampling of category B households resulted in biases towards larger households. To account for these biases, a weighting process is applied to the survey data. This weighting process is applied to the data when descriptive statistics are analyzed; weighting is not used for the econometric analyses.

Each year, over seven thousand households are interviewed for the PHS. In the 1997/98 PHS, there were 7,550 households included in the survey; in 1998/99 and 1999/2000 there were 7,794 and 7,879 households included respectively (Table 1). Households that did not grow crops of any kind were not included in the analysis because they are not relevant for this paper studying household fertilizer use. Additionally, due to data entry errors, there were a number of incomplete surveys. Incomplete household entries were identified and deleted from the final data utilized in this paper. Table 1 shows that after excluding households that did not grow crops and incomplete entries, there were 6,030 households surveyed in the 1997/98 PHS survey, 6,407 households in the 1998/99 survey, and 7,557 households in the 1999/2000 survey. The total number of households represented by the survey, properly weighted, was 877,338 for 1997/98 PHS; 901,156 for 1998/99 PHS; and 801,202 for 1999/200.

Table 1: Number of households surveyed with and without weighting

	1997/98	1998/99	1999/2000
Number of households:			
All households including bad entries	7,550	7,794	7,879
Households used in the current paper i.e. complete entries and farming	6,030	6,407	7,557
Number of households with weighting:			
All households including bad entries	1,160,650	1,111,473	839,580
Households used in the current paper i.e. complete entries and farming	877,338	901,156	801,202

Models utilized for the current study

Probit model for use of fertilizer

As previously described, the decision to use fertilizer in this paper will be modeled as a binary decision: a household either uses or does not use fertilizer. In situations such as this when the dependent variable is a discrete dummy variable (use fertilizer = 1; don't use fertilizer = 0), linear estimation is inappropriate for at least three reasons (Green 1993, Wooldridge 2000). First, the error term cannot be normally distributed since it can take only two values. Second, the error is heteroskedastic because it can be shown that the variance of the error term is not constant. Third, the estimated probabilities generated via a linear estimation would not necessarily lie between zero and one. Probabilities greater than one or less than zero are not acceptable; e.g. the use of fertilizer cannot be predicted with over one hundred percent certainty. Other estimation methods are used when the dependent variable is a discrete dummy variable.

For the reasons outlined above, estimating a binary response model typically utilizes maximum likelihood estimation (MLE) techniques (Wooldridge 2000). Appropriate MLE models include the logit or probit model. The difference between these techniques is insignificant (Green 1993). The current study utilizes a probit model to analyze the factors affecting the use of fertilizer among small- and medium-holding households in Zambia. The probit model takes the basic form:

$$Y_i = G(I_i) \tag{1}$$

$$I_i = b_0 + \sum_{j=1}^{n} b_j X_{ji} \tag{2}$$

where: Y_i is the observed response (1 or 0) for the i^{th} household;
I_i is the underlying stimulus (reasons why the household used fertilizer or not);
G is the functional relationship between observation (Y_i) and the stimulus index (I_i);
i = 1, 2, ..., m, is the index of observations, the sample size;
X_{ji} is the j^{th} explanatory variable for the i^{th} observation;
b_j is an unknown parameter; and
j = 0, 1, 2, ..., n, where n is the total number of explanatory variables.

For the probit model $G(\bullet)$ is the standard normal distribution (cdf) and the model becomes:

$$Y_i = \int_{-\infty}^{I_i} g(I_i) \cdot dZ_i \tag{3}$$

where: $g(\bullet)$ is the pdf of the standard normal distribution.

The output of the probit model parallels the output from traditional ordinary least squares (OLS) estimation techniques (Wooldridge 2000, Green 1993, and StataCorp 1999). The parameter estimate of each independent variable (b_j) is reported with an (asymptotic) standard error and *t*-tests. However, interpretation of the parameter estimates is slightly different: each one-unit increase in the explanatory variable (X_{ji}) leads to increasing the probit index by 0.08233 standard deviations (StataCorp 1999).

Obviously, this sort of interpretation is difficult. The standard procedure overcoming these obstacles is a transformation of the estimates into corresponding changes in probability. These new, transformed variables correspond to the marginal impact of changes in the explanatory variables and leads to more meaningful interpretation. The underlying meaning of the reported standard errors and *t*-tests follows that of traditional OLS results.

Measures of the model "goodness-of-fit" include the percent correctly predicted and pseudo *R*-squared measurements. Percent correctly predicted measures just that, the percentage of times the predicted output correctly matches the actual observation. Another similar measure is to compare the percentage observed versus percentage predicted by the model. The pseudo *R*-squared measure of model goodness-of-fit is analogous to, but not as reliable as, the *R*-squared obtained from standard OLS regressions.

Ordinary Least Squares model for total quantity of fertilizer used

The analysis of factors that affect the total quantity of fertilizer used will be accomplished with an ordinary least squares model. The form of the OLS will follow standard procedures:

$$Y = X \cdot \beta + e \tag{4}$$

where: *Y* is a vector of the independent variable (quantity of fertilizer used);
X is a vector of independent explanatory variables (reasons that explain how much fertilizer the household used);
ß is a vector of parameter estimates; and
e is the error term randomly distributed around a mean of zero.

CHAPTER 4
METHOD AND MODEL SPECIFICATION

Chapter 4 continues the introduction to the probit model and how it will be implemented in this paper. First, the operational variables (I_i) of Equation (3) will be identified. Second, the model specifications employed will be discussed and outlined.

Previous discussion mentioned three categories of variables that affect a household's decision to use a technology such as fertilizer: market, household, and geographical. For the time being, only the latter two categories will be included in the analysis, market related variables will be analyzed and included in subsequent chapters. Most studies of new technology adoption and use usually ignore market prices, so the first analysis parallels these standard methods; including market price in the analysis breaks with standard operating procedure and will be reported separately.

The dependent variable, use of fertilizer is a composite of household use of basal fertilizer and top dressing fertilizer. Using Table 2 as a guide, there are four potential combinations of use and non-use of basal fertilizer and top dressing fertilizer. Households could: (i) use neither basal nor top dressing (NEITHER); (ii) use basal fertilizer only (USEBAS); (iii) use top dressing fertilizer only (USETOP); or (iv) use both basal and top dressing fertilizer (USEBOTH). For the current study, a fifth category of fertilizer use was created. USE1 is the summation of all households that use basal fertilizer only, those that use top dressing only, and those that use both (i.e. USE1 = USEBAS + USETOP + USEBOTH).

Table 2: Fertilizer use matrix

	Household uses top dressing fertilizer	
Household uses basal fertilizer	No	Yes
No	NEITHER	USETOP
Yes	USEBAS	USEBOTH
Household uses either or both	USE1 = (USEBAS + USETOP + USEBOTH)	

To ensure robust results across all four potential dependent variables, probit analyses were performed on each of the possible dependent variables (USEBAS, USETOP, USEBOTH, and USE1). No significant differences appeared among the results; therefore the dependent variable chosen for the current analyses was USE1, "use of basal fertilizer, top dressing fertilizer, or both". Defining the dependent variable as USE1 ensures inclusion of all households that used at least one type of fertilizer.

Operational variables

The dependent variable USE1, is specified as a function of both exogenous household-level variables (HHvar) and geographical variables (GEOvar) that are reasonably thought to enter into a reduced form model of fertilizer use. This is represented by equation 5.

$$USE1 = f(HHvar, GEOvar) \tag{5}$$

Household-level variables

The household-level variables (HHvar) include data related to the gender and age of the head of household, the number of members in the household, size of total household cropped area, and productive asset ownership of the household.

GENDER: dummy variable representing the gender of head of household. Male-headed households are theorized to use fertilizer more readily than female-headed households. GENDER takes the value of one if the household head is male and is zero for female-headed households.

AGE: age of head of household, in years. For the current study AGE is hypothesized to have a negative coefficient indicating that younger head of households will have a higher probability of using fertilizer.

MALE and FEMALE: number of males (females) of any age in the household. Larger household sizes increase the labor availability for household tasks. Therefore, households with more members are more likely to have more labor available to apply fertilizer. Larger households are expected to use fertilizer more readily than smaller ones. The number of males in a household may have a more significant impact than the number of females.

AREATOTL: total area cropped by the household in hectares. Households with larger farm areas are hypothesized to use fertilizer more than smaller ones. Had it been available, the variable total area owned would have been preferred to total area cropped. Total area owned provides information relating to the potential land a household could crop and therefore more exogenous to the use of fertilizer decision.

FARMEQ: a dummy variable representing ownership of farm equipment. Plows, harrows, and draft animals are included in this definition of farm equipment. Households that own these types of assets would more likely use fertilizer than those without. FARMEQ takes the values of one if the household owns any farm equipment and is zero otherwise.

TRANS: a dummy variable representing ownership of transportation equipment. Transportation equipment includes any transportation related asset such as bicycles, wheelbarrows, and ox carts. Ownership of mechanical assets such as lorries and vans is excluded because too few households own these assets to be of any significance overall. Households owning transportation equipment would more likely use fertilizer since they would be in a better position to get it from the distribution center to the farmstead. TRANS takes the values of one if the household owns any transportation equipment and is zero otherwise.

Geographical-level variables

Several geographical related variables (GEOvar) were created by combining the PHS province and district definitions with maps of the country obtained from the government of Zambia. Dummy variables are used to account for regional differences arising from location of fertilizer distributors, transportation infrastructure, climate, soil productivity, and soil types.

PROV: dummy variables representing the politically defined geographical regions corresponding to the provinces of Zambia. Politically, the Republic of Zambia is divided into nine provinces (Figure 1). These provincial-level dummy variables will be incorporated into models that include other geographical variables. The province-level dummy variables will account for geographically related differences between households not otherwise included in the model. As for the values of these various provincial-level dummy variables, no distinct econometric interpretation of their values can be made at this point because they incorporate all of the sources of inter-provincial variation not clearly included in the models.

Figure 1: Provinces of Zambia

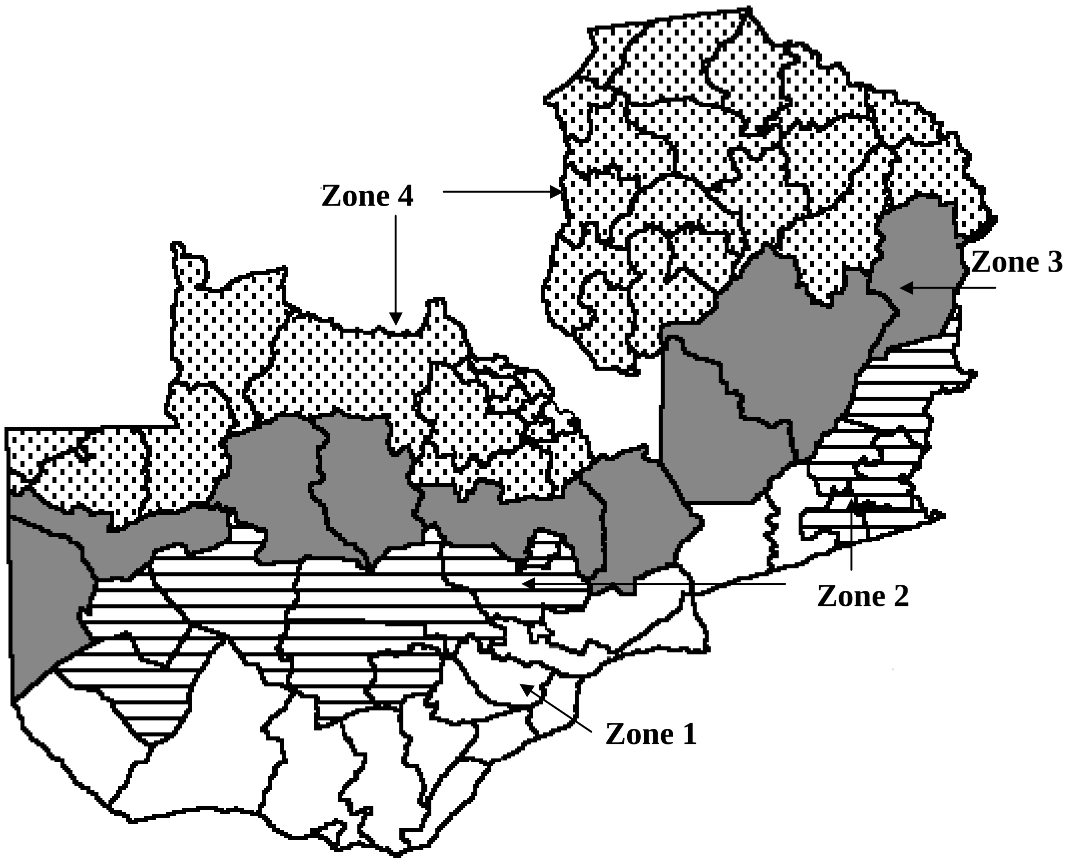
DIST: dummy variables representing the politically defined geographical regions corresponding to the districts of Zambia. Each province is further subdivided into multiple districts; there are seventy-two districts in Zambia. District-level dummy variables will represent all physical and geographical-level variations across the survey in the models in which they are used. These other factors include soil types and productivity, levels of infrastructure and access to markets. As the case with the provincial-level dummy variables, the district dummy variables incorporate all of the omitted inter-district variation not specifically included in the models.

AGROZONE: ecological zone dummy variables representing average level of rainfall in the district. Geographically, the country is divided into three regions based on levels of annual rainfall. The lowest levels of rainfall, Zone A, are found on the southern and southeastern parts of the country in Eastern, Lusaka, and Southern provinces, these areas typically have less than 800mm of rainfall per year. The highest levels occur in the northern regions of the country, Zone C. These regions include most of Northern, Luapula, and Copperbelt provinces and typically receive over 1000mm of rainfall annually. Zone B, the region between Zones A and C, receives between 800mm and 1000mm of rainfall annually on average.

These rainfall zones follow the contour of the southern part of the country and divide the country more or less through the middle. However, due to the limitations and availability of digitized maps of the country, *four* ecological regions were defined in this paper (Figure 2). This modification incorporates ecological-zone boundaries that do not fall directly into specific districts. As a result, the ecological zones incorporated in this paper do not directly correspond to specific, measured levels of annual rainfall but represent relative levels of rainfall in each particular region. ZONE1 corresponds to the districts located entirely in Zone A; ZONE2 represents districts that contain parts of both Zones A and B; ZONE3 includes districts in both Zones B and C; and ZONE4 is composed of districts entirely in Zone C.

Holding other factors constant, households located within districts with heavier rainfall would be expected to utilize fertilizer more often than would households in districts with lower levels of rainfall because the crops and fertilizer respond more productively with adequate levels of water. Therefore, households in ecological zones three and four (ZONE3 and ZONE4) would be anticipated to use fertilizer more than the other zones on average because adequate fertilizer response requires sufficient levels of rainfall. However, ZONE4 is characterized by poor soil types which may negate the benefit of more annual rainfall than other areas.

Figure 2: Ecological zones of Zambia by district



FERT: a dummy variable representing whether there is a major fertilizer depot located in the household's district (0 if no, one if yes). These fertilizer depots represent private traders of fertilizer, but the government through its programs, contracts these companies to use fertilizer at these depots for government distribution programs. These depots therefore represent joint commercial operations and government distribution programs; the government programs distribute fertilizer on loan, which has given rise to illegal parallel markets trading in government fertilizer. A dummy variable representing households located in districts that had a major fertilizer distribution depot is used. The *a priori* assumption is that households located within districts with fertilizer depots can acquire fertilizer at lower cost (including transactions costs) and will tend to utilize fertilizer more than households in districts without them. The shortcoming of this variable definition is discussed below. The variable FERT takes a value of one if the household resides in a district containing a fertilizer depot and is zero otherwise.

RAIL: a dummy variable representing whether the household is located in a district that is considered well-connected with railroad and/or major highway access. For many households in Zambia, impassable roads restrict access to fertilizer markets (Rashid and Zejjari 1998). The shortcoming of this variable definition is discussed below. The variable RAIL takes a value of one if the household resides in a district containing a rail-line or major transportation road and is zero otherwise.

Figure 3: Districts with at least one fertilizer depot

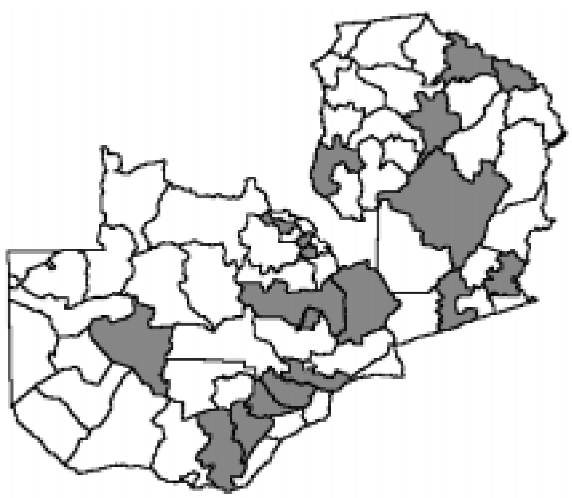
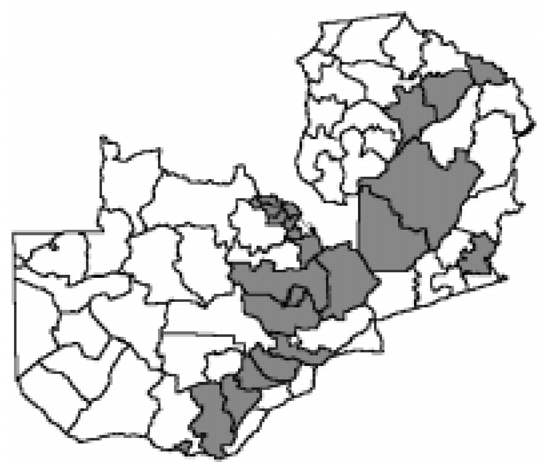


Figure 4: Districts considered well-connected



The shortcoming of both the FERT and RAIL variables is that they treat all households in each district the same. Households within a district containing a fertilizer depot but actually located far from the depot are treated the same as households located close to the fertilizer depot. Similarly, households living close to a fertilizer depot in an adjacent district may actually be close to the depot, but would not be considered close by virtue of the district they live it. The shortcoming of the RAIL variable follows similar reasoning.

Table 3 summarizes the number of fertilizer depots and number of well-connected districts located within each of Zambia's nine provinces. Fertilizer depots were located in nineteen districts. These distribution centers were heavily concentrated within the central region of the country (Figure 3). The line of rail and major highways connected 23 districts during the three-year period. The well-connected districts are shown in Figure 4.

Table 3: Selected characteristics of Zambian provinces

Province	Total number of districts	Number of districts with fertilizer depots	Number of well-connected districts
Central	6	3	5
Copperbelt	9	3	7
Eastern	8	2	1
Luapula	7	1	0
Lusaka	3	1	1
Northern	12	4	4
Northwestern	7	0	0
Southern	11	4	5
Western	7	1	0
Total	70	19	23

Despite the thoroughness of the three Post Harvest Surveys used in this paper, several variables were not available for inclusion in the analyses presented in this paper. Variables such as actual distance to the nearest fertilizer depot and household access to all-weather roads have been mentioned. Other variables that could not be included were household access to credit, off-farm employment and earnings, ages and levels of education of family members, and use of fertilizer in the past.

Model specifications

Slightly different variations of the probit model specification were estimated using different groupings of the household and geographical independent variables. Table 4 lists the dependent and independent variables used in these upcoming analyses. As previously mentioned, each model used the same dependent variable: "household uses basal fertilizer, top dressing fertilizer, or both".

The first model (Model 1) incorporates both the household-level variables and geographical variables. As shown, this model includes dummy variables associated with fertilizer depots, infrastructure access, ecological zones, and provincial level location. The results of this model will indicate the relationships between household-level characteristics, fertilizer depots, level of transportation infrastructure, ecological zone, and provincial location on a household's use of fertilizer.

$$USE1 = f(HHvar, FERT, RAIL, AGROZONE, PROV) \qquad \text{(Model 1)}$$

The second model (Model 2) also includes all household-level variables. However, in this model the only geographic variables used are district level dummy variables. To prevents multicollinearity between the variables, the dummy variables associated with fertilizer depots, infrastructure access, and ecological zones cannot be incorporated in a model with district dummy variables because all are defined at the district level. The advantage of Model 2 is that the district dummy variables control for all of the inter-district effects of fertilizer use and provide a within-district interpretation of the household variables. The limitation is that we are unable to directly interpret the factors accounting for the observed differences of fertilizer use between districts.

$$USE1 = f(HHvar, DIST) \qquad \text{(Model 2)}$$

Model 3 and Model 4 introduce a new set of variables: YEARvar. In these models, all households from each PHS survey are combined into one data set. A dummy variable corresponding to the year of the survey differentiates households. By incorporating a year variable, these models will describe the significance of the other variables across all of the survey periods analyzed. Additionally, the year variable will show how the use of fertilizer has changed (if at all) across the three PHS surveys.

Overall, Model 3 and Model 4 mimic Model 1 and Model 2 respectively. They utilize both household-level variables and geographic-level variables. However, these third and fourth models include only the GENDER, AGE, MALE, FEMALE, AREATOTL, and FARMEQ household-level variables; the variable TRANS is dropped. The transportation assets included in the PHS questions in survey period 1999/2000 changed, this variable does not consistently measure the same transportation assets and is not compatible across each of the surveys. Model 3 parallels Model 1 in that it utilizes the dummy variables associated with fertilizer depots, infrastructure access, ecological zones, and provincial level location, in addition to the year trend variable. Model 4 includes the district level dummy variables, in addition to the year trend variables.

$$USE1 = f(HHvar, FERT, RAIL, AGROZONE, PROV, YEARvar) \quad \text{(Model 3)}$$

$$USE1 = f(HHvar, DIST, YEARvar) \quad \text{(Model 4)}$$

Table 4: Definition of variables and models

Variable description	Abbreviation	Variables used in each model			
		Model 1	Model 2	Model 3	Model 4
Dependent variable					
Household uses basal or top dressing fertilizer	USE1	X	X	X	X
Independent variables					
Household-level variables	*HHvar*				
Gender of head of household	GENDER	X	X	X	X
Age of head of household	AGE	X	X	X	X
Number of males in household	MALE	X	X	X	X
Number of females in household	FEMALE	X	X	X	X
Total area cropped	AREATOTL	X	X	X	X
Own farm equipment	FARMEQ	X	X	X	X
Own transportation equipment	TRANS	X	X	n/a	n/a
Geographical variables	*GEOvar*				
Fertilizer depot located in district	FERT	X		X	
Well-connected district	RAIL	X		X	
Ecological zone dummy variables (4 variables)	AGROZONE	X		X	
Provincial dummy variables (9 variables)	PROV	X		X	
District dummy variables (70 variables)	DIST		X		X
Year variables	*YEARvar*				
Household interviewed in 1997/98	YEAR9798			X	X
Household interviewed in 1998/99	YEAR9899			X	X
Household interviewed in 1999/2000	YEAR9900			X	X

n/a indicates this variable not appropriately defined in each three PHS to utilize in this model.

CHAPTER 5
ANALYSIS AND USE OF FERTILIZER BY HOUSEHOLD AND GEOGRAPHICAL CHARACTERISTICS

This chapter will provide a basic analysis of the use of fertilizer by small- and medium-sized farming householder agriculture in Zambia. The household-level data used originates from the PHS data of the 1997/98, 1998/99, and 1999/2000 agricultural seasons. A household is considered to use fertilizer if it used any quantity of basal fertilizer, top dressing fertilizer, or both types of fertilizer on any crop.

Table 5 shows the use of fertilizer matrix by all agricultural households for each of the three survey periods. Overall, fertilizer use has increased slightly over the three-year survey period. Table 5 also shows the percent of households using at least one type of fertilizer.

Table 5: Fertilizer use matrix: household use of basal and top dressing fertilizer

	Household uses top dressing fertilizer					
Household uses basal	1997/98		1998/99		1999/2000	
fertilizer	No	Yes	No	Yes	No	Yes
No (%)	83.9	2.3	81.4	2.6	79.8	2.4
Yes (%)	2.1	11.7	1.5	14.5	1.6	16.2
Use either type or both		16.1		18.6		20.2

Application rate of fertilizer

Table 6 shows the average application rates of both basal and top dressing fertilizers. Use between the two is fairly equal with households applying slightly less top dressing than basal fertilizer. Intensity of fertilizer use is traditionally how fertilizer use is compared. However, total average quantity of fertilizer used by households is reported as well as average intensity of fertilizer use. This is because care must be exercised in interpreting the values for intensity of fertilizer use from how the values are generated.

Households responding to the PHS questionnaires indicate the total area they planted to crops and total fertilizer use. Since the total fertilizer is not necessarily applied to the total area planted, the calculation of intensity of fertilizer use may be prone to errors since households do not indicate the actual area fertilized.

Table 6: Quantity and intensity of fertilizer applied to crops

	1997/98	1998/99	1999/2000
Total quantity used (kg)			
Basal fertilizer	155.7	147.1	158.7
Top dressing fertilizer	145.1	133.4	143.1
Intensity of use (kg/ha)			
Basal fertilizer	146.4	134.8	145.8
Top dressing fertilizer	131.1	124.7	130.8

The Zambian Ministry of Agriculture, Forestry and Fisheries provides general fertilizer application rates for crops grown across the country. These recommendations for inputs are posted in many MAFF offices as the “General Fertilizer Recommendations for Major Crops in Zambia”. Application rates of fertilizer for maize are 200 kilograms of basal fertilizer and 200 kilograms of top dressing fertilizer per hectare (FSRP 2001). These suggested application rates may be useful, but such broad recommendations are problematic because they ignore factors that affect yield responses of fertilizer such as differences in climate and terrain (Benson *et al.* 1997). Area specific recommendations are more appropriate than nationwide ones. Nevertheless, the data above suggest that overall quantities of fertilizer applied in Zambia are lower than the recommended quantities by a factor of approximately twenty-five percent.

Household characteristics

Table 7 summarizes the descriptive statistics of variables analyzed in this paper for all households in the three Post Harvest Surveys that grew crops. There are few notable differences between reported household characteristics across the three-year sample period. The one exception is ownership of transportation assets. The reported ownership of these types of assets fell from roughly twenty-five percent in the first two survey periods to five percent in the last survey period. This reported drop in asset ownership is due to a change in the survey question actually asked: transportation equipment included ox-carts, bicycles, and wheelbarrows on the PHS from the 1997/98 and 1998/99 surveys; only ox-carts were considered in the PHS for the 1999/2000 agricultural season. Households that owned wheelbarrows or bicycles, but not ox-carts, would be included in the first two years as owning transportation equipment, but not during the last survey period. The increase in the value of these assets corresponds to the exclusion of these less-expensive assets.

Table 7: Characteristics of households that grow crops

	1997/98	1998/99	1999/2000
Characteristics of household head			
Female	23.2%	24.0%	23.5%
Male	76.8%	76.0%	76.5%
Age (in years)	44.6	44.9	42.7
	(14.65)	(15.13)	(14.11)
Household size (number of members)	5.73	6.04	6.14
	(3.00)	(3.263)	(3.40)
Males	2.71	2.95	3.05
	(1.73)	(1.92)	(2.09)
Females	3.02	3.09	3.09
	(1.90)	(2.02)	(2.00)
Total hectares cropped	1.36	1.47	1.45
	(1.32)	(1.44)	(1.34)
Total per capita hectares cropped	0.275	0.284	0.281
	(0.277)	(0.293)	(0.296)
Value of household crop production	603.9	544.1	470.0
(1,000s ZK)	(1011.70)	(789.27)	(751.63)
Households owning farm equipment (%)	12.8%	14.2%	13.8%
Average number owned	1.7	1.8	1.7
	(1.24)	(1.26)	(1.16)
Value for those owning (1,000s ZK)	422.8	385.6	325.7
	(287.94)	(265.27)	(214.04)
Households owning transportation equipment (%)	23.9%	26.6%	5.4%
Average number owned	1.2	1.2	1.1
	(0.59)	(0.61)	(0.48)
Value for those owning (1,000s ZK)	322.0	272.6	509.0
	(159.14)	(133.91)	(214.06)

Note: Standard deviation in (). Zambian Kwacha values in 2000 ZK.

Table 8 divides each sample period into two groups by use of fertilizer. Consistently across the surveys, when compared to households that do not use fertilizer, households that use fertilizer tend to have slightly younger heads of households, larger number of household members, and crop larger areas. Average value of household crop production was found to be substantially larger for households using fertilizer than for households not using fertilizer: in 1997/98 household crop income was 1.9 times higher for fertilizer-using households, in 1998/99 it was 1.5 times higher, and in 1999/2000 it was 1.7 times higher.

Households that used fertilizer were over twice as likely to own productive assets such as farm equipment and transportation equipment as households that did not use fertilizer. Additionally, for households that did own assets, they tended to own more of them in absolute terms than other non-fertilizer using households.

Another striking result shown in this table is the percent of female-headed households that use fertilizer (Table 9 further explores this finding). Female-headed households are about half as likely to use fertilizer as male-headed households: between nine percent and thirteen percent of the female-headed households used fertilizer while between eighteen percent and twenty-three percent of male-headed households used fertilizer.

Table 8: Household characteristics by use of fertilizer

	Household use of fertilizer					
	1997/98		1998/99		1999/2000	
	No	Yes	No	Yes	No	Yes
Characteristics of household head						
Female	91.5%	8.5%	87.7%	12.3%	87.2%	12.8%
Male	81.6%	18.4%	79.5%	20.5%	77.6%	22.4%
Age	45.0	42.8	45.1	44.2	42.6	43.2
Household size (number of members) *	5.5	6.9	5.8	7.0	5.9	7.1
Males*	2.6	3.3	2.8	3.4	2.9	3.6
Females*	2.9	3.6	3.0	3.5	3.0	3.5
Total area cropped (ha) *	1.23	2.00	1.32	2.15	1.30	2.03
Per capita total area cropped (ha) *	0.26	0.34	0.27	0.35	0.27	0.34
Value of household crop production (1,000s ZK) *	460.0	1342.5	424.4	1057.9	339.2	917.5
Households owning farm equipment (%)	13.4	30.7	13.0	29.2	11.0	31.5
Average number owned *	1.6	1.9	1.6	2.2	1.5	1.9
Value for those owning (1,000s ZK) *	401.9	470.2	345.6	468.5	297.2	368.4
Households owning transportation equipment (%)	22.7	49.5	22.6	52.2	3.8	18.9
Average number owned *	1.2	1.3	1.2	1.3	1.1	1.2
Value for those owning (1,000s ZK) *	308.2	352.3	260.9	294.7	498.2	517.9

Note: Zambian Kwacha values in 2000 ZK.

* indicates differences are significant at 1% level of significance for every year.

Table 9 provides additional detail on the observation made in Table 8 of the difference in fertilizer use by female-headed households and male-headed households. The data in Table 9 indicate that female-headed households make up roughly one-quarter of the number of households included in this data set. These households generally used less fertilizer than male-headed households, tended to have fewer household members, and cropped smaller areas on average. In addition to smaller aggregated cropped area, larger proportions of female-headed households cropped smaller areas than male-headed households: roughly one half of all female-headed households cropped areas less than 0.75 hectares while less than one-third of male-headed households cropped such small farms. Only five or six percent of all female-headed households cropped areas larger than 2.5 hectares while between 14 and 16 percent of male-headed households cropped farms this size or larger.

Table 9: Household characteristics by gender of head of household

	1997/98		1998/99		1999/2000	
	Female	Male	Female	Male	Female	Male
Percent of all households	23.2	76.8	24.0	76.0	23.5	76.5
Percent using fertilizer						
No	91.5	81.6	87.7	79.5	87.2	77.6
Yes	8.5	18.4	12.3	20.5	12.8	22.4
Household size*	4.7	6.0	5.1	6.3	5.3	6.4
Total hectares cropped*	0.98	1.48	1.10	1.59	1.09	1.56
Distribution of cropped area (%)						
0 - 0.75 ha	46.2	28.2	47.8	26.1	41.2	26.2
0.75 - 1.5 ha	36.8	36.8	36.6	34.9	35.3	35.4
1.5 - 2.5 ha	11.9	20.7	14.4	23.1	16.9	22.2
2.5 + ha	5.1	14.3	6.2	15.9	6.6	16.3
Asset ownership (% own)						
Farm equipment	5.3	15.1	6.3	17.0	7.0	15.8
Transportation Equipment	8.8	28.5	11.8	31.3	2.2	6.3

* indicates differences are significant at 1% level of significance for every year.

Physical and geographical characteristics

Table 10 presents breakdowns of the population of farming households by their geographical location. Eastern and Northern are the most heavily populated provinces accounting for approximately 40 percent of all households. Population is fairly equally distributed across each of the four ecological zones with Zone 3 having the fewest and Zone 4 having the largest number of households. The results indicate that approximately one-third of all households live in a district with a fertilizer depot and one-third live in a district considered well-connected. Slightly less than one-quarter of all households live in districts with a fertilizer depot and considered well-connected.

Table 10: Population by geographical characteristics (% of all households)

	1997/98	1998/99	1999/2000
Provinces			
Central	9.1	8.9	8.4
Copperbelt	4.4	4.0	4.3
Eastern	22.0	20.8	23.4
Luapula	13.7	13.8	13.1
Lusaka	1.8	1.9	2.2
Northern	18.4	19.0	16.6
Northwestern	6.3	6.2	6.2
Southern	12.5	13.4	13.1
Western	11.7	11.9	12.8
Ecological zones			
Zone 1	21.3	21.9	22.2
Zone 2	26.4	25.8	28.7
Zone 3	12.2	12.2	11.8
Zone 4	40.1	40.1	37.4
Fertilizer depot in district			
No	64.8	65.5	66.7
Yes	35.2	34.5	33.3
Well-connected district			
No	68.0	68.0	70.2
Yes	32.0	32.0	29.8
Fertilizer depot *and* well-connected district			
No	76.5	76.5	77.7
Yes	23.5	23.5	22.3

While overall fertilizer use increased from sixteen percent in 1997/98, to eighteen percent in 1998/99, to twenty percent in 1999/2000, fertilizer use varied widely across provinces (Table 11). Central, Copperbelt, and Lusaka provinces exhibited the highest rates of fertilizer use across the three years. The most notable and consistent increases in use occurred in Eastern and Southern provinces. Use in Eastern rose by eight percent and in Southern by sixteen percent. The lowest rates of use, as well as notable declining rates of use took place in Luapula, Northwestern, and Western provinces. The wide ranges of fertilizer use across provinces may be attributable to many different factors such as soil types and types of crops grown, weather patterns, level of transportation infrastructure and access to markets.

Table 11: Fertilizer use by province

	Percent of households using fertilizer		
Province	1997/98	1998/99	1999/2000
Central	31.2	39.4	33.7
Copperbelt	30.0	40.3	32.4
Eastern	20.1	20.9	28.5
Luapula	6.2	6.9	5.0
Lusaka	32.4	31.4	36.5
Northern	14.1	16.4	14.4
Northwestern	5.6	6.5	3.5
Southern	22.0	27.6	38.7
Western	3.0	2.7	1.1
National average	16.1	18.6	20.2

Analysis by ecological zones also yields notable differences in fertilizer use by region. Contrary to expectations, higher rates of fertilizer use occur in the dryer, southern areas of the country (Zone 1 and Zone 2) in 1998/99 and 1999/2000 (Table 12). These results may be attributed to many factors including differences in soil types and consistency of rainfall as previously mentioned. Fertilizer use appears to be increasing in the dryer regions at the same time it is decreasing in the wetter areas of the country.

Table 12: Fertilizer use by ecological zone

	Percent of households using fertilizer		
Ecological zone	1997/98	1998/99	1999/2000
Zone 1	17.4	20.6	29.0
Zone 2	20.6	24.4	27.1
Zone 3	18.9	18.1	15.7
Zone 4	11.6	13.8	11.0

Fertilizer use occurs more often in districts with a fertilizer depot. During the survey periods, nineteen of the seventy districts included in the survey had fertilizer depots. Conforming to expectations, households located in these districts were more likely to use fertilizer. Thirty-five percent of households with fertilizer depots in their districts used fertilizer in 1999/2000 (Table 13).

Table 13: Fertilizer use by fertilizer depot in district

	Percent of households using fertilizer		
Fertilizer depot in district	1997/98	1998/99	1999/2000
No	9.9	12.7	12.7
Yes	27.6	29.7	35.0

Overall use of fertilizer in Zambia is also related to the level of infrastructure in each district. While the quality and availability of infrastructure varies greatly across the country, there are twenty-three districts considered well-connected, meaning they had higher levels of infrastructure than the others. Higher levels of infrastructure constituted either rail line or major highway access. Table 14 shows a higher percentage of households used fertilizer if they were located in one of these well-connected districts.

Table 14: Fertilizer use by well-connected districts

	Percent of households using fertilizer		
Well-connected district	1997/98	1998/99	1999/2000
No	7.7	9.8	11.0
Yes	33.8	37.2	41.8

While previous tables, (Table 13 and Table 14) show fertilizer to be higher in both districts with fertilizer depots and well-connected districts, Table 15 demonstrates this finding more explicitly and in more detail. As shown, fertilizer use occurs at higher rates in districts with a fertilizer depot *or* considered well-connected than in districts without depots and with lower levels of transportation infrastructure. The final columns of Table 15 indicate that in districts with a fertilizer depot *and* with higher levels of infrastructure fertilizer use is significantly higher than in other districts. This result further supports previous findings as well as develops an understanding of how these characteristics affect household use of fertilizer in Zambia. The district in which a household lives appears to have a large effect upon a household's use of fertilizer.

However, households located in districts without fertilizer depots and not well-connected in Central, Copperbelt, Eastern, and Lusaka provinces exhibited rates of fertilizer use comparable to households living in districts with both characteristics but in other provinces; e.g. household use of fertilizer in Northern districts with both fertilizer depot and well-connected was 26 percent in 1999/2000, which is lower than fertilizer use in districts lacking fertilizer depots and not considered well-connected in Central, Copperbelt, and Lusaka provinces. This finding suggests several things may be occurring in these areas. Differences in the ecological zones could be part of the explanation. Another possibility is that households in these districts may have higher rates of asset ownership. These alternative explanations cannot be addressed using bivariate analysis. These issues will be addressed using econometric techniques in Chapter 6.

Table 15: Fertilizer use by fertilizer depots and well-connected districts, by provinces

Province	Districts	Districts with neither fertilizer depot nor well-connected				Districts with fertilizer depot or well-connected				Districts with fertilizer depot and well-connected			
	N	N	Households using fertilizer (%)			N	Households using fertilizer (%)			N	Households using fertilizer (%)		
			97/98	98/99	99/00		97/98	98/99	99/00		97/98	98/99	99/00
Central	6	1	13.4	27.1	27.1	2	25.4	37.3	32.4	3	49.5	49.9	39.9
Copperbelt	9	2	22.1	38.1	27.5	4	34.4	41.5	30.1	3	36.1	43.1	57.4
Eastern	8	6	10.4	13.9	21.8	1	9.7	8.0	15.4	1	49.8	51.2	56.4
Luapula	7	6	6.3	5.7	4.1	1	5.6	13.2	10.5	0	--	--	--
Lusaka	3	2	24.5	33.5	36.3	0	--	--	--	1	52.0	26.8	37.0
Northern	12	7	8.1	10.7	7.7	2	13.9	15.3	16.8	3	25.4	26.8	26.2
Northwestern	7	7	5.6	6.5	3.5	0	--	--	--	0	--	--	--
Southern	11	6	3.2	4.5	11.7	1	11.4	24.6	28.3	4	29.8	36.8	52.0
Western	7	6	0.9	0.8	0.4	1	10.0	9.6	3.9	0	--	--	--
Total	70	43	7.45	9.7	10.7	12	16.1	20.4	18.7	15	36.7	38.7	46.4

Cropping patterns

A cross-country analysis of the use of fertilizer such as this must consider to which types of crops the fertilizer is applied. Table 16, columns a, b, and c, demonstrates that maize is the most commonly planted crop and has consistently been grown by over seventy percent of all households. Other commonly grown crops are root crops (grown by nearly half of all households), groundnuts (grown by roughly one-third of all households), and sorghum and millet (grown by about one-quarter of all households). The other half of Table 16, columns d, e, and f, shows the total land area planted to the crop groups. While over one third of all households grow these crops, the total area planted to groundnuts and sorghum and millet represented less than twenty percent of total cropped land among these households in Zambia. Root crops were planted on about 25 percent of all cropped land while maize was grown on roughly half.

Table 16: Household planting patterns and total area cropped by crop groups

	Percent of households growing crop			Percent of total hectares planted		
	(a) 1997/98	(b) 1998/99	(c) 1999/2000	(d) 1997/98	(e) 1998/99	(f) 1999/2000
Maize	70.2	75.0	76.2	44.2	45.0	49.5
Sorghum & millet	24.7	26.2	24.7	7.9	8.4	7.8
Groundnuts	38.8	38.9	25.2	10.2	9.2	6.2
Cotton	9.8	8.7	5.5	6.7	5.4	3.2
Tobacco [a]	0.9	0.5	0.9	0.5	0.2	0.5
Root crops [b]	45.4	51.6	52.8	25.1	26.2	27.9
Beans [c]	12.0	13.1	9.3	2.8	3.1	2.4
Other crops [d]	4.9	5.4	6.4	2.5	2.5	2.6
				100.0%	100.0%	100.0%

[a] Tobacco includes burley tobacco and Virginia tobacco.

[b] Root crops includes cassava, sweet potatoes, and Irish potatoes.

[c] Beans includes soyabeans, mixed beans groundbeans, cowpeas, and velvet bean

[d] Other crops includes sunflower, rice, coffee, vegetables, and all other crops grown.

Columns a, b, and c of Table 17 show that maize is fertilized by over twenty percent of the households that grow maize. However, columns d, e, and f show that almost all of the total quantity of fertilizer used is applied to maize; over ninety percent of all fertilizer applied to crops by these households is used on maize.

Cash crops grown by these households do not represent a significant use of fertilizer. Cotton was grown by less than ten percent of these households and received less than one percent of total fertilizer. Conversely, while less than one percent of households grew tobacco, over eighty-five percent of those households used fertilizer on tobacco. Despite the highest rate of fertilizer application, this paper will not analyze fertilizer use on tobacco because fewer than one percent of all households grew tobacco (accounting for less than one-tenth of one percent of all fertilizer used). There are too few observations for meaningful analysis, as well as little variation in the dependent variable. Unfortunately, due to the structure of the questions, there is no way of knowing which crops the "Other Crops" group includes with any precision. It may be enlightening to understand the substantial decline in fertilizer use on those crops.

Table 17: Household use of fertilizer by crop groups

	Percent of this crop fertilized			Percent of total fertilizer used *		
	(a) 1997/98	(b) 1998/99	(c) 1999/2000	(d) 1997/98	(e) 1998/99	(f) 1999/2000
Maize	20.2	22.7	26.0	89.4	95.7	98.9
Sorghum & millet	1.0	0.4	0.8	0.2	0.1	0.2
Groundnuts	0.1	0.1	0.1	0.2	0.1	--
Cotton	0.2	0.4	0.1	0.1	--	--
Tobacco [a]	85.5	92.2	82.9	--	--	--
Root crops [b]	0.1	0.3	0.2	--	0.2	0.1
Beans [c]	1.7	0.9	1.3	0.3	--	0.2
Other crops [d]	6.4	5.8	2.8	9.9	4.0	0.7
				100.0%	100.0%	100.0%

* -- indicates less than 0.05 percent of total fertilizer was used on this crop group.

[a] Tobacco includes burley tobacco and Virginia tobacco.

[b] Root crops includes cassava, sweet potatoes, and Irish potatoes.

[c] Beans includes soyabeans, mixed beans groundbeans, cowpeas, and velvet bean.

[d] Other crops includes sunflower, rice, coffee, vegetables, and all other crops grown.

Table 18 shows an analysis of crops grown by ecological zone. The trends shown demonstrate why overall fertilizer use is lower in the regions of the country that receive more rainfall. Since maize receives the vast majority of fertilizer used in Zambia and is planted on over half of cropped land in Zones 1 and 2, higher rates of fertilizer use in these regions is not unexpected. Similarly, since root crops are the primary crop in Zone 4, lower rates of fertilizer use are not surprising in these areas since root crops do not respond well to fertilizer (Yanggen *et al.* 1998). These trends suggest that other factors such as soil types and consistency of rainfall (which effect household cropping decisions) in these regions may be determining fertilizer use patterns.

Table 18: Total area planted to crop groups by ecological zone

Crop Groups	Zone 1	Zone 2	Zone 3	Zone 4
1997/98				
Maize	68.1%	57.8%	38.2%	17.8%
Millet & Sorghum	5.1%	3.5%	22.8%	9.2%
Ground Nuts	14.0%	12.5%	5.2%	7.2%
Cotton	5.9%	15.9%	4.7%	0.0%
Tobacco [a]	0.1%	1.5%	0.0%	0.0%
Root Crops [b]	1.1%	4.4%	24.4%	59.7%
Beans [c]	1.3%	1.7%	1.8%	5.1%
Other Crops [d]	4.4%	2.8%	2.8%	0.9%
1998/99				
Maize	69.7%	59.1%	41.9%	19.8%
Millet & Sorghum	5.4%	3.4%	22.1%	10.1%
Ground Nuts	12.5%	11.2%	4.2%	7.0%
Cotton	6.1%	13.2%	2.6%	0.0%
Tobacco [a]	0.0%	0.8%	0.1%	0.0%
Root Crops [b]	2.2%	7.3%	24.3%	55.8%
Beans [c]	1.2%	1.4%	3.0%	5.5%
Other Crops [d]	2.9%	3.6%	1.7%	1.7%
1999/2000				
Maize	77.4%	62.4%	42.2%	22.8%
Millet & Sorghum	5.0%	3.0%	21.5%	9.9%
Ground Nuts	7.6%	7.8%	2.7%	4.9%
Cotton	2.1%	8.8%	0.8%	0.0%
Tobacco [a]	0.0%	1.6%	0.0%	0.0%
Root Crops [b]	4.2%	10.4%	29.9%	56.9%
Beans [c]	1.0%	1.5%	1.2%	4.3%
Other Crops [d]	2.6%	4.4%	1.7%	1.2%

[a] Tobacco includes burley tobacco and Virginia tobacco.

[b] Root crops includes cassava, sweet potatoes, and Irish potatoes.

[c] Beans includes soyabeans, mixed beans groundbeans, cowpeas, and velvet bean.

[d] Other crops includes sunflower, rice, coffee, vegetables, and all other crops grown.

In addition to fertilizer use being influenced by the household’s proximity to fertilizer distributors, their ability to purchase and transport the fertilizer, and their sales of output at local markets, important consideration must be given to the response of the crops to the fertilizer being applied. Maize consistently exhibits the best overall yield response to fertilizer in Sub-Saharan Africa (Yanggen *et al.* 1998). Sorghum, millet, groundnuts, and cotton yield response is generally moderate when compared to the high yield response of maize.

Table 19 demonstrates the yield response of maize across Zambia. Since previous analyses have shown that maize receives the vast majority of fertilizer applied to crops in Zambia (Table 16 and Table 17), yield analysis of other crops is ignored. The data indicate that households using fertilizer on maize can expect to receive substantially higher yields than those not applying fertilizer to maize. The findings are consistent across each ecological zones. Since the data suggest that yields are over fifty percent higher using fertilizer on maize, there appears to be a definite output response from using fertilizer on maize.

Table 19: Maize yield with and without use of fertilizer

	Yield (1,000 kg/ha) *		
	1997/98	1998/99	1999/2000
Overall maize yield	1.28	1.43	1.48
HH does not use fertilizer on maize	1.15	1.29	1.31
Ecological zone			
Zone 1	1.13	1.30	1.44
Zone 2	1.09	1.28	1.36
Zone 3	1.30	1.23	1.26
Zone 4	1.18	1.34	1.14
HH uses fertilizer on maize	1.89	1.99	2.02
Ecological zone			
Zone 1	1.83	1.91	2.01
Zone 2	1.79	2.06	2.09
Zone 3	2.22	1.92	2.01
Zone 4	1.88	2.00	1.90

* indicates differences are significant at 1% level of significance for every year.

CHAPTER 6
ECONOMECTIC ANALYSIS OF FERTILIZER USE ON MAIZE IN ZAMBIA

The previous chapter addressed the question of what household and geographical characteristics are likely impact a household's decision to use fertilizer. Chapter 6 further develops that exploration. The econometric analyses that follow measure the quantitative interactions between these dependent variables identified as relevant in understanding the use of fertilizer by small- and medium-households in Zambia.

In all of the following analyses, the sample sizes have been reduced. The number of observations was restricted to include only households located in districts in which there was at least one household using fertilizer. This restricted sample guarantees to the extent possible that all households included in this analysis might reasonably have been able to access fertilizer. The underlying assumption of this restriction is if at least one household used fertilizer in a district, other households at least had access to fertilizer as well. This procedure is designed to exclude households that did not use fertilizer because using it was not an option.

Another modification to the data utilized in this chapter is that this section of the paper focuses on households that grow maize. Restricting the data in this way ensures that the analysis is based on a sample of households with similar production patterns including cultivation of the crop that receives the bulk of fertilizer applied in Zambia. As previously shown, maize received 90 percent or more of all fertilizer used in Zambia. This additional change should improve the interpretation of the econometric results. Table 20 repeats some data presented in columns a, b, and c in Table 16 and further demonstrates that households growing maize constitute the vast majority of households using fertilizer. In 1997/98 over ninety-six percent of the households that used fertilizer grew maize, and in 1999/2000 ninety-nine percent of all households that used fertilizer grew maize.

Table 20: Fertilizer use matrix, households growing maize

	1997/98	1998/99	1999/2000
Households growing maize as percent of			
All households growing crops	70.2	75.0	76.2
All households using fertilizer	96.4	98.1	99.3

Table 21 shows the sample sizes for each survey period after incorporating the restrictions on the data. In 1997/98 the sample fell by 2,339 households (39 percent), in 1998/99 the sample shrunk by 3,552 households (46 percent), and in 1999/2000 the sample size fell by 2,727 households (37 percent).

Table 21: Original and restricted sample sizes

	Number of households		
	1997/98	1998/99	1999/2000
Entire sample (all households growing crops)	6,030	7,794	7,879
Restricted sample (households growing maize in districts with at least one household using fertilizer)	3,691	4,242	5,152

Correlations between the variables used in the analyses are presented in Table 22, Table 23, and Table 24. Multicollinearity issues were examined, but none of the correlations between independent variables were over 0.60. The highest correlation (0.522 in 1998/99 and 0.531 in 1999/2000) is between location of a fertilizer depot in the district (FERT) and districts with higher levels of transportation infrastructure (RAIL).

Table 22: Correlations between the variables, 1997/98

	gender	age	male	female	areatotl	farmeq	trans	fert	rail	zone1	zone2
gender	1.000										
age	-0.095	1.000									
male	0.225	0.115	1.000								
female	0.080	0.128	0.454	1.000							
areatotl	0.163	0.151	0.380	0.355	1.000						
farmeq	0.154	0.140	0.324	0.281	0.485	1.000					
trans	0.191	0.039	0.244	0.180	0.364	0.387	1.000				
fert	0.003	-0.014	0.057	0.045	0.092	0.135	0.084	1.000			
rail	0.042	-0.002	0.090	0.102	0.101	0.126	0.106	0.529	1.000		
zone1	0.009	0.007	0.076	0.089	0.118	0.250	0.064	0.464	0.176	1.000	
zone2	-0.039	0.041	-0.024	-0.017	0.014	0.079	0.033	-0.257	-0.169	-0.450	1.000
zone3	-0.016	0.018	-0.007	0.009	-0.017	-0.071	-0.043	0.158	0.314	-0.189	-0.263
zone4	0.045	-0.065	-0.043	-0.073	-0.118	-0.280	-0.069	-0.273	-0.196	-0.346	-0.483
p1	0.016	0.060	0.064	0.100	0.091	0.087	0.057	-0.094	0.278	-0.244	0.159
p2	-0.025	-0.020	-0.039	-0.051	-0.097	-0.131	-0.004	-0.112	0.142	-0.173	-0.241
p3	-0.065	-0.029	-0.097	-0.115	0.004	-0.005	0.083	0.078	-0.213	0.001	0.480
p4	0.057	-0.049	-0.036	-0.023	-0.039	-0.122	-0.009	-0.178	-0.200	-0.127	-0.178
p5	-0.004	-0.011	0.005	0.020	-0.046	-0.039	-0.077	-0.029	-0.023	0.359	-0.161
p6	0.026	-0.016	-0.008	-0.026	0.006	-0.140	-0.071	0.088	-0.020	-0.192	-0.269
p7	0.012	-0.026	-0.019	-0.045	-0.106	-0.131	-0.063	-0.246	-0.239	-0.152	-0.212
p8	0.060	0.002	0.143	0.153	0.139	0.330	0.074	0.279	0.316	0.597	-0.191
p9	-0.062	0.090	-0.033	-0.028	-0.074	-0.027	-0.131	0.025	-0.212	-0.135	0.300

	zone3	zone4	p1	p2	p3	p4	p5	p6	p7	p8	p9
zone3	1.000										
zone4	-0.203	1.000									
p1	0.481	-0.262	1.000								
p2	-0.101	0.499	-0.131	1.000							
p3	-0.210	-0.385	-0.272	-0.192	1.000						
p4	-0.075	0.368	-0.097	-0.068	-0.142	1.000					
p5	-0.068	-0.124	-0.088	-0.062	-0.129	-0.046	1.000				
p6	0.141	0.385	-0.146	-0.103	-0.214	-0.076	-0.069	1.000			
p7	0.027	0.361	-0.115	-0.082	-0.169	-0.060	-0.055	-0.091	1.000		
p8	-0.147	-0.269	-0.190	-0.134	-0.278	-0.099	-0.090	-0.149	-0.118	1.000	
p9	-0.079	-0.145	-0.102	-0.073	-0.150	-0.053	-0.049	-0.081	-0.064	-0.105	1.000

Table 23: Correlations between the variables, 1998/99

	gender	age	male	female	areatotl	farmeq	trans	fert	rail	zone1	zone2
gender	1.000										
age	-0.074	1.000									
male	0.219	0.126	1.000								
female	0.087	0.112	0.428	1.000							
areatotl	0.165	0.112	0.384	0.308	1.000						
farmeq	0.147	0.157	0.290	0.245	0.439	1.000					
trans	0.217	0.045	0.235	0.183	0.337	0.351	1.000				
fert	0.030	0.011	0.060	0.059	0.104	0.103	0.115	1.000			
rail	0.047	-0.012	0.084	0.070	0.079	0.089	0.108	0.522	1.000		
zone1	-0.003	-0.004	0.061	0.066	0.073	0.244	0.059	0.421	0.162	1.000	
zone2	0.003	0.045	-0.019	-0.010	0.019	0.117	0.058	-0.194	-0.136	-0.401	1.000
zone3	-0.049	-0.009	-0.001	0.002	-0.048	-0.118	-0.085	0.076	0.222	-0.209	-0.273
zone4	0.034	-0.037	-0.037	-0.053	-0.053	-0.263	-0.054	-0.244	-0.169	-0.360	-0.470
p1	0.002	0.024	0.084	0.078	0.076	0.085	0.036	-0.046	0.321	-0.219	0.139
p2	0.022	-0.003	-0.042	-0.036	-0.081	-0.124	0.007	-0.108	0.149	-0.161	-0.210
p3	-0.025	-0.005	-0.084	-0.095	-0.008	0.018	0.026	0.050	-0.221	-0.014	0.478
p4	0.030	-0.006	-0.014	-0.021	-0.018	-0.097	0.057	-0.128	-0.188	-0.121	-0.159
p5	-0.015	0.013	0.005	0.014	-0.041	-0.016	-0.052	0.005	0.009	0.354	-0.142
p6	-0.008	-0.024	-0.006	-0.034	0.053	-0.160	-0.071	0.049	-0.016	-0.226	-0.295
p7	0.003	-0.026	-0.023	0.003	-0.099	-0.110	-0.094	-0.242	-0.238	-0.154	-0.201
p8	0.041	-0.020	0.103	0.110	0.105	0.297	0.075	0.239	0.280	0.639	-0.187
p9	-0.050	0.066	-0.031	-0.007	-0.089	-0.019	-0.027	0.028	-0.210	-0.135	0.338

	zone3	zone4	p1	p2	p3	p4	p5	p6	p7	p8	p9
zone3	1.000										
zone4	-0.245	1.000									
p1	0.438	-0.257	1.000								
p2	-0.109	0.446	-0.115	1.000							
p3	-0.113	-0.402	-0.245	-0.180	1.000						
p4	-0.083	0.337	-0.087	-0.064	-0.136	1.000					
p5	-0.074	-0.127	-0.078	-0.057	-0.121	-0.043	1.000				
p6	0.043	0.486	-0.161	-0.118	-0.252	-0.089	-0.080	1.000			
p7	0.104	0.276	-0.110	-0.080	-0.171	-0.061	-0.054	-0.113	1.000		
p8	-0.163	-0.281	-0.171	-0.125	-0.267	-0.095	-0.085	-0.176	-0.120	1.000	
p9	-0.092	-0.159	-0.097	-0.071	-0.151	-0.054	-0.048	-0.100	-0.068	-0.106	1.000

Table 24: Correlations between the variables, 1999/2000

	gender	age	male	female	areatotl	farmeq	trans	fert	rail	zone1	zone2
gender	1.000										
age	-0.077	1.000									
male	0.208	0.196	1.000								
female	0.055	0.169	0.442	1.000							
areatotl	0.157	0.177	0.345	0.296	1.000						
farmeq	0.123	0.162	0.261	0.228	0.397	1.000					
trans	0.104	0.172	0.262	0.223	0.414	0.606	1.000				
fert	0.025	0.010	0.043	0.030	0.103	0.087	0.075	1.000			
rail	0.048	0.061	0.122	0.093	0.107	0.077	0.073	0.531	1.000		
zone1	0.035	-0.001	0.059	0.069	0.012	0.248	0.108	0.355	0.115	1.000	
zone2	-0.060	0.041	-0.052	-0.033	0.015	0.092	0.102	-0.196	-0.136	-0.431	1.000
zone3	-0.023	-0.007	-0.005	-0.015	-0.054	-0.117	-0.065	0.099	0.245	-0.209	-0.252
zone4	0.045	-0.037	0.000	-0.023	0.010	-0.258	-0.168	-0.209	-0.138	-0.377	-0.457
p1	0.021	0.052	0.050	0.074	0.019	0.041	0.063	-0.058	0.297	-0.239	0.171
p2	0.030	0.030	0.036	0.006	-0.001	-0.108	-0.066	-0.102	0.156	-0.180	-0.218
p3	-0.065	-0.038	-0.084	-0.081	0.007	0.012	0.084	0.062	-0.203	0.018	0.407
p4	-0.006	-0.036	-0.041	-0.038	-0.054	-0.107	-0.074	-0.121	-0.187	-0.133	-0.161
p5	0.021	0.033	0.001	0.001	-0.070	-0.010	-0.015	0.026	0.032	0.340	-0.147
p6	0.038	-0.006	0.010	-0.008	0.118	-0.156	-0.106	0.060	-0.018	-0.231	-0.279
p7	0.010	-0.069	-0.010	-0.009	-0.092	-0.100	-0.049	-0.208	-0.202	-0.144	-0.174
p8	0.033	0.013	0.119	0.126	0.085	0.314	0.121	0.223	0.267	0.592	-0.187
p9	-0.061	0.016	-0.097	-0.091	-0.125	-0.018	-0.072	-0.047	-0.251	-0.073	0.316

	zone3	zone4	p1	p2	p3	p4	p5	p6	p7	p8	p9
zone3	1.000										
zone4	-0.221	1.000									
p1	0.445	-0.253	1.000								
p2	-0.106	0.478	-0.121	1.000							
p3	-0.096	-0.379	-0.240	-0.181	1.000						
p4	-0.078	0.353	-0.089	-0.067	-0.134	1.000					
p5	-0.071	-0.128	-0.081	-0.061	-0.122	-0.045	1.000				
p6	0.050	0.484	-0.155	-0.117	-0.232	-0.086	-0.079	1.000			
p7	0.070	0.275	-0.096	-0.073	-0.144	-0.054	-0.049	-0.093	1.000		
p8	-0.152	-0.276	-0.175	-0.132	-0.261	-0.097	-0.089	-0.169	-0.105	1.000	
p9	-0.104	-0.189	-0.120	-0.090	-0.179	-0.067	-0.061	-0.116	-0.072	-0.130	1.000

Review of models employed

Prior to discussing details from the econometric analysis, a quick review of the model formats:

USE1 = f(HHvar, FERT, RAIL, AGROZONE, PROV) (Model 1)

USE1 = f(HHvar, DIST) (Model 2)

USE1 = f(HHvar, FERT, RAIL, AGROZONE, PROV, YEARvar) (Model 3)

USE1 = f(HHvar, DIST, YEARvar) (Model 4)

In Model 1 and Model 3, the ecological zone dummy variable Zone 4 and Eastern province were chosen as the omitted ecological zone variable and provincial level variable. The model results are normalized in terms of this province and ecological zone combination. Zone 4 and Eastern province were chosen because they contained the largest number of farmers. Similarly, in Models 2 and 4, Chipata district in Eastern province was chosen as the base variable for the same reason.

The results of the probit analysis of Model 1 are presented in Table 25 (page 62), Model 2 in Table 26 (page 63), and the results of Model 3 and Model 4 are in Table 28 (page 66). Overall, each model predicts a household's probability of fertilizer use fairly well, as demonstrated by the accuracy of the observed versus the predicted values from the models shown at the bottom of each table of results. For example, looking at the results of Model 1, 1997/98, approximately 27 percent of the sample included in the probit model used fertilizer; the model predicted that about 23 percent of the households would use fertilizer.

Analysis of household-level variables

The signs of the coefficients of each household-level variable are as anticipated. Contrary to results reported by Croppenstedt and Demeke 1996 and Doss and Morris 2001, the coefficient on the GENDER variable is significant across each year and each model, with the exception of Model 1, 1998/99. The 1997/98 coefficient of 0.2364 from Model 1 indicates that male-headed households growing maize were found to be more likely to use fertilizer than female-headed households. This value's corresponding marginal impact (dF/dx) of 0.0685 indicates that male-headed households growing maize are approximately seven percent more likely to use fertilizer than female-headed households.

The coefficient of the AGE variable, which was not found to be significant by Green and Ng'ong'ola 1993, Croppenstedt and Demeke 1996, and Nkonya *et al.* 1997, was found to be consistently significant, although of small magnitude, in the models used here. These negative coefficients contradict the findings for Tanzanian households (Kaliba *et al.* 2000) and suggest that younger heads of households that grow maize are more likely to use fertilizer than older ones. Again using Model 1, 1997/98 values as a guide, the marginal impact of one additional year of age of the head of household was found to reduce the likelihood of using fertilizer by approximately one fifth of a percent (-0.0019). For example, the likelihood of a thirty year-old head of household to use fertilizer would be one percent greater than a thirty-five year-old head of household. Models using AGE-squared were estimated to examine possible non-linear relationship, and no significant differences appeared in the model results.

The positive signs of the coefficients representing the number of males in a household (MALE) and the number of females in a household (FEMALE) indicate that households growing maize with more male members and more female members are more likely to use fertilizer. This result appears to be robust across studies (Nkonya *et al.* 1997, Kherallah *et al.* 2001, Doss and Morris 2001). Interestingly, the coefficients on these variables are not jointly significant in Models 1 and 2: for 1997/98, the number of males in a household significantly affected a household's use of fertilizer, while the number of females was not found to be significant; and for 1998/99 and 1999/2000, the number of females significantly impacted a household's use of fertilizer while the number of males did not significantly impact the use of fertilizer by the household. For the cross-year models, Models 3 and 4, these variables were both found to be significant in a household's use of fertilizer.

The positive coefficient on AREATOTL conforms to our *a priori* expectations that for these maize-growing households, those cropping more area are more likely to use fertilizer. The large associated z-score on this variable indicates that this variable is statistically significant at any traditional level of significance. Despite its significance in the model, the magnitude of total area cropped on fertilizer use is quite small. Using the data from Model 1, 1997/98, each additional hectare of land a household crops is anticipated to increase the likelihood of fertilizer use by almost three percent (dF/dx of 0.0267).

Conforming to our a priori expectations, Model 1 and Model 2 show that ownership of farm equipment and transportation equipment increased the likelihood of fertilizer use by households growing maize. Model 1 indicates that ownership of farm equipment increased a household's use of fertilizer by almost eight percent in 1999/2000. One of the most significant results suggests that ownership of transportation equipment has a larger impact than ownership of farm equipment on a household's use of fertilizer. Households owning transportation assets had rates of fertilizer use approximately thirteen percent higher than those not owning these types of assets in the 1999/2000 survey year. Since the questions about household's ownership of productive assets were not consistent across each of the three survey periods, Models 3 and 4 do not include the ownership of transportation equipment variables (TRANS).

Analysis of physical and geographical-level variables

The analysis of physical and geographical-level variables refers primarily to Model 1 and Model 3 because these models incorporate the variables PROV, FERT, RAIL, and the ecological zones; analysis of the district-level dummy variables present in Model 2 and Model 4 follows this analysis. Although not as strongly as anticipated, the models support the hypotheses that households growing maize and located in districts with a major fertilizer depot (FERT) are more likely to utilize fertilizer. The coefficient of FERT is positive throughout each model and significant in Model 3 and survey year 1999/2000 in Model 1, this variable was not found to be significant in 1997/98 or in 1998/99 for Model 1. Interpreting the result shown for the 1999/2000 PHS indicates the marginal impact of a fertilizer depot in the household's district would increase the probability of fertilizer use by about eight percent (0.0808).

Perhaps the most important finding relating to the geographical variables is the consistency and significance of the RAIL variable. Conforming to expectations and work by Croppenstedt and Demeke 1996, the level of infrastructure was found to positively affect the use of fertilizer by households growing maize. The results of Model 1 indicate that households growing maize in districts with higher levels of infrastructure leads to an increase in the likelihood of fertilizer use by nearly 25 percent (1997/98 RAIL dF/dx of 0.2407; 1998/99 RAIL dF/dx of 0.2324; and 1999/2000 RAIL dF/dx of 0.2306).

The effects of the ecological zone variables closely conform to *a priori* expectations. The negative parameter estimates for Zone 1 and Zone 3 suggest that households growing maize in these regions tend to use fertilizer less often than households in Zone 4, the wettest region of the country. These results are easily reconciled with the data presented in Table 12, which indicated that fertilizer use was consistently lowest in Zone 4. By excluding households that do not grow maize, the probit models focus the analysis on households more likely to use fertilizer since maize is the primary crop receiving fertilizer.

The coefficient results for Zone 2 presented an anomaly in the models that is less easily explained. In 1997/98, Model 1 found households in Zone 2 to be less likely to use fertilizer than households in Zone 4; however in 1999/2000 households in Zone 2 were found to be more likely to use fertilizer than in Zone 4. Since it is unlikely that the conditions within this region of the country changed such that fertilizer use became more likely in two years, this interesting result must be explained by changes in fertilizer use within this region that are not identified in the survey. One likely factor in this finding is that government fertilizer distribution may have changed significantly in this region. Government fertilizer distribution is administratively determined and often fluctuates from one area to another from year to year. This region corresponds to areas of Eastern, Central, Southern, and Western provinces.

As for the provincial level variables, the results for Model 1 show that in 1997/98, five of the eight provincial dummy variables were found to be significant at a ten percent level of significance or better, in 1998/99 and 1999/2000 seven and four of the dummy variables were found to be significant, respectively. Positive signs indicate fertilizer use to be higher for households in that province than in Eastern province, negative signs indicate lower probability of fertilizer use in that province than in Eastern province. Three provinces exhibited consistent signs across each of the three probit models, Lusaka, Northwestern, and Western provinces each The positive and significant coefficient on Lusaka province (P4) indicates that households growing maize in that province are more likely to utilize fertilizer than households growing maize in Eastern province in 1997/98. The consistently negative coefficients on Northwestern and Western provinces (P9) indicate that households growing maize in these provinces are less likely to utilize fertilizer than are households in Eastern province (P3).

Several provinces exhibited changing trends in fertilizer use when compared to Eastern province in these models. For example, there were negative signs on the coefficients for both Central and Copperbelt provinces in 1997/98 but then positive signs on their coefficients in 1998/99. Since these parameter estimates include all of the potential differences in fertilizer use between provinces that are not otherwise directly accounted for in the model, something else must be accountable for these significant changes in fertilizer use. As in the case of the ecological zones, the likely change may be fertilizer distribution patterns.

Table 27 shows the marginal impact of the district-level dummy variables that were significant at the ten percent level for Model 2. Districts in which there was no fertilizer use are dropped from the analysis. The values presented show the relative impact of fertilizer use compared to Chipata district. Only three districts showed greater probability of fertilizer use than Chipata: Mkushi, Chingola, and Mazabuka.

Table 25: Results of probit Model 1

	1997/98				1998/99				1999/2000			
Variable	Coefficient	z		dF/dx	Coefficient	z		dF/dx	Coefficient	z		dF/dx
GENDER	0.2364	3.302	***	0.0685	0.0941	1.614		0.0305	0.2462	4.564	***	0.0813
AGE	-0.0063	-3.591	***	-0.0019	-0.0043	-2.802	***	-0.0014	-0.0045	-3.101	***	-0.0016
MALE	0.0377	2.719	***	0.0116	0.0141	1.193		0.0047	0.0122	1.251		0.0042
FEMALE	0.0177	1.525		0.0055	0.0271	2.475	**	0.0089	0.0202	2.035	**	0.0070
AREATOTL	0.0869	6.492	***	0.0267	0.0863	6.902	***	0.0284	0.0743	7.203	***	0.0257
FARMEQ	0.1099	1.549		0.0345	0.1153	1.754	*	0.0387	0.2223	3.389	***	0.0792
TRANS	0.3520	6.394	***	0.1121	0.4559	9.170	***	0.1554	0.3564	4.382	***	0.1309
FERT	0.1101	1.447		0.0339	0.0732	1.105		0.0242	0.2324	4.015	***	0.0808
RAIL	0.7700	9.951	***	0.2407	0.6928	10.090	***	0.2324	0.6573	10.884	***	0.2306
ZONE1	-1.0296	-4.721	***	-0.2519	-0.0872	-0.458		-0.0283	-0.1532	-0.897		-0.0518
ZONE2	-0.7015	-3.637	***	-0.2012	0.1730	1.060		0.0579	0.3334	2.177	**	0.1178
ZONE3	-0.4382	-2.790	***	-0.1166	-0.1391	-1.062		-0.0443	-0.1024	-0.818		-0.0346
P1 (Central)	-0.1761	-1.697	*	-0.0517	0.2512	2.700	***	0.0871	-0.0226	-0.278		-0.0078
P2 (Copperbelt)	-0.8510	-3.837	***	-0.1910	0.4831	2.586	***	0.1755	0.2882	1.659	*	0.1051
P4 (Luapula)	-0.3504	-1.562		-0.0947	0.3292	1.700	*	0.1173	0.1752	0.971		0.0629
P5 (Lusaka)	0.7094	4.527	***	0.2571	0.6621	4.618	***	0.2475	0.5089	4.250	***	0.1920
P6 (Northern)	-0.2139	-1.163		-0.0615	0.2781	1.743	*	0.0968	0.2102	1.399		0.0753
P7 (Northwestern)	-0.8888	-3.956	***	-0.1932	-0.2207	-1.207		-0.0682	-0.3508	-2.000	**	-0.1098
P8 (Southern)	-0.1251	-1.089		-0.0372	-0.2121	-1.983	**	-0.0666	0.1043	1.212		0.0367
P9 (Western)	-0.3943	-2.476	**	-0.1049	-0.6088	-4.322	***	-0.1632	-1.1289	-8.852	***	-0.2705
Constant	-0.7331	-3.286	***		-1.3995	-7.551	***		-1.2973	-7.554	***	
Sample	3,691				4,242				5,152			
Log likelihood	-1,822.3372				-2,177.5694				-2,722.0693			
Observed P.	0.2715				0.3025				0.3340			
Predicted P.	0.2349				0.2683				0.2956			

***, **, * denote statistical significance at 1%, 5%, 10% levels respectively.

Table 26: Results of probit Model 2

Variable	1997/98 Coefficient	z		dF/dx	1998/99 Coefficient	z		dF/dx	1999/2000 Coefficient	z		dF/dx
GENDER	0.2171	2.912	***	0.0599	0.1165	1.910	*	0.0361	0.2256	4.009	***	0.0723
AGE	-0.0067	-3.592	***	-0.0019	-0.0046	-2.894	***	-0.0015	-0.0050	-3.264	***	-0.0017
MALE	0.0374	2.591	***	0.0109	0.0138	1.113		0.0044	0.0125	1.235		0.0042
FEMALE	0.0155	1.280		0.0045	0.0340	2.996	***	0.0108	0.0293	2.839	***	0.0098
AREATOTL	0.0847	6.050	***	0.0248	0.0843	6.466	***	0.0267	0.0781	7.219	***	0.0262
FARMEQ	0.2042	2.725	***	0.0622	0.1774	2.523	**	0.0581	0.2698	3.922	***	0.0942
TRANS	0.3359	5.739	***	0.1021	0.4444	8.414	***	0.1462	0.3545	4.223	***	0.1273
Constant	-0.4472	-3.502	***		-0.4435	-3.746	***		-0.1368	-1.259		
– District dummy variables shown in Table 27												
Sample	3,691				4,242				5,152			
Log likelihood	-1,683.2855				-2,012.5785				-2,544.5027			
Observed P.	0.2685				0.3025				0.3340			
Predicted P.	0.2152				0.2487				0.2772			

***, **, * denote statistical significance at 1%, 5%, 10% levels respectively.

Table 27: Marginal impacts of district-level dummy variables, Model 2

	dF/dx [a]				dF/dx [a]		
District	1997/98	1998/99	1999/2000	District	1997/98	1998/99	1999/2000
Chibombo	-0.1047		-0.0782	Luwingu			-0.2527
Kapiri Mposhi			-0.1074	Mbala	-0.1697	-0.2187	-0.2270
Mkushi	0.3199	0.1898	0.1359	Mpika			-0.1024
Mumbwa	-0.2017	-0.1432	-0.2098	Mporokoso			-0.1466
Serenje	-0.1274	-0.1953	-0.2449	Mpulungu		-0.2048	-0.1577
Chililabombwe			-0.1338	Mungwi	0.4061		
Chingola	0.1410	0.5167	0.4199	Kabompo	-0.1844	-0.2096	-0.2829
Kalulushi	-0.1460		-0.1692	Kasempa	-0.2090	-0.2384	-0.2356
Luanshya	-0.1580	-0.1526		Mufumbwe		-0.2467	
Lufwanyama	-0.1195	-0.1233	-0.1697	Mwinilunga	-0.1924	-0.1834	-0.2654
Masaiti	-0.1416			Solwezi	-0.1893	-0.2210	-0.2744
Mpongwe	-0.1783		-0.2184	Zambezi	-0.2109	-0.2500	
Mufulira	-0.1444			Choma	-0.1220	-0.1569	-0.0817
Chadiza	-0.1282	-0.1119		Gwembe	-0.1319	-0.2454	-0.2259
Chama		-0.2216	-0.2773	Itezhi-tezhi	-0.2152	-0.2533	-0.2717
Katete	-0.2339	-0.2419	-0.2297	Kalomo	-0.0977	-0.1146	-0.1135
Lundazi	-0.1510	-0.1210	-0.1576	Livingstone	-0.1469	-0.1401	-0.1714
Mambwe		-0.2421		Mazabuka		0.1104	0.1638
Nyimba			-0.2858	Monze	-0.2058	-0.2332	-0.1688
Petauke	-0.2285	-0.2409	-0.2703	Namwala	-0.2188	-0.2482	-0.2668
Chiengi	-0.1946	-0.2294	-0.2620	Siavonga			-0.2486
Kawambwa			-0.1433	Sinazongwe		-0.2507	-0.2652
Milenge		-0.2178	-0.2177	Kaoma	-0.1948	-0.2290	-0.2742
Mwense	-0.1636	-0.2443	-0.2840	Mongu	-0.2161	-0.2521	-0.2857
Nchelenge	-0.2182			Senanga			-0.2948
Samfya			-0.1955	Shang'ombo			-0.2862
Chongwe			-0.1072				
Kafue			-0.1106				
Isoka	-0.1638	-0.1526	-0.2744				

[a] All districts reported are significant at 10% level, other districts not reported.
Notes: results are relative to Chipata district; districts not reported when no fertilizer use in district.

Model 3 and Model 4 combine all households from each of the three survey years and analyze them together by incorporating a variable to indicate the year in which the household was surveyed. Both models reinforce the importance of the household-level characteristics in fertilizer use. Each of the household variables was significant at the one percent level in each model. The variable showing the greatest impact on fertilizer use was ownership of farm equipment, increasing the probability of fertilizer use by ten percent (transportation equipment could not be included because of inconsistency in survey questions). The second and third largest impacts were gender of head of household (increasing fertilizer use by seven percent) and total area cropped (each additional hectare of land cropped resulted in increases in fertilizer use of three percent).

The ecological zone variables corresponding to Zone 1 and Zone 3 conformed to the previous results and suggested households in these areas were less likely to use fertilizer on maize than households in Zone 4. However, the data do not suggest there to be any difference in household use of fertilizer in Zone 2 compared to Zone 4. The province variable results suggest that households in Lusaka province were more likely to use fertilizer than those in Eastern province while households in Northwestern, Southern, and Western provinces were less likely to use fertilizer than in Eastern province. Fertilizer use in Central, Copperbelt, Luapula, and Northern provinces was not shown to be significantly different than in Eastern province.

Table 29 shows the marginal impact of the district-level dummy variables that were significant at the ten percent level for Model 4. The values presented show the relative impact of fertilizer use compared to Chipata district. In this model, only Mkushi and Chingola districts showed greater probability of fertilizer use than Chipata.

Table 28: Results of probit Model 3 and probit Model 4

	Model 3				Model 4			
Variable	Coefficient	z		dF/dx	Coefficient	z		dF/dx
GENDER	0.2292	6.724	***	0.0728	0.2215	6.292	***	0.0683
AGE	-0.0047	-5.316	***	-0.0016	-0.0052	-5.615	***	-0.0017
MALE	0.0230	3.522	***	0.0076	0.0224	3.335	***	0.0072
FEMALE	0.0243	3.932	***	0.0080	0.0284	4.469	***	0.0092
AREATOTL	0.0922	13.842	***	0.0307	0.0936	13.584	***	0.0302
FARMEQ	0.2864	8.024	***	0.0995	0.3361	8.974	***	0.1146
FERT	0.1666	4.476	***	0.0557				
RAIL	0.6987	18.116	***	0.2361	– *District dummy variables*			
ZONE1	-0.3167	-2.941	***	-0.0998	*shown in Table 29*			
ZONE2	0.0554	0.582		0.0185				
ZONE3	-0.1873	-2.425	**	-0.0594				
P1 (Central)	0.0256	0.496		0.0086				
P2 (Copperbelt)	0.1704	0.888		0.0328				
P4 (Luapula)	0.1704	1.523		0.0591				
P5 (Lusaka)	0.5727	7.335	***	0.2131				
P6 (Northern)	0.1130	1.220		0.0385				
P7 (Northwestern)	-0.3968	-3.658	***	-0.1168				
P8 (Southern)	-0.0962	-1.699	*	-0.0314				
P9 (Western)	-0.8152	-10.285	***	-0.2051				
year9899	0.1361	4.230	***	0.0459	0.1384	4.153	***	0.0454
year9900	0.2230	7.230	***	0.0751	0.2435	7.614	***	0.0798
Constant	-1.3599	-12.326	***		-0.4069	-5.880	***	
Sample	13,085				13,085			
Log likelihood	-6,866.3088				-6,462.9213			
Observed P.	0.3062				0.3062			
Predicted P.	0.2731				0.2579			

***, **, * denote statistical significance at 1%, 5%, 10% levels respectively.

Table 29: Marginal impacts of district-level dummy variables, Model 4 (all 3 years)

District	dF/dx [a]	District	dF/dx [a]
Chibombo	-0.0543	Chinsali	-0.0789
Kapiri Mposhi	-0.0581	Isoka	-0.2293
Mkushi	0.1671	Kasama	-0.0858
Mumbwa	-0.1968	Luwingu	-0.1936
Serenje	-0.2178	Mbala	-0.2273
Chililabombwe	-0.0900	Mpika	-0.0731
Chingola	0.3081	Mporokoso	-0.0893
Kalulushi	-0.1095	Mpulungu	-0.1991
Kitwe	-0.1080	Kabompo	-0.2491
Luanshya	-0.1558	Kasempa	-0.2410
Lufwanyama	-0.1543	Mufumbwe	-0.2564
Masaiti	-0.0798	Mwinilunga	-0.2325
Mpongwe	-0.1835	Solwezi	-0.2469
Mufulira	-0.0878	Zambezi	-0.2578
Chadiza	-0.1046	Choma	-0.1158
Chama	-0.2532	Gwembe	-0.2109
Katete	-0.2420	Itezhi-tezhi	-0.2580
Lundazi	-0.1676	Kalomo	-0.1037
Mambwe	-0.2522	Livingstone	-0.1623
Nyimba	-0.2623	Monze	-0.2067
Petauke	-0.2546	Namwala	-0.2544
Chiengi	-0.2428	Siavonga	-0.2243
Kawambwa	-0.0704	Sinazongwe	-0.2495
Mansa	-0.0886	Kaoma	-0.2473
Milenge	-0.2055	Mongu	-0.2669
Mwense	-0.2534	Senanga	-0.2658
Nchelenge	-0.2569	Shang'ombo	-0.2613
Samfya	-0.1243		
Chongwe	-0.0836		
Kafue	-0.0929		

[a] All districts reported are significant at 10% level, other districts not reported.
Notes: results are relative to Chipata district; districts not reported when no fertilizer use in district.

Putting it all together: an analysis of fertilizer use by hypothetical households

Using data from a probit analysis, scenarios can be created to estimate the probability of fertilizer use by households with varying characteristics. Table 30 provides a simulation analysis based on the results of Model 1, 1999/2000. The table is organized into several groups to demonstrate the effects of changes in household traits on the probability of fertilizer use. Traditionally in analyses such as these only one variable is changed while holding all other variables constant. However, this procedure is not appropriate here because household characteristics do not necessarily remain constant in reality; i.e. households cropping larger area tend to have larger family sizes and older heads of households. Keeping this observation in mind, all households were divided into three roughly equal groups by total area cropped. From these three groups, median values of total area cropped, age of household head, and number of male and female members were determined and these values are used in the analysis.

The first two households (Household A and Household B) represent typical small households located in Eastern province in a district without a fertilizer depot and with low levels of district infrastructure. Each household crops 0.5 hectares but Household A has the characteristics of a male-headed household and Household B represents a female-headed household (the change in the AGE variable indicates that female heads of household are slightly older). The probability of the male-headed household (Household A) using fertilizer is 22 percent and for the female-headed household it is 15 percent. The difference of approximately seven percent represents the effect of gender on the probability of fertilizer use.

Households A, C and D represent an analysis of fertilizer use by households of different sizes according to the three household groupings. Household A represents a household cropping an area of 0.5 hectares; Household C represents a larger-sized household cropping 1.25 hectares; and Household D, a significantly larger household, crops 3.5 hectares (in these cases, the larger households have older heads of household and more male and female members than the smaller Household A). There is a 24 percent probability that a household like Household C, which crops over twice the area of Household A, would use fertilizer. Interestingly, the likelihood of the larger household using fertilizer is less than 30 percent despite being over six times larger than Household A (which was 22 percent likely to use fertilizer). While the variable was found to be significant in the economic model, in practice the impact on fertilizer use of increased total cropped area may not be very significant.

The difference between Household D and Household E is ownership of assets. Household E represents a large household that owns both farm equipment and transportation equipment. This household is estimated to have increased probabilities of fertilizer use compared to Household D, which does not own these types of assets. Ownership of farming assets and transportation equipment has increased the likelihood of fertilizer use from 30 percent to 52 percent.

Households F and G (both having the same characteristics as Household A) show the impact of household location in a district with a fertilizer depot or in a district with higher levels of infrastructure. Household F demonstrates that living in a district with a fertilizer depot has increased the likelihood of fertilizer use by this type of household to about 30 percent. The impact of district infrastructure is much greater: Household G, located in a well-connected district, is estimated to be 46 percent likely to use fertilizer.

The effect of living in a different ecological zone and province are explored using Households H, I, and J. Each household exhibits the same characteristics as Household A but Household H is located in a different ecological zone, Household I is located in a different province and therefore by extension a different ecological zone, and Household J is located in another different province. Household H (in Zone 1) is predicted to use fertilizer with a probability of 11 percent, compared to 22 percent for Household A (in Zone 2) the different ecological zone has resulted in a large change in expected fertilizer use. Household I is located in Lusaka province and Zone 1 with a 23 percent probability of fertilizer use. Household J, in a region of Western province considered Zone 3, is not likely to use fertilizer at all (probability of fertilizer use of one percent).

Table 30: Hypothetical household use of fertilizer: analysis of model 1, 1999/2000

	Coefficient	dF/dx	A	B	C	D	E	F	G	H	I	J
Household variables												
Gender of household head	0.2462 ***	0.0813	1	0	1	1	1	1	1	1	1	1
Age of household head	-0.0045 ***	-0.0016	41	42	46	46	46	41	41	41	41	41
Male (number in household)	0.0122	0.0042	3	3	4	4	4	3	3	3	3	3
Female (number in household)	0.0202 **	0.0070	3	3	4	4	4	3	3	3	3	3
Total area cropped (ha)	0.0743 ***	0.0257	0.5	0.5	1.25	3.5	3.5	0.5	0.5	0.5	0.5	0.5
Ownership of assets:												
plows and harrows	0.2223 ***	0.0792	0	0	0	0	1	0	0	0	0	0
transportation equipment	0.3564 ***	0.1309	0	0	0	0	1	0	0	0	0	0
Geographical variables												
Fertilizer depot in district	0.2324 ***	0.0808	0	0	0	0	0	1	0	0	0	0
Well-connected district	0.6573 ***	0.2306	0	0	0	0	0	0	1	0	0	0
Ecological zones												
Zone 1	-0.1532	-0.0518	0	0	0	0	0	0	0	0	1	0
Zone 2	0.3334 **	0.1178	1	1	1	1	1	1	1	0	0	0
Zone 3	-0.1024	-0.0346	0	0	0	0	0	0	0	1	0	1
Zone 4 (omitted)	0.0000		0	0	0	0	0	0	0	0	0	0
Provinces												
P1 Central	-0.0226	-0.0078	0	0	0	0	0	0	0	0	0	0
P2 Copperbelt	0.2882 *	0.1051	0	0	0	0	0	0	0	0	0	0
P3 Eastern (omitted)	0.0000		1	1	1	1	1	1	1	1	0	0
P4 Luapula	0.1752	0.0629	0	0	0	0	0	0	0	0	0	0
P5 Lusaka	0.5089 ***	0.1920	0	0	0	0	0	0	0	0	1	0
P6 Northern	0.2102	0.0753	0	0	0	0	0	0	0	0	0	0
P7 Northwestern	-0.3508 **	-0.1098	0	0	0	0	0	0	0	0	0	0
P8 Southern	0.1043	0.0367	0	0	0	0	0	0	0	0	0	0
P9 Western	-1.1289 ***	-0.2705	0	0	0	0	0	0	0	0	0	1
Constant term	-1.2973 ***		1	1	1	1	1	1	1	1	1	1
P(I) =			22.1	15.2	23.7	29.6	51.7	29.6	45.6	11.4	22.8	1.1

***, **, * denote statistical significance at 1%, 5%, 10% levels respectively.

CHAPTER 7
FERTILIZER MARKETS, USE, AND PRICES IN ZAMBIA

The probit analysis of household use of fertilizer presented in the previous chapter followed traditional modeling techniques. Most studies of technology use ignore the effect of price on the use of the new technology; this procedure may be appropriate when using small, geographically homogenous samples. However, since the current study employs a large, nation-wide dataset, the price of fertilizer may fluctuate and affect a household's use of fertilizer. This chapter will begin with a brief description of the market for fertilizer in Zambia and be followed by analysis of national levels of fertilizer use and prices of fertilizer in Zambia. The concluding section of the chapter presents an econometric model of fertilizer use based on previous analyses but with a modified sample size to incorporate the market price of fertilizer into the model.

Brief description of the marketing system in Zambia

The government has been involved in fertilizer distribution to small- and medium-holding farming households in Zambia for over a decade. Prior to 1994, the government forced several lending institutions to increase their lending to smallholder farming households in order to assist purchases of fertilizer inputs by these households (Pletcher 2000). The increased volume of loans this caused strained these institutions until they became insolvent.

In 1994 the government tried a new tact and organized the Agricultural Credit Management Programme (ACMP) with the intent of leading the private sector back into the rural credit market. The ACMP provided fertilizer to farmers by offering them credit that did not need to be repaid. The effects of the government actions resulted in a belief by farmers that the government will continually provide fertilizer and subsidize the credit with which to purchase it. The ACMP actually undermined efforts by the private sector to provide more fertilizer (Pletcher 2000).

Rather than importing fertilizer itself, government support of fertilizer use by smallholder farmers has focused on purchasing fertilizer for distribution to smallholder farmers from private sector fertilizer distributors. These government policies further exacerbate the dilemma faced by smallholders. Smallholder farmers can purchase fertilizer using their own resources or wait for government credit to purchase fertilizer (FSRP 2002).

Purchases of fertilizer

Table 31 shows the total amounts of basal and top dressing fertilizer used during the three survey periods. Use is fairly equally distributed between basal and top dressing fertilizers and has increased between each of the three periods. While the quantity of fertilizer purchased with cash vastly outnumbers the quantity of fertilizer purchased with credit, credit purchases have been increasing across the three survey periods from around five percent in 1997/98 to nearly 20 percent of fertilizer purchases in 1999/2000.

Table 31: Total basal and top dressing fertilizer use

	1997/98	1998/99	1999/2000
Basal fertilizer			
Cash purchases (kg)	15,275,746	16,913,605	17,624,839
Credit purchases (kg)	890,412	1,802,144	4,422,778
Total kg purchases (kg)	16,166,158	18,715,749	22,047,617
Cash purchases (%)	94.5	90.4	79.9
Credit purchases (%)	5.5	9.6	20.1
Top dressing fertilizer			
Cash purchases (kg)	15,097,723	17,031,694	16,730,024
Credit purchases (kg)	796,451	1,773,034	3,739,148
Total purchases (kg)	15,894,174	18,804,728	20,469,172
Cash purchases (%)	95.0	90.6	81.7
Credit purchases (%)	5.0	9.4	18.3
Total fertilizer purchased (kg)	32,060,332	37,520,477	42,516,789

Table 32 shows that the vast bulk of fertilizer is purchased in four provinces. Central, Eastern, Northern, and Southern provinces account for over 80 percent of all fertilizer purchased in Zambia. The vast majority of credit purchases are made in Southern province: between 40 percent (1998/99) and 69 percent (1999/2000). These results correspond with previous findings that fertilizer use is higher in these provinces.

Table 32: Cash and credit purchases of fertilizer by province (% of total kg)

	Cash purchases			Credit purchases		
	1997/98	1998/99	1999/2000	1997/98	1998/99	1999/2000
Central	19.2	23.7	18.8	18.0	17.5	8.0
Copperbelt	4.6	4.8	9.9	0.5	3.4	2.4
Eastern	25.8	23.0	31.5	22.4	23.5	12.7
Luapula	2.6	4.2	2.0	0.2	1.6	1.2
Lusaka	3.3	2.5	3.7	1.1	0.8	--
Northern	11.0	11.7	10.1	4.7	11.1	7.0
Northwestern	0.6	1.1	0.5	--	0.7	0.2
Southern	32.2	28.3	22.6	47.6	40.3	68.6
Western	0.8	0.7	0.7	5.5	1.2	--
Total	100.0	100.0	100.0	100.0	100.0	100.0

The distribution of fertilizer purchases by districts is presented in Table 33. The trend shown in this data indicates that fertilizer is widely sold on a cash basis but concentrated in a few districts. In all but one case (Siavonga in 1999/2000) credit sales of fertilizer occur in districts in which there were also cash purchases of fertilizer.

Table 33: Cash and credit purchases of fertilizer by district (% of total kg)

	Cash purchases			Credit purchases		
District	1997/98	1998/99	1999/2000	1997/98	1998/99	1999/2000
Chibombo	6.3	11.3	6.1	1.4	13.3	5.0
Kabwe Urban	0.5	0.7	0.5	1.4	--	0.1
Kapiri Mposhi	4.0	4.3	2.9	7.5	0.5	1.5
Mkushi	4.3	3.7	4.7	0.8	--	0.2
Mumbwa	2.1	1.8	3.4	--	3.7	1.4
Serenje	2.0	1.8	1.2	6.9	--	--
Chililabombwe	0.4	0.3	0.7	--	--	--
Chingola	0.5	0.6	1.3	--	--	--
Kalulushi	0.2	0.3	0.8	--	0.3	0.3
Kitwe	0.0	0.1	0.2	--	--	--
Luanshya	0.8	0.6	0.7	--	0.6	0.1
Lufwanyama	1.4	0.7	3.6	--	2.5	--
Masaiti	0.7	1.2	2.1	--	--	1.2
Mpongwe	0.3	0.5	0.4	0.5	--	0.8
Mufulira	0.3	0.4	0.2	--	--	--
Chadiza	2.4	3.1	3.1	4.3	0.1	2.0
Chama	--	0.3	0.2	--	--	1.0
Chipata	15.2	12.6	16.6	13.2	8.4	3.6
Katete	0.5	1.1	3.4	--	5.7	0.2
Lundazi	4.3	3.8	4.2	0.8	3.3	1.8
Mambwe	--	0.2	0.0	--	0.8	--
Nyimba	--	--	0.3	--	--	--
Petauke	3.4	2.0	3.7	4.0	5.1	4.1
Chiengi	0.1	0.0	0.0	0.0	--	--
Kawambwa	0.9	1.9	0.5	0.0	--	0.5
Mansa	0.4	1.2	0.8	0.0	1.6	0.5
Milenge	0.2	0.1	0.3	0.0	--	--
Mwense	0.5	0.3	0.2	0.0	--	--
Nchelenge	0.1	--	--	0.0	--	--
Samfya	0.5	0.6	0.2	0.2	--	0.2
Chongwe	2.8	1.8	2.3	0.6	0.5	--
Kafue	0.4	0.7	1.4	0.5	0.3	--
Luangwa	--	--	--	--	--	--

Table 33 (con't)						
Chilubi	0.4	0.1	0.0	--	--	--
Chinsali	1.1	0.7	1.1	--	--	0.1
Isoka	0.6	0.9	0.2	--	--	0.5
Kaputa	--	--	--	--	--	--
Kasama	1.6	1.7	1.9	--	--	0.5
Luwingu	0.3	0.7	0.1	--	--	--
Mbala	1.4	1.7	1.5	1.4	0.9	1.7
Mpika	0.8	2.1	2.5	3.1	4.9	1.6
Mporokoso	0.9	0.8	0.4	--	0.6	--
Mpulungu	0.1	0.2	0.3	--	0.4	0.2
Mungwi	1.3	1.7	1.1	0.2	2.2	--
Nakonde	2.5	0.8	1.0	--	2.0	2.3
Chavuma	--	--	--	--	--	--
Kabompo	0.2	0.1	0.1	--	--	--
Kasempa	0.0	0.1	0.0	--	--	0.2
Mufumbwe	--	0.3	0.0	--	--	--
Mwinilunga	0.1	0.3	0.1	--	0.7	--
Solwezi	0.2	0.3	0.3	--	--	--
Zambezi	0.0	0.0	0.0	--	--	--
Choma	4.4	5.1	10.3	3.7	4.7	10.4
Gwembe	0.1	0.0	0.8	--	--	--
Itezhi-tezhi	0.0	0.0	0.0	--	--	--
Kalomo	4.3	3.2	4.4	18.0	29.0	14.3
Kazungula	--	--	--	--	--	--
Livingstone	0.0	0.3	0.1	--	--	--
Mazabuka	22.5	18.2	4.3	25.9	0.4	30.1
Monze	0.6	0.9	1.4	--	--	10.5
Namwala	0.3	0.5	1.2	--	6.2	0.6
Siavonga	--	--	--	--	--	2.0
Sinazongwe	--	0.1	0.1	--	--	0.6
Kalabo	--	--	--	--	--	--
Kaoma	0.7	0.7	0.6	5.5	0.4	--
Lukulu	--	--	--	--	--	--
Mongu	0.1	0.1	0.1	--	0.8	--
Senanga	--	--	--	--	--	--
Sesheke	--	--	--	--	--	--
Shang'ombo	--	--	--	--	--	--

Note: 0.0 indicates less than 0.05 percent of all fertilizer purchased in that district.
Note: -- indicates no fertilizer distributed in that district.

Table 34 lists the five districts in which the largest total quantity of fertilizer was purchased by cash and credit purchases. In each of the three years, these five districts had the largest amounts of total fertilizer purchased. Purchases of fertilizer in these five districts alone accounts for between 53 and 46 percent of all fertilizer purchased during the survey periods.

Table 34: Cash and credit purchases of fertilizer by top five districts (% of total kg)

District (Province)	1997/98	1998/99	1999/2000
Chibombo (Central)	6.0	11.5	5.9
Chipata (Eastern)	15.1	12.2	14.1
Choma (Southern)	4.4	5.1	10.3
Kalomo (Southern)	5.0	5.6	6.3
Mazabuka (Southern)	22.7	16.5	9.2
Total	53.2	50.9	45.9

These finding suggest that fertilizer is not distributed evenly. Since the data do not provide information about fertilizer distribution nor about ending stocks of fertilizer, a definitive answer cannot be given.

Fertilizer prices in Zambia

In-kind payments involve trading future maize production for fertilizer, and is therefore a less reliable value of the cost of the purchased fertilizer than is the price paid based on actual cash purchases. Therefore, analysis of prices will focus exclusively on cash prices paid for fertilizer. The price of fertilizer varied across the three periods of the surveys, Table 35 shows that the inflation-adjusted price actually decreased across the three years. This table also shows that the price varied between districts with fertilizer depots and those without, the price being lower on average in districts with fertilizer depots. The price for fertilizer also tended to be lower on average in districts with higher levels of infrastructure.

Table 35: Cash prices for basal and top dressing fertilizer (ZK/kg)

		1997/98	1998/99	1999/2000
Basal fertilizer		846	763	720
Fertilizer depot in district*				
	No	890	791	737
	Yes	819	740	706
Well-connected district*				
	No	906	802	742
	Yes	818	742	705
Top dressing fertilizer		859	773	738
Fertilizer depot in district*				
	No	914	804	763
	Yes	826	750	718
Well-connected district*				
	No	929	815	763
	Yes	826	751	722

Note: all prices in 2000 ZK.

* indicates differences are significant at 1% level of significance.

These averages hide the great extent of the variability of prices of both basal and top dressing fertilizer in Zambia. Reviewing Table 36 and the price histograms that follow (Figure 5 through Figure 10) the data indicate that households that purchased basal or top dressing fertilizer using cash reportedly paid a wide range of prices. On each graph, two vertical lines represent estimates of the price of basal or top dressing fertilizer for that year. For example, the base market price for basal fertilizer was around 600-640 ZK/kg in 1997/98. Table 36 suggests that more than seventy percent of households that paid cash for basal fertilizer in 1997/98 paid less than 600 Kwacha per kilogram of basal fertilizer. The histograms elaborate this point graphically.

Table 36: Percentiles of cash price paid for basal and top dressing fertilizer (ZK/kg)

Percentile	1997/98		1998/99		1999/00	
	Basal	Top Dressing	Basal	Top Dressing	Basal	Top Dressing
10	440	420	520	527	600	600
20	480	480	560	560	620	640
30	500	500	560	600	660	700
40	520	520	600	600	700	720
50	540	560	600	620	720	760
60	560	560	640	660	760	780
70	570	600	700	700	780	800
80	600	640	720	720	800	840
90	700	700	760	770	860	900

Explaining this range of prices, especially the finding that most households pay far less than market price for the fertilizer they use poses a challenge. Econometric tests using geographical-level variables do not explain the price a household paid for fertilizer. The following ordinary least squares analysis were performed:

Unit price of basal fertilizer = f(PROV, FERT, RAIL) (Model 5)

Unit price of basal fertilizer = f(DIST) (Model 6)

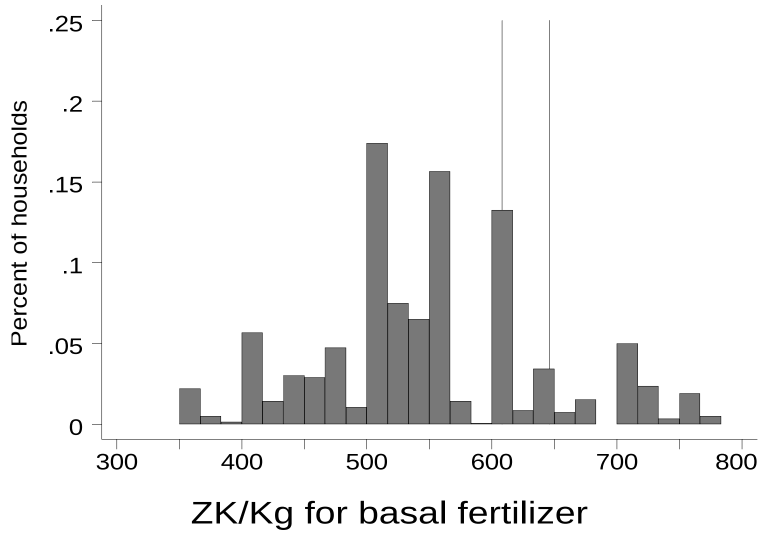
The results of each of these models, for each type of fertilizer, for each of the three survey periods indicated that the price of fertilizer using these dummy variables did not significantly explain this distribution of prices. The value of the adjusted R-squared was less than 0.1 in all cases. Therefore, this reported price variation does not occur between districts (i.e. higher prices in some districts but lower prices in others), but rather, the variation of fertilizer prices occurs within the districts themselves.

Table 37: Adjusted R-squared of Model 5 and Model 6

	1997/98	1998/99	1999/2000
Model 5	0.0473	0.0514	0.0457
Model 6	0.0597	0.0816	0.0687

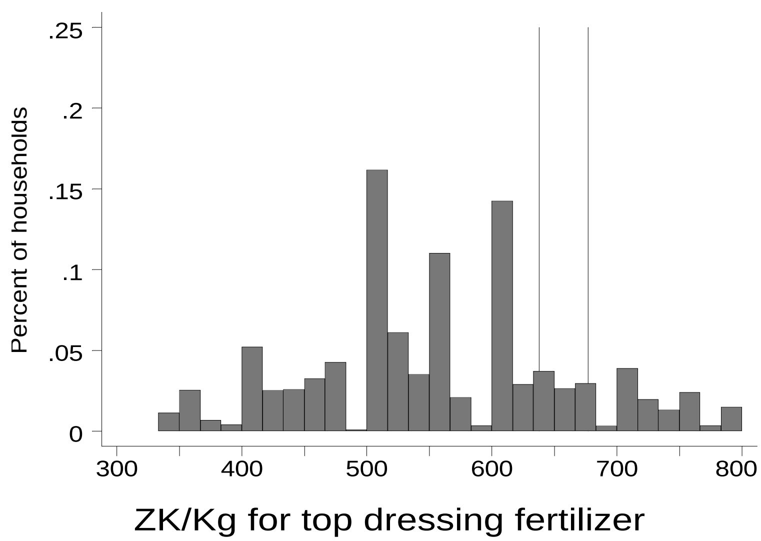
Since the data does not directly indicate reasons for this distribution of fertilizer prices, there must be some other reason. The data includes cash purchases of fertilizer; therefore, households paying for their fertilizer using subsidized credit should not be included among these households and therefore are not reasons for the low reported prices paid. Since 1997, government has been purchasing fertilizer from fertilizer traders to distribute to cooperatives and finally to households on credit terms. However, some fertilizer reaches households generous cash discounts from traders not intending to repay the government and its credit scheme (FSRP 2002).

Figure 5: Histogram of price of basal fertilizer with range of market price estimates, 1997/1998



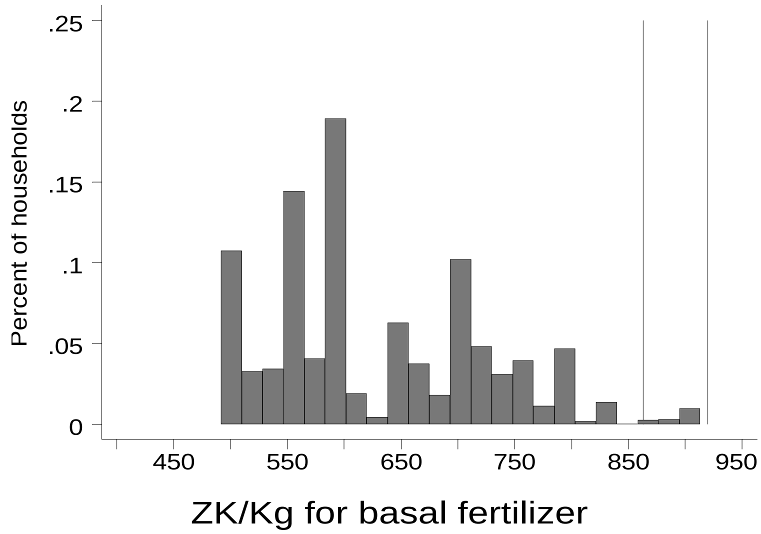
Note: data in real values, market price estimate includes transport costs.
Source: PHS survey data and Omnia.

Figure 6: Histogram of price of top dressing fertilizer with range of market price estimates, 1997/1998



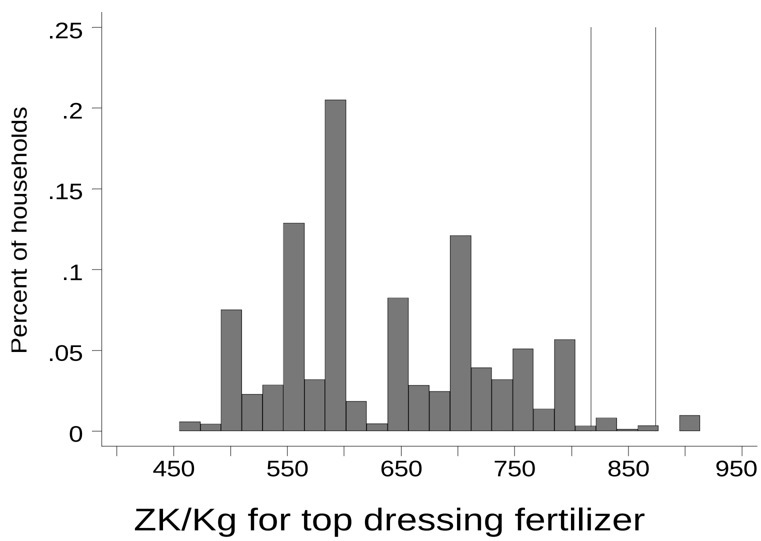
Note: data in real values, market price estimate includes transport costs.
Source: PHS survey data and Omnia.

Figure 7: Histogram of price of basal fertilizer with range of market price estimates, 1998/1999



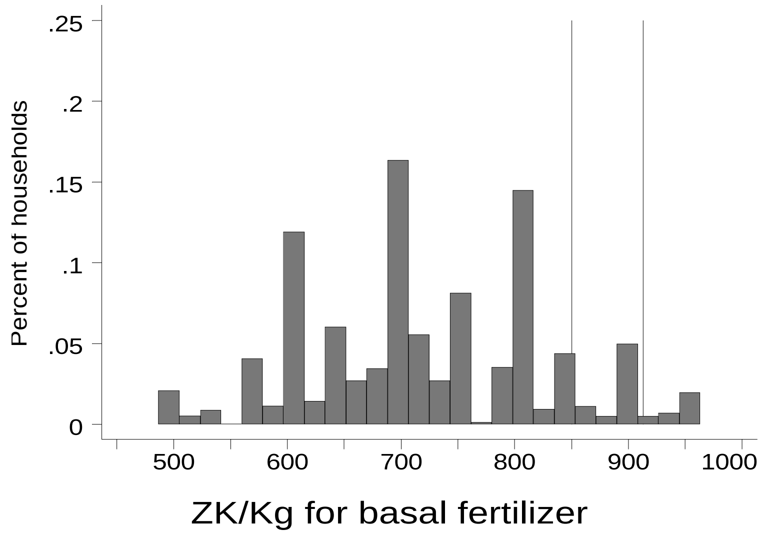
Note: data in real values, market price estimate includes transport costs.
Source: PHS survey data and Omnia.

Figure 8: Histogram of price of top dressing fertilizer with range of market price estimates, 1998/1999



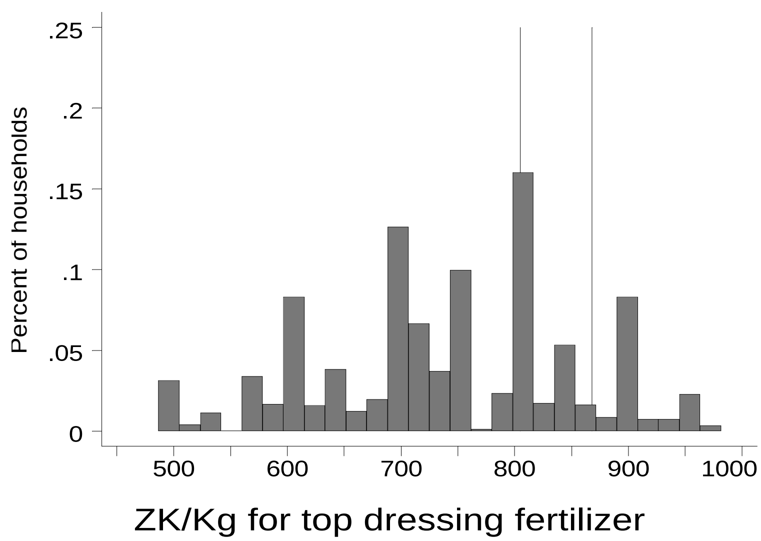
Note: data in real values, market price estimate includes transport costs.
Source: PHS survey data and Omnia.

Figure 9: Histogram of price of basal fertilizer with range of market price estimates, 1999/2000



Note: data in real values, market price estimate includes transport costs.
Source: PHS survey data and Omnia.

Figure 10: Histogram of price of top dressing fertilizer with range of market price estimates, 1999/2000



Note: data in real values, market price estimate includes transport costs.
Source: PHS survey data and Omnia.

Econometric analysis of fertilizer use on maize incorporating market prices

While a complete profitability analysis is beyond the scope of the current paper, using information about the price paid for fertilizer may indicate household characteristics that significantly affect a household's use of fertilizer and purchase it at near market prices. The analysis intends to identify characteristics that affect the use of fertilizer by households that pay the full market cost of the fertilizer. This is accomplished by a probit analysis of household use of fertilizer incorporating market prices into the model.

The probit model used in this chapter parallel those used previously. The samples are modified in order to include proxies for fertilizer prices. As shown, the price of fertilizer varied with most households paying less than full market price. Therefore, households that paid in the top thirty percent of cash prices are considered to be the only households using fertilizer at close to market price. While measuring the use of fertilizer by households that purchased it near market prices does not itself measure profitability per se, this inquiry will provide an analysis of households using fertilizer when they face full market prices. Model 7 will take the same form as Model 1, but fertilizer users are only those households paying the top 30 percent as nearest to full market cost.

USE1 = f(HHvar, FERT, RAIL, AGROZONE, PROV) (Model 7)

The results of Model 7 presented in Table 38 diverge from those in Table 25 (page 62) of the original Model 1 that includes all households. Whereas previous analysis suggested significance of many of the independent variables in predicting household use of fertilizer, the current results suggest otherwise. For households paying near market prices for their fertilizer, only two variables were consistently significant.

Household ownership of transportation equipment (TRANS) and higher levels of district infrastructure (RAIL) were both significant across all three surveys and contributed between two to four percent to a household's use of fertilizer. No other household or geographical variable was significant across each of the survey periods.

A surprising result of the current analysis relates to the changing sign of the coefficient of total area planted by the household (AREATOTL). The positive coefficient in 1997/98 indicates that households cropping larger areas of maize are more likely to use fertilizer than smaller ones. This finding parallels earlier results. However, despite being significant at the one percent level, the impact is practically negligible: each additional hectare of cropped maize area is predicted to increase the probability of fertilizer use by less than half of a percent (dF/dx of 0.0045). Model 1 indicated total area cropped to increase fertilizer use by over two percent for each additional hectare planted (Table 25).

The negative coefficient of total area cropped for 1999/2000 suggests that the relationship between cropped area and fertilizer use has reversed itself. The magnitude of this impact was also not significant however; each additional hectare of cropped maize in 1999/2000 *decreased* the probability of fertilizer use by half of a percent (dF/dx of -0.0049). The reversal of this relationship suggests that households cropping smaller areas are more likely to use fertilizer at near market prices; households cropping smaller areas would require less fertilizer and may therefore be more able to purchase it at market prices.

This new model (Model 7) supports the importance of ownership of transportation equipment and level of district infrastructure in influencing fertilizer use found in previous models. However, the role of total cropped area in fertilizer use seems questionable given the current analysis.

Table 38: Results of probit Model 7

	1997/98				1998/99				1999/2000			
Variable	Coefficient	z		dF/dx	Coefficient	z		dF/dx	Coefficient	z		dF/dx
GENDER	0.0829	0.788		0.0073	0.0683	0.756		0.0064	0.1723	2.058	**	0.0154
AGE	-0.0044	-1.684	*	-0.0004	-0.0010	-0.442		-0.0001	-0.0030	-1.351		-0.0003
MALE	0.0272	1.396		0.0025	0.0338	2.052	**	0.0033	0.0276	2.084	**	0.0027
FEMALE	0.0053	0.356		0.0005	0.0318	2.180	**	0.0031	0.0099	0.702		0.0010
AREATOTL	0.0486	2.795	***	0.0045	-0.0113	-0.654		-0.0011	-0.0505	-3.127	***	-0.0049
FARMEQ	-0.0537	-0.513		-0.0048	0.1122	1.194		0.0115	0.0288	0.281		0.0028
TRANS	0.1381	1.729	*	0.0132	0.2586	3.563	***	0.0269	0.2532	2.106	**	0.0292
FERT	0.1286	1.124		0.0120	0.0491	0.512		0.0048	0.0436	0.515		0.0043
RAIL	0.5052	4.425	***	0.0499	0.3792	3.801	***	0.0390	0.3918	4.456	***	0.0408
ZONE1	-0.2801	-0.908		-0.0230	-0.1124	-0.357		-0.0104	0.3569	1.441		0.0402
ZONE2	0.0567	0.211		0.0053	-0.1873	-0.665		-0.0174	0.3536	1.604		0.0380
ZONE3	-0.0060	-0.027		-0.0005	-0.3865	-1.605		-0.0295	0.0508	0.279		0.0051
P1 (Central)	-0.0433	-0.292		-0.0039	0.1648	1.197		0.0177	0.1486	1.298		0.0158
P2 (Copperbelt)	0.0477	0.155		0.0046	0.3561	1.157		0.0444	0.6163	2.503	**	0.0907
P4 (Luapula)	-0.1526	-0.437		-0.0125	-0.1353	-0.405		-0.0119	0.0131	0.045		0.0013
P5 (Lusaka)5	-0.0226	-0.083		-0.0020	0.2479	1.201		0.0291	-0.1667	-0.900		-0.0142
P6 (Northern)	-0.0950	-0.377		-0.0082	-0.1504	-0.545		-0.0134	0.3072	1.439		0.0361
P7 (Northwestern)	0.0633	0.206		0.0061	-0.2664	-0.841		-0.0214	-0.0933	-0.346		-0.0085
P8 (Southern)	-0.0691	-0.392		-0.0061	-0.1755	-1.084		-0.0154	-0.2803	-2.066	**	-0.0233
P9 (Western)	-0.7448	-2.040	**	-0.0395	-0.2127	-1.007		-0.0176	-0.9272	-3.601	***	-0.0487
Constant	-1.9756	-6.247	***		-2.0137	-6.463	***		-2.1205	-8.475	***	
Sample	3,691				4,242				5,152			
Log likelihood	-736.4356				-872.6149				-1,088.0547			
Observed P.	0.0561				0.0587				0.0600			
Predicted P.	0.0435				0.0464				0.0465			

***, **, * denote statistical significance at 1%, 5%, 10% levels respectively.

CHAPTER 8
ECONOMETRIC ANALYSIS OF THE QUANTITY OF FERTILIZER USED

This chapter explores factors likely to affect the quantity of fertilizer a household uses. To do this, a subset of all households included in the PHS and in previous analyses will be used: only those households that purchased basal fertilizer with cash are included in the following analyses. Since the use of basal fertilizer and top dressing fertilizer are fairly equally distributed and households that use one type generally use the other, focusing on purchases of basal fertilizer will not bias the results. Chapter 7 showed that households purchasing fertilizer with cash greatly outnumber the households purchasing fertilizer on credit, so omission of credit payments should not cause problems either.

Model used

When analyses such as this is performed, the dependent variable is traditionally intensity of fertilizer use. This paper deviates from the norm and uses total quantity of fertilizer as the dependent variable. This change was necessary because, as previously described, the data does not provide as accurate information regarding intensity of fertilizer use as would be desired.

The econometric model utilized in this chapter will be an ordinary least squares estimation. The equation to be evaluated is:

Quantity basal fertilizer used = f(HHvar, GEOvar, cash price paid) (Model 8)

An additional equation will be evaluated; Model 9 will incorporate the same format as Model 8 but will utilize only households paying in the top 30% of all cash purchases. This second analysis will provide additional insights similar to the probit models utilizing similar decision rules to analyze quantity of fertilizer used by households paying near market prices.

Reviewing the models to be used, all of the independent variables have been described, with the exception of cash price of basal fertilizer. The cash price paid for basal fertilizer is the Zambian Kwacha price paid per kilogram of fertilizer purchased by the household. The relationship between this variable and the dependent variable is expected to follow standard economic theory and have a negative coefficient indicating that as the price of fertilizer increases the quantity purchased decreases.

Analysis of results

The results of the OLS regressions are shown in Table 39 and Table 40. In survey periods 1997/98, 1998/99, and 1999/2000, Model 8 predicted around 39, 35 and 42 percent of the variability of total fertilizer consumption as indicated by the measures of adjusted *R*-squared for the three survey years. The comparable values for Model 9 were 54, 47, and 37 percent.

For Model 8, none of the independent variables was significant in all three of the survey periods. In 1997/98, each additional hectare of land a household cropped resulted in an additional 50 kg of fertilizer on average. However, the variables with the largest effect on the quantity of fertilizer a household used were the ecological zone variables and provincial-level variables. Households in Zone 1 used approximately 260 kg of fertilizer than households in Zone 4. Households in Central and Copperbelt provinces used 107 and 149 kg more fertilizer than those in Eastern province on average, while households in Lusaka and Southern provinces used 180 kg less than households in Eastern province on average.

The regression results for Model 9 suggested that the number of males in the household had a consistently significant impact on the quantity of fertilizer a household used. Each additional male household member increased the total quantity of fertilizer used by between 9 and 15 kg on average. The only other independent variable that was significant across each of the three surveys was total area cropped. For each additional hectare of land a household cropped, use of fertilizer increased by between 29 and 41 kg on average.

The coefficients on the variable representing the price of basal fertilizer were consistently negative in Model 9, but not significantly different from zero. The negative relationship follows economic theory that suggests that at higher prices, less fertilizer would be purchased and used. In Model 8 however, the price of basal fertilizer had a positive coefficient in 1999/2000 that was significant at the one percent level of significance. This surprising result suggests that more fertilizer was purchased at higher prices than at lower prices during this survey period. These results are plausible in light of the wide distribution of fertilize prices owning to subsidized government distribution programs. Model 8 does not remove non-commercial sales from the sample before estimation, while Model 9 does.

Table 39: Results of OLS Model 8

	1997/98			1998/99			1999/2000		
	Coefficient	t		Coefficient	t		Coefficient	t	
GENDER	23.1683	0.925		16.7001	1.321		-2.7355	-0.176	
AGE	-0.3083	-0.572		0.0729	0.234		-0.3416	-0.830	
MALE	-1.4176	-0.396		12.9456	5.579	***	9.8413	3.711	
FEMALE	11.3157	4.215	***	1.6442	0.795		-2.5228	-1.021	***
AREATOTL	48.1390	15.358	***	31.2827	15.172	***	44.0281	18.392	
FARMEQ	-4.0800	-0.219		47.6968	3.921	***	34.4438	2.133	***
TRANS	-6.0310	-0.391		10.1695	1.056		7.7365	0.415	**
FERT	41.8852	1.850	*	-12.7985	-0.935		-4.9766	-0.299	
RAIL	-33.0362	-1.390		18.7762	1.255		22.3418	1.293	
ZONE1	260.2024	3.470	***	118.5317	2.666	***	75.4598	1.413	
ZONE2	86.5884	1.512		34.0296	1.049		-9.4035	-0.214	
ZONE3	7.8058	0.163		42.1659	1.593		24.9589	0.687	
P1 (Central)	107.0771	3.542	***	23.7004	1.356		45.4005	2.135	
P2 (Copperbelt)	149.2888	2.277	**	52.2343	1.390		50.9523	1.026	**
P4 (Luapula)	107.8109	1.614		37.8268	0.979		46.0308	0.855	
P5 (Lusaka)	-175.9667	-3.040	***	-79.1891	-2.142	**	-15.7708	-0.410	
P6 (Northern)	91.3942	1.645		22.9082	0.738		-28.0938	-0.656	
P7 (Northwestern)	109.4354	1.323		18.9826	0.433		56.4555	0.795	
P8 (Southern)	-175.5344	-3.394	***	-57.1818	-1.713	*	-51.8550	-1.547	
P9 (Western)	-58.7699	-0.949		11.6868	0.209		151.4694	2.896	
Price of basal (KW/kg)	-0.0252	-0.463		0.0021	0.091		0.0068	0.316	***
Constant	-117.8843	-1.512		-74.7090	-1.831	*	-12.2377	-0.238	
Sample	729			930			1189		
F	22.74			32.90			31.75		
Prob > F	0.00			0.00			0.00		
R-squared	0.4031			0.4321			0.3636		
Adj R-squared	0.3854			0.4189			0.3521		

***, **, * denote statistical significance at 1%, 5%, 10% levels respectively.

Table 40: Results of OLS Model 9

	1997/98			1998/99			1999/2000		
	Coefficient	t		Coefficient	t		Coefficient	t	
GENDER	-62.7941	-1.655	*	22.5804	1.181		10.5396	0.404	
AGE	-1.2137	-1.696	*	0.2368	0.469		-0.8119	-1.126	
MALE	9.2221	1.686	*	14.7279	4.092	***	7.6817	1.733	*
FEMALE	19.7138	6.225	***	1.3976	0.456		-3.6196	-0.869	
AREATOTL	28.9174	6.459	***	36.8770	11.200	***	41.1069	10.422	***
FARMEQ	25.4655	0.940		75.1833	3.696	***	67.0401	2.137	**
TRANS	10.6388	0.519		-4.6446	-0.304		18.1172	0.526	
FERT	53.4440	1.872	*	0.4734	0.023		-15.2590	-0.609	
RAIL	-75.0395	-2.404	**	-4.6267	-0.184		31.4451	1.183	
ZONE1	913.3316	5.338	***	119.1165	1.637		84.9073	0.956	
ZONE2	177.3669	2.199	**	30.8031	0.612		-16.9946	-0.243	
ZONE3	-20.7208	-0.325		3.0254	0.079		29.2976	0.642	
P1 (Central)	195.0489	4.268	***	61.1351	1.864	*	89.1283	1.940	*
P2 (Copperbelt)	278.0258	3.098	***	59.2253	1.020		87.5911	1.137	
P4 (Luapula)	206.3451	2.412	**	68.7146	1.234		47.0843	0.572	
P5 (Lusaka)	-719.5467	-4.559	***	-49.4756	-0.778		104.4546	1.259	
P6 (Northern)	191.3557	2.423	**	49.1489	1.011		-19.0700	-0.278	
P7 (Northwestern)	173.3256	1.789	*	27.4269	0.488		70.0183	0.658	
P8 (Southern)	-776.8463	-4.962	***	-45.4063	-0.763		-90.0756	-1.482	
P9 (Western)	-85.5016	-1.203		-15.8277	-0.251		272.1887	3.503	***
Price of basal (KW/kg)	-0.0689	-0.992		-0.0069	-0.229		-0.0120	-0.450	
Constant	-92.6346	-0.815		-94.7448	-1.539		15.5204	0.192	
Sample	255			378			421		
F	15.33			16.89			12.69		
Prob > F	0.00			0.00			0.00		
R-squared	0.5801			0.4991			0.4004		
Adj R-squared	0.5422			0.4696			0.3688		

***, **, * denote statistical significance at 1%, 5%, 10% levels respectively.

CHAPTER 9
CONCLUSIONS AND IMPLICATIONS

The uniqueness of the current study, by employing a large, multi-year data set as well as both household and geographical variables, provides robust insights into the decision to use fertilizer by households in Zambia. The findings are particularly relevant from an empirical standpoint because the multi-year data has shown that some results are not consistent across time and surveys.

Main findings

This thesis has addressed the following areas of research. First, it determined household characteristics that significantly impact the use of fertilizer by small- and medium-sized farming households in Zambia. The number of family members and household ownership of assets such as plows, harrows, and transportation equipment were found to impact the use of fertilizer. Two other characteristics were found to be even more significant. The gender of the head of household and total area cropped by the household both significantly affected household use of fertilizer.

Second, this paper determined how the physical and geographic characteristics of household location affect its use of fertilizer. Among the more significant factors was the level of infrastructure within the district. Location near a fertilizer depot was found to be significant as well. Households living in dryer areas (but still well-suited for crop production) tended to grow more maize and therefore use fertilizer more than in the regions of the country with higher levels of precipitation and relatively poor soils.

The third, and most significant, contribution of this paper was to econometrically test how the various household and geographic characteristics interact and influence a household’s use of fertilizer. A series of probit models determined that several of the characteristics previously assumed in this case to impact the use of fertilizer did not enter significantly into the models. Factors that were not as significant as anticipated included household proximity to a fertilizer distribution center and ownership of farm equipment. The model did verify the importance of other variables impacting a household's use of fertilizer. Total area cropped was significantly related to household use of fertilizer although the magnitude of this relationship was quite small. The variables resulting in the most significant impact on fertilizer use were found to be ownership of transportation assets and the level of transportation infrastructure within the district. Households located in districts with higher levels of infrastructure were over twenty percent more likely to use fertilizer than other households, regardless of the size of the household's cropped area and level of assets, even after controlling for other geographic factors such as ecological zone and depots for wholesale distribution of fertilizer.

The price of fertilizer was shown to vary greatly, with most households paying less than full market price for the fertilizer they used. A test incorporating a modified sample of households using fertilizer at near market prices was performed to account for this situation. Previous findings were refined after restricting the sample to households that purchased fertilizer near market prices. These additional tests corroborated some of the previous findings but at the same time contradicted others. Ownership of transportation equipment and household location in a district with higher levels of infrastructure remained significant. The effect of total area cropped on household use of fertilizer was questionable after incorporating this additional model that adjusted for full market fertilizer purchases.

Analyzing overall quantities of fertilizer used by households represented the fourth area of study in this paper. Not surprisingly, a significant factor influencing the quantity of fertilizer a household uses was found to be total area cropped. The other factors that significantly impacted the quantity of fertilizer a household used were ecological zone variables and provincial location variables. The household characteristics such as gender of head of household, age of head of household, and ownership of productive assets, did not significantly enter into these equations with any consistency.

Profitability of fertilizer use on maize

The limitations of the current study and data prevent a full-scale profitability analysis of fertilizer use. An analysis of the profitability of specific crops themselves cannot be provided. While the discussion has centered on the quantity of fertilizer application, factors related to fertilizer application, and yield benefits of fertilizer application, these findings do not provide definitive indications of the profitability of fertilizer use in Zambia.

A full profitability analysis of the use of fertilizer would require a much broader understanding of households' costs and sales of production as well as better data related to yields and response rates to fertilizer. The work by Benson *et al.* 1997 in Malawi and FSRP 2001 in Zambia provides good references towards better understanding the potential for fertilizer profitability in this region.

The findings made to the Government of Malawi by the Maize Productivity Task Force (Benson *et al.* 1997) indicated that for some households in 1997, the most profitable use of fertilizer was not to use it. After conducting nationwide tests with selected farmers from across the country, fertilizer use was found to be beneficial only in some regions, and then at different rates of application than recommended by the government, and not profitable in others.

FSRP 2001 conducted trials of fertilizer application in various regions of Zambia using traditional farmer techniques and found that fertilizer use applied to maize can be profitable given the proper conditions. The risk of varying response rates represented a serious problem to fertilizer profitability in this study. Unfavorable weather, poor timing of fertilizer application, overall soil fertility, and use of other herbicides or weeding were cited as significant factors affecting the variability of maize yields. Other reasons fertilizer use on maize may be unprofitable include inappropriate application recommendations, lack of availability of improved seeds, inconsistent farmer management practices, and lack of access to credit (FSRP 2002).

Implications for policy

The current study has perhaps raised more questions than it has answered: Where should fertilizer use be promoted? Would it be better to promote proper intensity of fertilizer use by households currently using fertilizer or to promote increasing the use of fertilizer by households not currently using it? What can be done to increase fertilizer use where it is suitable?

The first two questions cannot be answered here. Further analysis and fertilizer usage trials such as those conducted by Benson *et al.* 1997 in Malawi and FSRP 2001 in Zambia can provide insights to these questions. The trends shown in crops grown by ecological zone, as well as varying levels of fertilizer use across the country, demonstrate that many farming households may already know the limitations to fertilizer use in some areas.

The current paper has addressed the third question. Female heads of household have been shown to use fertilizer less than male-headed households. However, questions remain whether this finding is the result of their small household size and cropped area, or due to biases to fertilizer access due to their gender. Several other characteristics, ownership of farming assets and total area cropped, were shown to positively affect a households' use of fertilizer. However, the magnitude of the impact of these characteristics on household use of fertilizer was significantly less than anticipated.

The most significant and robust findings across each of the models, even those including use of fertilizer at full market prices, were the importance of ownership of transportation assets and the levels of infrastructure in the district. Ownership of transportation equipment was estimated to increase the likelihood of a household using fertilizer by over ten percent. Households located in districts with higher levels of transportation infrastructure were found to be over 20 percent more likely to use fertilizer than households in other districts.

The policy implications for government seem straightforward. Poor transportation infrastructure, at this point in time, appears to be a main constraint to increased use of fertilizer by households in Zambia. Over time the factors acting to constrain household use of fertilizer will change and future analysis should be conducted to identify these new constraints to fertilizer use as they develop.

APPENDIX
QUESTIONS ASKED ON THE PHS SURVEYS

The Post Harvest Survey is an annual survey conducted jointly by the Zambian Central Statistical Office and Ministry of Agriculture, Forestry, and Fisheries. Three years of the surveys provided the data used in this thesis. This chapter provides documentation regarding the questions that were asked on the PHS to generate the data used in the current paper.

Dependent variable

USE1: Household uses fertilizer
- Q: Did you use any basal dressing fertilizers during the 1997/98 agricultural season?
- Q: Did you use any top dressing fertilizers during the 1997/98 agricultural season?

Independent variables

GENDER: Gender of head of household
- Q: Sex of head of household.

AGE: Age of head of household
- Q: Age of head of household.

MALE: Number of males in household
- Q: Household population of males.

FEMALE: Number of females in household
- Q: Household population of females.

AREATOTL: Total area cropped
- Q: What was the total area under crops during the 1997/98 agricultural season?

FARMEQ: Ownership of farm equipment
- Q: Did you are any member of the household own any plough(s) during the 1997/98 agricultural season?
- Q: Did you or any member of the household own any harrow(s) during the 1997/98 agricultural season?

TRANS: Ownership of transportation equipment

- Q: Did you or any member of the household own any transport equipment during the 1997/98 agricultural season?
  - For PHS years 1997/98 and 1998/99 transportation equipment defined as ox-carts and bicycles.
  - For PHS year 1999/2000 transportation equipment defined as ox-carts.

Other variables

Quantity of fertilizer used

- Q: How much basal fertilizers did you buy/barter into your possession for the 1997/98 agricultural season?
- Q: How much top dressing fertilizers did you buy/barter into your possession for the 1997/98 agricultural season?

Price paid for fertilizer

- Q: How much was spent, in cash/kind, on the purchase of the basal fertilizers?
- Q: How much was spent, in cash/kind, on the purchase of the top dressing fertilizers?

Yield of maize

- Q: How many 90 kg bags of maize did you produce?
- Q: What was the total area planted to maize for grain during the 1997/98 agricultural season?

REFERENCES

Adesina, Akinwumi A. and Jojo Baidu-Forson (1995). “Farmers' Perceptions and Adoption of New Agricultural Technology: Evidence from Analysis in Burkina Faso and Guinea, West Africa”, *Agricultural Economics*. v. 13: 1-9.

Adesina, Akinwumi A. and Moses M. Zinnah (1993). “Technology Characteristics, Farmers' Perceptions and Adoption Decisions: A Tobit Model Application in Sierra Leone”, *Agricultural Economics*. v. 9: 297-311.

Benson, Todd, J.D.T. Kumwenda, K.M. Chavula, A.C. Conroy, A. Gomez, R.B. Jones, E.E. Kanyenda, S.K. Mughogho and B.J. Sizilande (1997). "The 1995/96 Fertilizer Verification Trial - Malawi: Economic Analysis of Results for Policy Discussion". Ministry of Agriculture and Livestock Development, Malawi.

Croppenstedt, Andre and Mulat Demeke (1996). “Determinants of Adoption and Levels of Demand for Fertilizer for Cereal Growing Farmers in Ethiopia”, *Centre for the Study of African Economies Working Paper Series*. v. 96 (n. 3).

Demeke, Mulat, Valerie Kelly, T.S. Jayne, Ali Said, J.C. Le Vallee and H. Chen (1998). "Agricultural Market Performance and Determinants of Fertilizer Use in Ethiopia". Grain Market Research Project, Addis Ababa.

Doss, Cheryl R. and Michael L. Morris (2001). “How Does Gender Affect the Adoption of Agricultural Innovations? The Case of Improved Maize Technology in Ghana.”, *Agricultural Economics*. v. 25: 27-39.

Feder, Gershon, Richard E. Just and David Zilberman (1985). “Adoption of Agricultural Innovations in Developing Countries: A Survey”, *Economic Development and Cultural Change*. v. 33: 255-98.

FSRP (2001). "Fertilizer Profitability in Maize and Cotton in Zambia (Draft)". Food Security Research Project, Lusaka, Zambia.

FSRP (2002). “Policy Options for Improving the Performance of the Fertilizer Marketing System in Zambia”, *Food Security Research Project, Lusaka, Zambia*. (n. 4).

Ghadim, Amir K. Abadi and David J. Pannell (1999). “A Conceptual Framework of Adoption of an Agricultural Innovation”, *Agricultural Economics*. v. 21: 145-54.

Green, D.A.G. and K.H. Ng'ong'ola (1993). “Factors Affecting Fertilizer Adoption in Less Developed Countries: An Application of Multivariate Logistic Analysis in Malawi”, *Journal of Agricultural Economics*. v. 44: 99-109.

Green, William H. (1993) Econometric Analysis. New York, Macmillan Publishing Company.

Greenland, D.J. and H. Nabhan. (2001) Soil Fertility Management in Support of Food Security in Sub-Saharan Africa. Rome, Food and Agriculture Organization of the United Nations.

Hiebert, Dean (1974). "Risk, Learning and the Adoption of Fertilizer Responsive Seed Varieties", *American Journal of Agricultural Economics*. v. 56: 764-68.

Kaliba, Aloyce R.M., Hugo Verkuijl and Wilfred Mwangi (2000). "Factors Affecting Adoption of Improed Maize Seeds and Use of Inorganic Fertilizer for Maize Production in the Intermediate and Lowland Zones of Tanzania", *Journal of Agricultural and Applied Economics*. v. 32 (n. 1): 35-47.

Kennedy, Peter. (1998) A Guide to Econometics. Cambridge, MA, MIT Press.

Khanna, Madhu (2001). "Sequential Adoption of Site-Specific Technologies and Its Implications for Nitrogen Productivity: A Double Selectivity Model.", *American Journal of Agricultural Economics*. v. 83 (n. 1): 35-51.

Kherallah, Mylene, Nicholas Minot, Richard Kachule, Bio Goura Soule and Philippe Berry. (2001) Impact of Agricultural Market Reforms on Smallholder Farmers in Benin and Malawi, International Food Policy Research Institute.

Megill, David J. (2000). "Implications of Sample Design for Post-Harvest Survey on Analysis of Survey Data". Sampling Consultant, Food Security Research Project, Lusaka, Zambia.

Negatu, W. and A. Parikh (1999). "The Impact of Perception and Other Factors on the Adoption of Agricultural Technology in the Moret and Jiru *Woreda* (District) of Ethiopia", *Agricultural Economics*. v. 21: 205-16.

Nkonya, Ephram, Ted Schroeder and David Norman (1997). "Factors Affecting Adoption of Improved Maize Seed and Fertiliser in Norther Tanzania", *Journal of Agricultural Economics*. v. 48 (n. 1): 1-12.

Pletcher, James (2000). "The Politics of Liberalizing Zambia's Maize Markets", *World Development*. v. 28 (n. 1): 129-142.

Rashid, Abdur and Mohamed Zejjari (1998). "Crop and Food Supply Assessment Mission to Zambia". FAO/WFP.

Rauniyar, Ganesh P. and Frank M. Goode (1992). "Technology Adoption on Small Farms", *World Development*. v. 20 (n. 2): 275-282.

Sain, Gustavo and Julio Martinez (1999). "Adoption and Use of Improved Maize by Small-Scale Farmers in Southeast Guatemala", *CIMMYT Economics Paper*. v. 99-04.

Sanchez, Pedro A., Keith D. Shepherd, Meredith J. Soule, Frank M. Place, Roland J. Buresh, Anne-Marie N. Izac, A. Uzon Mokwunye, Fred R. Kwesiga, Cyrus G. Ndiritu and Paul L. Woomer (1997). Soil Fertility Replenishment in Africa: An Investment in Natural Resouce Capital. Replenishing Soil Fertility in Africa. Madison, WI, Soil Science Society of America: 1-46.

Scoones, Ian and Camilla Toulmin (1999). “Soil Nutrient Budgets and Balances: What Use for Policy?”, *Managing Africa's Soils*. v. 6.

Shakya, P.B. and J.C. Flinn (1985). “Adoption of Modern Varieties and Fertilizer Use on Rice in the Eastern Tarai of Nepal”, *Journal of Agricultural Economics*. v. 36: 409-19.

Shampine, Allan (1998). “Compensating for Information Externalities in Technology Diffusion Models”, *American Journal of Agricultural Economics*. v. 80 (n. 2): 337-46.

StataCorp. (1999) Stata Statistical Software: Release 6.0 Reference Manual. College Station, Texas, Stata Press.

Wooldridge, Jeffrey M. (2000) Introductory Econometrics: A Modern Approach. United States, South-Western College Publishing.

Yanggen, David, Valerie Kelly, Thomas Reardon and Anwar Naseem (1998). “Incentives for Fertilizer Use in Sub-Saharan Africa: A Review of Empirical Evidence on Fertilizer Response and Profitability”, *MSU International Development Working Papers*. v. 70.