HOUSEHOLD-LEVEL IMPACTS OF FERTILIZER SUBSIDIES IN MALAWI

By

Jacob Ricker-Gilbert

A DISSERTATION

Submitted to
Michigan State University
In partial fulfillment of the requirements
For the degree of

DOCTOR OF PHILOSOPHY

Agricultural, Food & Resource Economics

2011

ABSTRACT

HOUSEHOLD-LEVEL IMPACTS OF FERTILIZER SUBSIDIES IN MALAWI

By

Jacob Ricker-Gilbert

Chapter 1 uses a double-hurdle model with panel data from Malawi to investigate how fertilizer subsidies affect farmer demand for commercial fertilizer. The paper controls for potential endogeneity caused by the non-random targeting of fertilizer subsidy recipients. Results show that on average one additional kilogram of subsidized fertilizer crowds out 0.22 kilograms of commercial fertilizer, but crowding out ranges from 0.18 among the poorest farmers to 0.30 among relatively non-poor farmers. This indicates that targeting fertilizer subsidies to the rural poor is likely to maximize the contribution of the subsidy program to total fertilizer use.

Chapter 2 uses three waves of panel data in Malawi to address how fertilizer subsidies affect the agricultural labor market in Malawi. This article directly estimates how the subsidy program affects agricultural labor supply, labor demand, and median community-level wage rates, none of which have been well quantified to this point. Results from this study indicate that subsidized fertilizer has a significant negative effect on the amount of off-farm agricultural labor that recipient households supply. The average participant in the subsidy program reduces the number of days of off-farm agricultural labor supplied by 9.6% across the sample. This finding indicates that subsidy recipients may move back towards own farm production. The supply-side effect of the subsidy program is small however, as the average household that acquires subsidized fertilizer only reduces off-farm labor supply by 2.5 days on average. Therefore, the reduction in labor supply from the subsidy likely has a limited effect on household income. Fertilizer subsidies do not have a significant effect on demand for hired-in labor. This result provides some evidence that the subsidy program could have off-setting effects on the demand side, as increased demand for hired-in labor caused by boosts in production could be offset by a

decrease in demand for labor as the subsidy decreases fertilizer price relative to labor price. Finally, a one kilogram increase in the average amount of subsidized fertilizer acquired per household in a community boosts median off-farm wage rate by 0.2%, but an increase of one standard deviation of subsidized fertilizer per household in a community reduces wage rate by 0.1%. This finding indicates that while greater average quantities of subsidized fertilizer in a community boost wage rates, the more unevenly that the fertilizer is distributed, the less of a positive impact it has on wage rates. The increase in median wage is mainly due to contraction of agricultural labor supply. It also provides some evidence that households who do not receive subsidized fertilizer may benefit indirectly through a slight increase in agricultural wage rates.

Chapter 3 uses panel data from Malawi to measure how receiving subsidized fertilizer in the current year and in previous years affects several different measures of household well-being. Our model accounts for potential endogeneity of subsidized fertilizer due to the non-random way in which it is distributed to recipients. Results indicate that receiving subsidized fertilizer in a given year raises maize and tobacco production as well as the net value of rainy-season crop production in that year. Receipt of subsidized fertilizer over the prior three seasons also has a significant positive effect on current year maize production. However, receipt of subsidized fertilizer in the prior three consecutive years has no discernable effect on the net-value of total crop production in the current year. Moreover, we find no evidence that prior or current receipt of subsidized fertilizer contributes to off-farm or total household income. Lastly, we find no significant evidence that receiving subsidized fertilizer raises farmers' livestock and durable asset wealth. Potential general equilibrium benefits resulting from the subsidy program cannot be discounted, but the direct comparison of recipient and non-recipient households indicates that enduring effects of the subsidy beyond the year of receipt apply to maize production only and not to overall household income or asset wealth.

Dedicated to my wife Amanda; thank you for your love and support over the past four years.

ACKNOWLEDGEMENTS

I am grateful to my major professor Thom Jayne and my other committee members, Roy Black, Eric Crawford, Bob Myers, Songqing Jin, and Jeff Wooldridge. I also appreciate the support of other colleagues, Duncan Boughton, Valerie Kelly, Ephraim Chirwa, Andrew Dorward, David Mather, and Margaret Beaver. I would also like to thank fellow graduate students, in particular Nicole Mason, Bill Burke, Joshua Ariga, Sonja Perakis, Tim Komerak, Xuan Wei, and Alex Shanoyan for their help throughout my time at MSU.

TABLE OF CONTENTS

LIST OF TABLES ... ix

INTRODUCTION ... 1
Data ... 3
Chapter 1: Subsidies and Crowding Out: A Double-Hurdle Model of Fertilizer Demand in Malawi ... 4
Chapter 2: Measuring the Spill-Over Effects from Subsidizing Fertilizer: The Impact on the Agricultural Labor Market in Malawi ... 5
Chapter 3: Enduring Effects of Fertilizer Subsidy Programs on Recipient Farm Households: Evidence from Malawi ... 7
Subsidized Fertilizer Recipient Targeting ... 8
Other ... 9
REFERENCES ... 10

CHAPTER 1: SUBSIDIES AND CROWDING OUT: A DOUBLE-HURDLE MODEL OF FERTILIZER DEMAND IN MALAWI ... 12
Fertilizer Distribution and Subsidies in Malawi ... 15
Conceptual Framework ... 17
Empirical Model ... 19
Data ... 24
Results ... 27
Conclusions ... 34
Endnotes ... 37
REFERENCES ... 47

CHAPTER 2: MEASURING THE SPILL-OVER EFFECTS FROM SUBSIDIZING FERTILIZER: THE IMPACT ON THE AGRICULTURAL LABOR MARKET IN MALAWI ... 51
Fertilizer Distribution and Subsidies in Malawi ... 57
Ganyu Labor in Malawi ... 59
Conceptual Framework ... 61
Empirical Model ... 65
Identification Strategy ... 67
Data ... 71
Results ... 75
Conclusions ... 80
Endnotes ... 82
APPENDICES ... 93
APPENDIX A: FACTORS AFFECTING THE NUMBER OF DAYS HOUSEHOLDS SUPPLY AGRICULTURAL LABOR; HOUSEHOLD LEVEL PREDICTED WAGE USING HECKMAN PROCEDURE; THREE WAVES FOR *GANYU* SUPPLYING POPULATION ... 94
APPENDIX B: FACTORS AFFECTING THE NUMBER OF DAYS HOUSEHOLDS SUPPLY AGRICULTURAL LABOR; COMMUNITY LEVEL PREDICTED WAGE; TWO WAVES FOR *GANYU* SUPPLYING POPULATION. 97
REFERENCES ... 99

CHAPTER 3: WHAT ARE THE ENDURING EFFECTS OF FERTILIZER SUBSIDY PROGRAMS ON RECIPIENT FARM HOUSEHOLDS? EVIDENCE FROM MALAWI ... 104
Fertilizer Distribution and Subsidies in Malawi ... 108

Conceptual Framework 110
Measures of Household Well-being 112
Methodology 114
Identification Strategy 115
Data 121
Results 125
Conclusions 134
Endnotes 136
APPENDICES 152
APPENDIX C: RESULTS WITH INTERACTION OF LAGGED SUBSIDIZED FERTILIZER QUANTITIES 153
APPENDIX D: RESULTS WITH 2008/09 HOUSEHOLD DATA AND FIVE YEARS OF LAGGED SUBSIDIZED FERTILIZER DATA 164
REFERENCES 169

LIST OF TABLES

Table 1.1 Descriptive Statistics of Variables Used in the Analysis 39

Table 1.1 Continued 40

Table 1.2 Quantity of Fertilizer Used by Malawian Farmers in Survey, by Source; Full Sample (in Kilograms) 41

Table 1.4 Double Hurdle Model of Factors Influencing Demand for Commercial Fertilizer (Subsidized Fertilizer Treated as Endogenous) 43

Table 1.5 Average Partial Effects (APE) of Subsidized Fertilizer on Commercial Fertilizer Demand at Different Quintiles of Asset Distribution with Different Estimators, Using the Full Sample 45

Table 1.6 Average Partial Effects (APE) of Subsidized Fertilizer on Commercial Fertilizer Demand at Different Quintiles of Landholding Distribution with Different Estimators, Using the Full Sample 46

Table 2.1 Comparison Statistics for *Ganyu* Supplying and *Ganyu* Demanding Households 83

Table 2.2 *Ganyu* Supply and Demand Summary Statistics by Year 84

Table 2.3 Subsidized fertilizer acquired by Ganyu Supplying and Demanding Households at Different Points of the Distribution (in Kilograms) 85

Table 2.4 Factors Affecting the Quantity of Subsidized Fertilizer a Household Acquires 86

Table 2.5 Factors Affecting Community Level Agricultural Wage Rates; Three Waves 87

Table 2.6 Factors Affecting the Number of Days Households Supply Agricultural Labor; Community Level Predicted Wage; Three Waves 88

Table 2.7 Effect of Fertilizer Subsidies on *Ganyu* Labor Supply, by Asset Quintile, For the Ganyu Supplying Population 90

Table 2.8 Factors Affecting the Number of Days Households Demand Hired-in Agricultural Labor; Community Level Predicted Wage; Three Waves 91

Table 2.A1 Factors Affecting the Number of Days Households Supply Agricultural Labor; Household Level Predicted Wage Using Heckman Procedure; Three Waves for *Ganyu* Supplying Population 94

Table 2.B1 Factors Affecting the Number of Days Households Supply Agricultural Labor; Community Level Predicted Wage; Two Waves for *Ganyu* Supplying Population 97

Table 3.1 Means and Medians of Variables Used in the Analysis, by Region and Survey Year 137

Table 3.2 Distribution of Variable Measuring Kilograms of Subsidized Fertilizer Acquired by Households in Malawi, by Year 138

Table 3.3 Factors Influencing the Quantity of Subsidized Fertilizer Received by Households 139

Table 3.4 Factors Influencing the Value of Household Assets 140

Table 3.5 Factors Influencing Household Maize Production 141

Table 3.6 Factors Influencing Household Tobacco Production 143

Table 3.7 Factors Influencing the Net Value of Rainy-Season Crop Production 145

Table 3.8 Factors Influencing Off-farm Income 147

Table 3.9 Factors Influencing Total Household Income 149

Table 3.10 Impact of Subsidized Fertilizer Received Over Time on Measures of Household Well-being 151

Table 3.C1 Factors Influencing the Value of Household Assets 153

Table 3.C2 Factors Influencing Household Level Maize Production 155

Table 3.C3 Factors Influencing Household Level Tobacco Production 157

Table 3.C4 Factors Influencing Net Value of Rainy-Season Crop Production 159

Table 3.C5 Factors Influencing Off-farm Income 160

Table 3.C6 Factors Influencing Total Household Income 162

Table 3.D1 Factors Influencing the Value of Household Assets 164

Table 3.D2 Factors Influencing Household Level Maize Production 165

Table 3.D3 Factors Influencing Net Value of Rainy-Season Crop Production 166

Table 3.D4 Factors Influencing Off-farm Income 167

Table 3.D5 Factors Influencing Total Household Income 168

INTRODUCTION

This dissertation evaluates how the fertilizer subsidy program in Malawi, which was scaled up beginning in 2005, affects smallholder decision making and well-being. Rigorous evaluation of the Malawi fertilizer subsidy program is highly relevant to current development policy debates because fertilizer subsidies are being broadly promoted as a means to boost production of maize and other staple crops in order to improve food security in Sub-Saharan Africa (SSA). The Malawi fertilizer subsidy program received popular acclaim in a front-page New York Times article (Dugger 2007) and is widely being perceived as a test case for possible broader implementation elsewhere in Africa. Furthermore numerous other countries in SSA including Senegal, Mali, Nigeria, Kenya, Tanzania, Zambia, have also implemented programs that make fertilizer available to farmers below commercial market prices.

Although fertilizer subsidy programs are receiving broad support, the cost of financing large scale subsidy programs is high. For example, in 2008 Malawi spent roughly 70% of the Ministry of Agriculture's budget, or almost 16% of the government's total budget, subsidizing fertilizer and hybrid maize seed (Dorward and Chirwa 2011). In Zambia, 57% of total government spending on agriculture was devoted to fertilizer and maize subsidies in 2010, equivalent to 2% of the nation's gross domestic product (Nkonde et al. 2011, IMF 2010). Despite relatively high costs, to date little empirical research has been conducted to quantify the benefits of such programs in order to compare them against the costs.

The major methodological contribution of this dissertation is that it provides a useful method for dealing with an endogenous covariate, which in this case is the amount of subsidized fertilizer that a household acquires, in the context of a non-linear panel data model. In addition, the subsidized fertilizer variable is a corner solution, and in chapter 1 the dependent variable in the structural model, quantity of commercial fertilizer purchased, is also a corner solution variable. In chapter 2, the dependent variables, days of agricultural labor that households' supply and demand are both corner solutions. These non-linear, corner solution variables necessitate the use of the control function approach to deal with endogeneity of subsidized fertilizer acquisition. Each essay provides detailed discussion on the identification strategies for dealing with subsidized fertilizer's potential endogeneity.

This dissertation is written in the form of three chapters that are formatted as separate articles. Chapter 1 estimates how much commercial fertilizer gets crowded out by an additional kilogram of subsidized fertilizer that farmers acquire. Estimating the extent of crowding out is essential for measuring program efficiency and for determining how much new fertilizer actually ends up on farmers' fields. Chapter 2 estimates the effect of the fertilizer subsidy program on supply and demand for off-farm agricultural labor. Chapter 2 also measures the potential spill-over benefits that the fertilizer subsidy program may have had on agricultural labor wage rates. This is important for measuring the spill-over effects of the subsidy program, and helps quantify how non-recipients of the subsidy may have benefited through increased agricultural labor wage rates. Chapter 3 estimates the impact of subsidized fertilizer on several different measures of household well-being, such as value of household livestock and durable assets, maize and tobacco production, net value of crop production, non-farm income, and total household income. Chapter 3 also measures the enduring effects of receiving subsidized fertilizer in previous years on the well-being indicators in the current year. In doing so, this essay takes steps to address whether or not subsidizing fertilizer provides benefits to farmers that can last longer than one year. This allows me to test whether or not fertilizer subsidies can help recipients break out of their low input, low output poverty trap.

In total the three essays should provide a broad evaluation of the subsidy program in Malawi. The titles of the dissertation chapters are as follows:

1) *Subsidies and Crowding Out: A Double-Hurdle Model of Fertilizer Demand in Malawi.*
2) *Measuring the Spill-Over Effects from Subsidizing Fertilizer: The Impact on the Agricultural Labor Market in Malawi.*

3) *What are the Enduring Effects of Fertilizer Subsidy Programs on Recipient Farm Households? Evidence from Malawi.*

Results from this study should provide useful information to policy makers who debate the merits of fertilizer subsidies. It should also provide a useful reference in the academic literature for those interested in ways to control for endogeneity in non-linear panel data models. Subsequent sections of the introduction discuss the data and each of the three essays in greater detail.

Data

Data used in this study come from three farm household surveys conducted by the Government of Malawi's National Statistical Office. The first wave of data comes from the Second Integrated Household Survey (IHHS2) in Malawi collected during the 2002/03 and 2003/04 growing seasons. The IHHS2 surveyed households in 26 districts in Malawi and in total 11,280 households were interviewed. The second wave of data comes from the 2007 Agricultural Inputs Support Survey (AISS1) conducted after the 2006/07 growing season. The budget for AISS1 was much smaller than the budget for IHHS2 and of the 11,280 households interviewed in IHHS2 only 3,485 of them lived in enumeration areas that were re-sampled in 2007. Of these 3,485 households 2,968 were re-interviewed in 2007, which gives us an attrition rate of 14.8%.

The third wave of data comes from the 2009 Agricultural Inputs Support Survey II (AISS2) conducted after the 2008/09 growing season. The AISS2 survey had a subsequently smaller budget than the AISS1 survey in 2007, so of the 2,968 households first sampled in 2003 and again in 2007, 1,642 of them lived in enumeration areas that were revisited in 2009. Of the 1,642 households in revisited areas, 1,375 were found for re-interview in 2009, which gives us an attrition rate of 16.3% between 2007 and 2009.

Note that the first year of the panel, while drawn from the same survey IHHS2, covers two different years. Since I know in which of the two years each household was surveyed, I address this issue by including a year dummy for each of the two years in the first survey and using the second survey as the control year. Furthermore since the time difference is just a single year one would not expect there to be many unobservable changes that vary over that time.

Chapter 1: Subsidies and Crowding Out: A Double-Hurdle Model of Fertilizer Demand in Malawi

The objective of this essay is to determine how much commercial fertilizer gets crowded out or displaced by subsidized fertilizer. The contribution of this study is 1) it is the first to deal with the likelihood that subsidized fertilizer is endogenous in a farmer's commercial fertilizer purchase decision; 2) it provides an overall measure of how much commercial fertilizer is displaced by the subsidy. The paper uses a Double-Hurdle (DH) model to separately address a farmers' decision to participate in fertilizer markets and the amount of fertilizer he or she acquires. The study uses a Control Function (CF) method to control for endogeneity when both the dependent variable (kilograms of commercial fertilizer), and the endogenous variable of interest, (kilograms of subsidized fertilizer) are corner solution outcomes, as many farmers do not use fertilizer, either commercial or subsidized, but for those who do, the distribution of the amount acquired is relatively continuous. Results indicate that on average each kilogram of subsidized fertilizer causes a farmer to purchase 0.22 fewer kilograms of commercial fertilizer when the model is estimated via DH. The crowding out effects are larger for farmers with more assets, as it ranges from -0.18 among the poorest farmers to -0.30 among relatively non-poor farmers. This indicates that targeting fertilizer subsidies to the rural poor is likely to maximize the contribution of the subsidy program to total fertilizer use.

A similar version of chapter 1 has been published in the *American Journal of Agricultural Economics* in 2011, however this dissertation version of the essay has a few additions not included in the published article. The first addition is that I compare crowding out estimates of -0.22 using the DH with crowding out estimates using a linear Fixed-Effects (FE) estimator and crowding out estimates using a Tobit estimator. The crowding out estimates are -0.60 using FE, and -0.35 using the tobit. It seems that the DH obtains a more conservative crowding out estimate because it explicitly considers the corner solution problem caused by 73% of farmers in the sample not purchasing commercial fertilizer. The DH estimates demand for commercial fertilizer in two steps, whereas the tobit estimator deals with the corner solution issue but estimates demand for commercial fertilizer in one step. The FE estimator ignores the corner solution issue entirely and estimates demand for commercial fertilizer as a linear model.

I also compare crowding out estimates across the distribution of the sample in terms of value of assets and landholding. Results indicate that crowding out increases as households get richer and obtain more land. When estimated via DH, crowding out ranges from -0.18 for the 20% of the sample with the fewest assets, to -0.30 for the 20% of household with the highest assets. Similarly, crowding out ranges from -0.15 for the 20% of the sample with the least amount of land to -0.34 for the 20% of the sample with the most land, when estimated via DH. These results make sense as people with more assets and land are more likely to buy fertilizer at commercial prices, so they will displace a greater portion of their commercial sales with the subsidy.

Chapter 2: Measuring the Spill-Over Effects from Subsidizing Fertilizer: The Impact on the Agricultural Labor Market in Malawi

The objective of this paper is to determine how targeted fertilizer subsidies affect the labor market in Malawi. This is an essential issue for understanding the benefits of the subsidy because many small farmers in Malawi and Sub-Saharan Africa tend small plots and are net consumers of maize and other staple crops. These households supplement their production shortfalls by working as agricultural laborers on other peoples' farms. Therefore any policy that affects the agricultural labor market, either through supply effects, demand effects or by raising agricultural wage rates could have an important impact on the livelihood of millions of small farmers in SSA.

The contribution of this paper is mainly empirical, as I estimate how fertilizer subsidies impact agricultural labor supply, agricultural labor demand and agricultural wage rates in Malawi. By using econometric methods with household level panel data, this essay provides new insights on the agricultural labor market in Malawi to complement previous whole-economy programming models of agricultural labor markets, that have been conducted on the agricultural labor market in the past (Dorward 2007; Dorward et al. 2008). Chapter 2 uses all three waves of data in the analysis. Results indicate that subsidized fertilizer has a significant negative effect on the amount of off-farm agricultural labor that recipient households supply. The average participant in the subsidy program reduces the number of days of off-farm agricultural labor supplied by 9.6% across the sample. This finding indicates that subsidy recipients may move back towards own farm production. The supply-side effect of the subsidy program is small however, as the average household that acquires subsidized fertilizer only reduces off-farm agricultural labor supply by 2.5 days on average. Therefore, the reduction in labor supply from the subsidy likely has a limited effect on household income. Fertilizer subsidies are found to have no significant effect on demand for hired-in labor, which indicates that the subsidy program could have off-setting effects on the demand side. Although the subsidy may increase production which could boost demand for hired-in labor, that effect could be offset because as the subsidy lowers the price of fertilizer, there may be a substitution effect by households who hire in labor towards applying more fertilizer and away from hiring labor to engage in labor intensive activities, such as composting .

Finally, a one kilogram increase in the average amount of subsidized fertilizer acquired per household in a community boosts the median off-farm wage rate by 0.2%, but an increase of one standard deviation of subsidized fertilizer per household in a community reduces the median wage rate by 0.1%. This finding indicates that while greater average quantities of subsidized fertilizer in a community boost wage rates, the positive impact is reduced if the distribution is less even. The increase in median wage is mainly due to contraction of agricultural labor supply. Since agricultural wage rates increase as a result of the subsidy, this study provides some evidence that households who do not receive subsidized fertilizer may benefit indirectly through a slight increase in agricultural wage rates. Less poor households who demand agricultural labor may have their welfare hurt by higher wage rates.

Chapter 3: Enduring Effects of Fertilizer Subsidy Programs on Recipient Farm Households: Evidence from Malawi

The objective of this study is to determine how fertilizer subsidies affect the well-being of rural households in Malawi in the year they receive the subsidy and also in future periods. Well-being is measured in this paper using indicators such as value of household livestock and durable assets, maize and tobacco production, net value of crop production, non-farm income, and total household income. The effect of fertilizer subsidies on these indicators provides a broad understanding of how the policy affects the lives of rural households. The contributions of this paper are 1) it provides empirical evidence of the subsidy's impact on important household-level well-being factors; 2) it measures the longer run dynamic effects of fertilizer subsidies on well-being.

All of the well-being indicators other than tobacco are treated as linear in this essay. I take steps to control for endogeneity and recognize that fertilizer subsidies, the potentially endogenous and key variable in the study, takes on non-linear properties. I also use recall data from the survey to construct variables for the quantity of subsidized fertilizer households received in past years. This allows me to test whether there is any dynamic effect on current year well-being caused by fertilizer received in past years. These results provide evidence on how well fertilizer subsidies kick-start the growth process to move households out of poverty.

Results from chapter 3 indicate that receiving subsidized fertilizer in a given year positively affects maize and tobacco production, as well as the net value of crop production in that year. An additional kilogram of subsidized fertilizer boosts maize production by 1.65 kilograms, tobacco production by 0.7% and net value of crop production by US $1.16 in the current year. I find that the only enduring effect from subsidizing fertilizer over time is on maize production, as one additional kilogram acquired by households in each of the three previous years boosts maize production by 3.16 kilograms in the current year on average.

Receipt of subsidized fertilizer in the previous three years has no discernable effect on the total net value of rainy-season crop production in the current year. Moreover, I find no evidence that prior or current receipt of subsidized fertilizer contributes to off-farm income or total household income, suggesting that receiving subsidized fertilizer may induce households to reallocate labor and other resources from other activities to the production of maize and tobacco. I also find no significant evidence to indicate that receiving subsidized fertilizer causes farmers to increase their livestock and durable asset wealth. General equilibrium benefits resulting from lower maize market prices cannot be discounted, but the weight of the evidence indicates that enduring effects of the subsidy apply mainly to maize production and not to overall household income or asset wealth.

Subsidized Fertilizer Recipient Targeting

In all three essays of this dissertation, the analysis of factors affecting how much subsidized fertilizer a household acquires is treated as a reduced form, which is used to deal with potential endogeneity of subsidized fertilizer in the structural models. Table 2.4 in chapter 2 presents the results for factors affecting how much subsidized fertilizer households in Malawi acquire across the three survey waves. From the table it is evident that in certain years households that have a member of parliament (MP) residing in their village receive significantly more subsidized fertilizer than households in other villages on average. This effect provides evidence that political connections affect subsidized fertilizer acquisition in Malawi.

Households in villages further from a paved road and households in villages further from the district capital receive significantly more subsidized fertilizer, as an additional kilometer from a paved road or main town gets the household 0.13 kilograms or 0.10 kilograms more subsidized fertilizer on average respectively. There is also evidence that poorer households with fewer assets and less land do not receive significantly more subsidized fertilizer than other households.

Households where the head attended school receive significantly more subsidized fertilizer than others. Households with more men over 65 also receive significantly more subsidized fertilizer. Each additional male over 65 years old in the household causes that household to acquire over 13 kilograms more subsidized fertilizer on average. Table 1.3 in chapter 1 shows that for each additional year that the household head has lived in the village that household acquires an additional 0.09 kilograms on average. These findings indicate that social connections affect how much subsidized fertilizer households obtain.

Other

Please note that since these essays are written to be relatively self-contained to facilitate submission to journals, some of the sections may have some repetition. For example the section on program background in Malawi is very similar in all three papers and parts of the methodology and data sections are similar among the papers. Some of the information in these papers will be more comprehensive than what would go in a journal article. These dissertation essays are meant to provide additional information that readers can reference from the articles.

REFERENCES

REFERENCES

Dorward, A. 2007. “Impacts of the Agricultural Input Subsidy Programme in Malawi: Insights fromRural Livelihood Modeling.” Working paper, Agricultural Input Subsidy Programme Evaluation. London, School of Oriental and African Studies.

Dorward, A., E. Chirwa, V. Kelly, T.S. Jayne, R. Slater, and D. Boughton. 2008. “Evaluation of the 2006/07 Agricultural Input Subsidy Programme, Malawi.” Final Report. Lilongwe, Malawi.

Dorward, A., and E. Chirwa. 2011. “The Malawi Agricultural Input Subsidy Programme: 2005/06 to 2008/09.” *International Journal of Agricultural Sustainability.* (16): 232-247.

IMF, 2010. Fifth Review Under the Three-Year Arrangement Under the Extended Credit Facility, Requests for Waiver of Nonobservance of Performance Criterion and Modification of Performance Criteria, and Financing Assurances Review. International Monetary Fund, Washington, DC.

Mason. N.M. 2011. “The Effects of the Zambian Food Reserve Agency on Maize Market Prices and Smallholder Farm Household Behavior.” Unpublished Dissertation. Department of Agriculture, Food and Resource Economics. East Lansing, Michigan.

Nkonde, C., N.M. Mason, N.J. Sitko, and T.S. Jayne. 2011. “Who Gained and Who Lost from Zambia’s 2010 Maize Marketing Policies?” FSRP Working Paper #49, Department of Agricultural, Food and Resource Economics, Michigan State University.

Ricker-Gilbert, J., T.S. Jayne and E. Chirwa. 2011. “Subsidies and Crowding Out: A Double-Hurdle Model of Fertilizer Demand in Malawi.” *American Journal of Agricultural Economics.* 93(1): 26-42.

CHAPTER 1
SUBSIDIES AND CROWDING OUT: A DOUBLE-HURDLE MODEL OF FERTILIZER DEMAND IN MALAWI

(Note: For citation purposes please refer to a similar article published earlier;
Ricker-Gilbert, J., T.S. Jayne and E. Chirwa. 2011. "Subsidies and Crowding Out: A Double-Hurdle Model of Fertilizer Demand in Malawi." *American Journal of Agricultural Economics.* 93(1): 26-42.)

Whenever a policy intervention is implemented in a market where the private sector is already established, that policy has the potential to crowd-out or displace commercial market activity. Evidence of crowding out has been found in a diverse range of circumstances, such as government fiscal policies displacing private investment (Spencer and Yohe 1970; Cebula 1987), in some cases causing household consumption to decline (Barro 1997); government programs meant to cover the uninsured prompting some already enrolled in private insurance to switch to the new program (Cutler and Gruber 1996; Kronick and Gilmer 2002); and local African manufacturers of mosquito bed nets going out of business after donors supplied them to communities for free (Easterly 2006). Understanding the degree to which government programs crowd out commercial market activity is essential for assessing impacts of any public policy.

Fertilizer subsidies are public policy interventions that are currently receiving a great deal of attention and funding in Sub-Saharan Africa (SSA). The goal of fertilizer subsidy programs as articulated by many African governments is to improve farmers' incomes and national food security by increasing food production. To achieve these goals, the subsidy must raise total fertilizer use. The degree to which a subsidy program raises total fertilizer use depends on the extent to which it crowds out farmers' purchase of commercial fertilizer.

Resurgent interest in fertilizer subsidies is based partially on the premise that they can involve the private sector and hence minimize the crowding out of commercial fertilizer. An example is the use of targeted input vouchers: Governments distribute vouchers to farmers according to certain criteria, e.g., those who are too poor to afford buying fertilizer from commercial sources. The voucher entitles the farmer to buy fertilizer from participating retailers at a subsidized price. The retailer then redeems the voucher to the government to obtain the full commercial price less the subsidized price. In principle, if vouchers are allocated in a manner that would not affect farmers' demand for commercial fertilizer, then crowding out would be negligible and the voucher program would result in a one ton increase in total fertilizer use for every ton of fertilizer distributed under the program. Other factors constant, this would maximize the contribution of a subsidy program to net farm income and national food production.

Targeted subsidies are supposed to work differently than conventional universal subsidy programs, including most of those implemented in Asia during its green revolution period. Universal subsidy programs were designed to introduce fertilizer onto the market at a discounted price, thereby shifting out the supply of fertilizer and lowering its cost to farmers. Empirical evidence from Asia and high income countries show that the costs of universal subsidies often outweighed the benefits as input suppliers usually captured a large part of the subsidy, because the price discount was not fully passed on to farmers (Brooks, Dyer and Taylor 2008).

To date there is major debate but little empirical evidence on the impact of targeted fertilizer subsidies in SSA. Concerns are often expressed whether such programs meet national policy objectives more efficiently than other public investments to agriculture (Harrigan 2008; Minde et al. 2008; GRAIN 2010). Nevertheless targeted fertilizer subsidies enjoy growing popular support in Africa and in some countries account for over 10% of the national budget. Therefore, measuring the degree to which targeted fertilizer subsidies crowd out commercial sales is essential for understanding program efficiency and their ultimate impacts on farm incomes and food production.

This study uses panel data from Malawi to determine how the subsidy program affects farmer demand for commercial fertilizer and hence the program's direct contribution to maize output and farmer income. We estimate a model of input demand based on the Singh, Squire and Strauss (1986) household model, but where fertilizer is available from two channels, commercial and subsidized, and where receipt of subsidized fertilizer is endogenous. The study then estimates crowding out using a two-step double-hurdle approach given that both the quantity of commercial fertilizer purchased and the quantity of subsidized fertilizer received by farmers take on properties of corner solutions, as many farmers in SSA do not use fertilizer from either source.[1]

Malawi makes for an interesting case study because since 2005/06 the country has implemented a large-scale targeted input voucher program for distributing subsidized fertilizer. Malawi's subsidy program received popular acclaim in a front-page New York Times article (Dugger 2007) and is widely perceived as being a test case for possible broader implementation elsewhere in Africa. However, relatively little is known about the extent to which voucher programs affect total fertilizer use and whether they are a cost-effective means to promote agricultural productivity growth. To our knowledge this is the first study to use farm panel data to analyze the impact of a targeted input subsidy voucher program in Malawi and one of the first to do so in Africa.

In addition to providing information that is relevant to current agricultural policy debates, the study offers an application that may be of more general relevance for modeling input demand in a two-channel system in which endogeneity and corner solutions feature prominently. This situation is likely to apply where the state and private sector operate in parallel marketing channels, where the actions of one channel affect farm behavior in the other, and where a large fraction of farmers do not participate in either market. Coady (1995) was perhaps the first author to explicitly consider the fact that some farmers do not use fertilizer because it is not profitable for them to do so at prevailing market prices (i.e., zero may be an optimal choice in contrast to an unobserved choice). Coady accounts for these different factors affecting fertilizer use by estimating a double-hurdle (DH) model, which was subsequently used by Croppenstedt, Demeke and Meshi (2003) to measure fertilizer adoption and use in Ethopia. Our study takes the DH model framework used by Coady and Croppenstedt, Demeke and

Meshi to investigate farmer demand for fertilizer, and applies it to the problem of measuring crowding out caused by fertilizer subsidies in a two-channel input distribution system.

To our knowledge, the only paper to model crowding out of commercial fertilizer demand is by Xu et al. (2009), who estimate the effect of the Fertilizer Support Program on commercial sales in Zambia. Our study improves upon and extends the work of Xu et al. in the following ways. First, and perhaps most importantly, we recognize the fact that fertilizer subsidies are not distributed randomly. The quantity of subsidized fertilizer that a household receives is likely to be endogenous when used as a covariate in a commercial fertilizer demand equation because the government has stated (and possibly unstated) targeting criteria for allocating the subsidies to households. Our paper gives serious treatment to dealing with the endogeneity of subsidized fertilizer in a model of commercial fertilizer demand. The second extension in our paper is that it provides estimates based on the Average Partial Effects (APE) of the data. The APE's are of greater interest than the partial effects at the average (PAE) in the case of non-linear models and with discrete variables because the APE's are averages of actual partial effects while the PAE's may not be representative of the actual population (Wooldridge 2002; Papke and Wooldridge 2008). Finally our paper provides an overall estimate of crowding out derived from our model. This calculation allows us to report a precise estimate of the additional total fertilizer used (commercial plus subsidized) for each additional kilogram of fertilizer distributed through a subsidy program.

The rest of the paper is organized as follows. The next section gives a brief background on fertilizer distribution in Malawi and the recent subsidy program. We then present the conceptual framework, methodology, and data. Subsequent sections describe the results, conclusions, and main implications for policy.

Fertilizer Distribution and Subsidies in Malawi

Small-scale fertilizer subsidy programs have existed for years in Malawi. However, after experiencing a drought-affected poor harvest in 2004/05, the Government of Malawi decided to embark on a large-scale targeted fertilizer voucher program primarily dedicated to increasing maize production and farmer incomes. The rains were good in 2005/06 and yields were high, making the subsidy program very popular. Consequently it was extended and scaled up further in the 2006/07 growing season. In that year the government procured and distributed 185,000 metric tons of fertilizer for the program, which was designed to reach roughly 60% of the smallholder farm households in Malawi. Each recipient was supposed to receive two coupons, which entitled them to receive two 50-kilogram bags of fertilizer from participating input retailers at 25% of the full commercial price. The program cost more than US $73 million with most of the bill being paid by the Malawian government and a minority by the UK's Department for International Development (DFID). Throughout the four years of program implementation to date, the subsidy program has accounted for 5% to 15% of the national budget.

Fertilizer was also available for purchase from private suppliers at commercial prices during both the 2005/06 and 2006/07 growing season. Six private firms won the right to procure and distribute subsidized fertilizer through their retail networks. Farmers who received coupons could redeem them at participating retailers' stores and pay 25% of the full commercial price of fertilizer. Retailers would then submit the coupon and receipt to the government for payment of the remaining 75%.

The process of determining who received coupons for fertilizer subsidies was subject to a great deal of local idiosyncrasies. At the regional level coupons were supposed to have been allocated based on the number of hectares under cultivation. At the village level, subsidy program committees and the village heads were supposed to determine who was eligible for the subsidy. The general eligibility criteria was that beneficiaries should be "full time smallholder farmers who cannot afford to purchase one or two bags of fertilizer at prevailing commercial prices as determined by local leaders in their areas" (Dorward et al. 2008). However, numerous unofficial criteria may have been used in voucher allocation, such as households' relationship to village leaders, length of residence and social and/or financial standing of the household in the village. Along the same lines it is also possible that unobservable factors affecting the demand for commercial fertilizer such as localized political turmoil or health shocks could also influence how much subsidized fertilizer a household receives. Therefore the quantity of subsidized fertilizer received is likely to be endogenous in a commercial fertilizer demand equation.

While the voucher program was designed to reduce the negative impact on private agro-dealers, unfortunately it does not address the problem of crowding out. If a voucher for subsidized fertilizer goes to a farmer who would otherwise have bought fertilizer at a commercial price, then the voucher program may shift the composition of retailer's profits from commercial fertilizer to subsidy program fertilizer with uncertain effects on the total quantity of fertilizer applied to the farmer's field. However, farmers clearly gained from the voucher even if they substituted subsidy fertilizer for commercial fertilizer or sold the voucher. In these cases the voucher acted as a cash transfer and contribution to income. It is the degree of crowding out, however, that determines the relative efficiency of a voucher program compared to other forms of assistance such as cash transfers.

Conceptual Framework

In order to measure the contribution of the subsidy program to total fertilizer use, we use the basic Singh, Squire and Strauss (1986) household model to derive fertilizer demand for an agricultural household in a developing country. When one assumes separability between production and consumption, the first order conditions for profit maximization give household demand for fertilizer as a function of input and output prices. The assumption of separability is unlikely to hold in a developing country like Malawi with its imperfect credit and labor markets along with risk factors caused by high weather variability and other shocks (Alwang and Siegel 1999; Bryceson 2006; Dorward 2006).

Therefore this study recognizes that in this context household production and consumption decisions are likely non-separable, so a household's socio-demographic characteristics will affect its desired level of input use (de Janvry and Sadoulet 2006). Beside socio-demographic characteristics, in this setting a household's demand for fertilizer is also affected by the introduction of a state fertilizer distribution system. Non-separability and the presence of subsidized fertilizer make the conceptual model in this paper slightly more complex than the traditional household input demand model. In a situation where subsidized fertilizer affects the quantity of commercial fertilizer that a non-separable household purchases, consider the following equation

(1) $F = f(S, P_f, P_a, T, C, Z, A)$

where *F* represents quantity of commercially priced fertilizer that a household purchases. The quantity of commercial fertilizer is affected by the amount of subsidized fertilizer a household receives which is represented by *S* in equation (1). The price of commercial fertilizer is represented by P_f while P_a represents the output price of the agricultural good. Transfer costs of using fertilizer, such as distance to a paved road are represented by *T*. Credit availability is denoted by *C*. Household socio-demographic characteristics are represented by *Z* and finally *A* represents the quantity of land owned by the household.

Previous literature documents that credit availability affects demand for fertilizer (Coady 1995; Croppenstedt, Demeke and Meschi 2003; Odhiambo and Magandini 2008). It is also well documented that fixed transport and transactions costs affect a farmer's decision to participate in markets (de Janvry, Fafchamps and Sadoulet 1991; Key, Sadoulet and de Janvry 2000; Croppestedt, Demeke and Meschi 2003; Holloway, Barrett and Ehui 2005; Bellmare and Barrett 2006; Halloway, Ehui and Teklu 2008). Because these costs affect fertilizer market participation, they need to be considered when building a model for commercial fertilizer demand in order to estimate crowding out.

Empirical Model

In order to estimate the degree to which subsidized fertilizer displaces commercial fertilizer, we specify the conceptual model in equation (1) and the error term as follows:

(2) $F_{it} = \alpha S_{it} + \mathbf{X}_{it}\boldsymbol{\beta} + \varepsilon_{it}$

(3) $\varepsilon_{it} = c_i + \mu_{it}$

The coefficient estimates and standard errors from α provide the estimate of crowding out. The vector of other explanatory variables that affect demand for commercial fertilizer is represented by $\boldsymbol{X}_{it}$ and $\boldsymbol{\beta}$ represents the vector of corresponding parameters. Included in $\boldsymbol{X}_{it}$ are factors such as maize prices, fertilizer prices, rainfall during the past growing season, household characteristics. The Costs of participating in commercial fertilizer markets are distance from the village to a paved road and whether or not there is a farm credit organization in the village (see table 1 for a full list of explanatory variables). The error term ε_{it} in equation (3) is a function of two components. The first component is unobserved time-constant factors, also called unobserved heterogeneity c_i, which affect household *i*'s demand for commercial fertilizer. These factors might include soil quality, the farmer's management ability and degree of risk aversion. The second component of the error term is unobserved time-varying household shocks affecting the demand for commercial fertilizer. These factors might include political turmoil and health shocks, as represented by μ_{it}.

Controlling for unobserved heterogeneity c_i

One of the challenges for measuring demand for fertilizer in Africa is that many farmers do not use fertilizer so the data take on the properties of non-linear corner solution variables. To obtain consistent estimates in non-linear panel models, the covariates must be independent of unobserved heterogeneity c_i. This is often a strong assumption, leading to biased coefficient estimates when using fixed effects. The assumption of independence between the covariates and c_i can be relaxed by modeling c_i using a framework called either correlated random effects (CRE) or the Mundlak-Chamberlain device following Mundlak (1978) and Chamberlain (1984). To implement the CRE framework in equation (2), we include a vector of variables containing the means for household (i) of all time-varying covariates, denoted by $\bar{X}$i. These variables have the same value for each household in every year but vary across households. One benefit of the CRE estimator is that by including the vector of time-averaged variables, we still control for time-constant unobserved heterogeneity as with fixed-effects while avoiding the incidental parameters problem in non-linear models. Another advantage of CRE is that it allows measurement of the effects of time-constant independent variables just as in a traditional random-effects environment (for more on the CRE framework see Wooldridge 2002).

Controlling for unobserved shocks μ_{it}.

Even after controlling for correlation between S_{it} and c_i, the estimate of crowding out will still be inconsistent if S_{it} is correlated with unobservable time-varying shocks μ_{it}. Many panel studies simply assume independence between covariates and μ_{it}, however this may be a strong assumption, particularly when the covariate of interest is not determined randomly. In this study, the quantity of subsidized fertilizer acquired is likely to be correlated with unobserved time-varying factors that affect the demand for commercial fertilizer because government and local leaders allocated subsidized fertilizer vouchers to households according to specific household characteristics, which may be unobservable to us as researchers.

This study uses the control function (CF) method to deal with correlation between S_{it} and μ_{it}. The CF method entails taking the residuals from a reduced form model of subsidized fertilizer allocation and including them as a covariate in the structural model of commercial fertilizer demand in equation (2). The significance of the coefficient on the residual both tests and controls for correlation between S_{it} and μ_{it} (for more information on the CF approach see Rivers and Vuong 1988; Smith and Blundel 1986; Vella 1993; Lewbel 2004; Papke and Wooldridge 2008)[2].

The reduced form model for subsidized fertilizer is modeled in one step using the tobit estimator because from the households' perspective, they have little control over how much fertilizer they receive. As mentioned earlier, subsidized fertilizer is allocated to households by community leaders. Thus, S_{it} represents a decision made by village leaders rather than being a household decision.

The CF approach requires an instrumental variable (IV) to be used in the reduced form model that is not in the structural fertilizer demand model; the IV should be correlated with the potentially endogenous variable S_{it} but not correlated with μ_{it} in the structural model when conditioned on other covariates. A good IV for this model is a variable denoting the number of years that the household head has lived in the village because it is a measure of socio-political capital that could influence how much subsidized fertilizer a household receives. Also, there is little reason to believe that after conditioning on other covariates $\boldsymbol{X_{it}}$, years lived in a village would be directly correlated with other time-varying factors in the error term of the commercial fertilizer demand model. This maintained hypothesis makes it reasonable to assume that the instrument itself is exogenous. The IV is time-constant but we assume that any leftover endogeneity after using CRE and the CF approach will be uncorrelated with the other covariates in the structural model. It should be noted that in essays 2 and 3 of this dissertation the IV of choice is whether or not a member of parliament (MP) resides in the community. The MP variable is not used in this essay because the coefficient on the MP variable is found to be insignificant (p-value=0.58) in the reduced form specification for the crowding out model.

Functional form and choice of double-hurdle model

After dealing with the potential endogeneity of subsidized fertilizer in a commercial fertilizer demand equation we need to address the functional form issues and find an estimator for equation (2). As mentioned earlier, one of the challenges associated with estimating commercial fertilizer displacement through a model of fertilizer demand is that a large percentage of the households in SSA do not purchase fertilizer. It may seem plausible that a Heckman selection approach would be appropriate in this context because a non-trivial portion of households report zero fertilizer use. However, the Heckman approach is designed for incidental truncation where the zeros are unobserved values, such as in the case of wage rate models when the sample includes unemployed persons.

A corner solution model is more appropriate than a selection model for this problem because inorganic fertilizer has been available for decades in Malawi, so it is safe to assume that the vast majority of farmers are aware of it. However due to market and agronomic conditions many of them choose not to use fertilizer. Therefore the zeros in the data reflect the farmer's optimal choice rather than representing a missing value.

The tobit estimator proposed by Tobin (1958) for a corner solution model could be used to model a farmer's fertilizer decision. The tobit is fairly restrictive however because it requires that the decision to purchase fertilizer and the amount purchased are determined by the same process.

The DH proposed by Cragg (1971) to address corner solution models is more flexible than the tobit because it accounts for the possibility that factors influencing fertilizer market participation and factors influencing quantity of fertilizer purchased may be different. The DH fits our problem of measuring crowding out because it allows for the fact that costs may affect a farmer's decision to participate in the market, such as distance to a road, but once the decision to participate has been made, those costs may not affect the quantity purchased. The DH model also allows the same factor to affect participation and amount consumed in different ways. In hurdle one the farmer decides whether or not to participate in the fertilizer market and if he or she chooses market participation, hurdle two considers the quantity of fertilizer purchased. The maximum likelihood estimator (MLE) in the first hurdle can be obtained using a probit estimator. Then the MLE for hurdle two can be estimated from a truncated normal regression model. The appropriateness of the DH against the Tobit estimator can be evaluated using a likelihood ratio test.

Cragg's original model assumes that conditional on the explanatory variables, the errors between hurdle 1 and hurdle 2 are independent, normally distributed and the covariance between the two errors equals zero. Several studies relax the independent error term assumption in the DH model (Jones 1992; Garcia and Labeaga 1996). These studies find that results are similar when the assumption was relaxed and when it was maintained. This paper maintains Cragg's original assumption.

Obtaining average partial effects

From the two-part DH model we seek the unconditional APE of the subsidized fertilizer coefficient averaged across *i* and *t* in order to calculate an overall measure of crowding out regardless of participation in commercial fertilizer markets. The first step in obtaining the APE is to derive the partial effect for the explanatory variable of interest for every observation *i* at a particular time *t* in the dataset. The APE is just the average of all partial effects for every observation in the dataset. Other elements of the independent variables and the unobservable factors are held constant at the household level (for further reading on APE's see Wooldridge 2002 and Bartus 2005). The standard errors of the APEs are obtained via the delta method or by bootstrapping.[3]

Data

Data used in this study come from two farm household surveys conducted by the Government of Malawi's National Statistical Office. The first wave of panel data comes from the nationally representative Integrated Household Survey-II (IHHS2), covering two cropping seasons; 2002/03 and 2003/04. A stratified random sample of 11,280 households was collected from IHHS2. The second panel wave comes from the 2007 Agricultural Inputs Support Survey (AISS), conducted after the 2006/07 growing season. The budget for AISS1 was much lower than for IHHS2 so only certain areas of the country were selected for re-sampling, however the sample is still considered nationally representative. In total 3,287 households were surveyed in AISS1.

Note that the first year of the panel, while drawn from the same survey, covers two different years. Since we know in which of the two years each household was surveyed, we address this issue by including a year dummy for each of the two years in the first survey and using the second survey as the control year. Furthermore since the time difference is just a single year one would not expect there to be many unobservable changes that vary over that time.

Attrition Bias

Potential attrition bias caused by households leaving the panel in different waves is a major issue that must be addressed. We found that of the 3,287 households sampled in the second wave, 2,591 of those households had been sampled in the first wave. After removing households with missing data and apparent enumerator errors, the balanced panel was composed of 2,406 households, leaving us with 4,812 observations over the two waves of data.

Our panel consists of two waves so all observations that are only available for one time period drop out due to the demeaning process when fixed-effects is used on an unbalanced panel with two waves (Wooldridge 2002, pg. 580). It is also legitimate to run fixed-effects on a balanced subset of an unbalanced panel. Doing so is equivalent to conditioning the data on selection into the panel in both time periods. In the same sense, the CRE framework which includes the household time averages as covariates in the model to control for unobserved heterogeneity can be run on a balanced subset in non-linear models with two waves. It would be of no benefit to add the time-averaged variables for households that appear only in one time period because the time averages are equivalent to the year *t* value (the only year that the household is in the dataset).

To ensure that the results using our balanced panel are robust to attrition bias, we compare our base results with those using inverse probability weights (IPW). The IPW technique involves three steps: (i) use probit to measure whether observable factors in the first wave affect whether a household is re-interviewed in the second wave; (ii) obtain the predicted probabilities (Pr_{it}) of being re-interviewed in the second wave; (iii) compute the IPW = ($1/Pr_{it}$) and apply it to all models estimated. (For more information on IPW see Robins, Rotnitzky and Zhao 1995; Fitzgerald, Gottshalk and Moffitt 1998; and Wooldridge 2002). In our models the impact of IPW does not significantly affect the coefficient or standard errors, which indicates that when using the CRE, attrition bias has little to no effect on our estimates. Therefore we exclude the IPW in our final estimation.

Fertilizer Use

During the first round of data collection there was a relatively small fertilizer subsidy program in operation, but commercial purchases accounted for about 94% of farmers' total fertilizer use. In 2006/07, after the second consecutive year of the fertilizer voucher program, roughly five times as much subsidized fertilizer was distributed as in the 2002/03 and 2003/04 seasons covered in the first survey. The proportion of total fertilizer use accounted for by commercial purchases fell from 94% to 26% by 2006/07.

Fertilizer Prices

Fertilizer prices used in the study are reported in Malawian Kwacha per kilogram of fertilizer. The price is an aggregation of Urea and Nitrogen/Phosphorus/Potassium (NPK) prices. These prices are based on what respondents in the survey say they paid for commercial fertilizer during the planting season from October to December. For those buying commercially we use the observed price that they paid, while for those who did not buy commercially we use the district median price to proxy for the price that the farmer faces for the input. Fertilizer prices are in real terms, which are constructed by dividing the nominal price of fertilizer by the CPI in Malawi.

Maize prices

In an input demand function, maize prices should be modeled as expectations, not realized post-harvest prices as contained in the survey data, because the latter are not known at the time that fertilizer use decisions are made. Hence we develop a naive expectation of the average real maize price for the six months prior to the planting season, which is May to October in Malawi. The prices are in Malawian Kwacha per kilogram and come from district-level monthly maize prices collected by the Ministry of Agriculture. We also recognize that tobacco prices affect demand for fertilizer. Unfortunately suitable tobacco price data for Malawi are not available and could not be included in the model yet they are controlled for to some extent by the inclusion of year and region dummies. Maize prices are in real terms, which are constructed by dividing the nominal price of fertilizer by the CPI in Malawi.

Rainfall

The rainfall variables come from district-level experiment station records. In an input demand equation the appropriate rainfall variable is also a farmer's expectation based on rainfall from previous years. We include the average cumulative rainfall over the previous five growing seasons to model farmer expectation. The standard deviation of rainfall over the past five years is also included to give an estimate of rainfall variability. This variable is expected to be negatively related to demand for commercial fertilizer.

All other explanatory variables were constructed from the household survey.

Results

The means and distribution of the variables used in the analysis are presented in Table 1.1, by survey wave. The proportion of farmers purchasing commercial fertilizer fell from 40% in the first wave to 16% in the second wave. Conversely the proportion of farmers receiving subsidized fertilizer rose from 31% in the first wave to 57% in the second wave, after the subsidy was scaled up. While farmers who received the subsidy coupons in 2006/07 were only supposed to have received 100 kilograms of discount fertilizer, the data indicate that people in fact received many quantities other than 100 kilograms. Total fertilizer use rose by 11% for households in the balanced panel between the first and second survey years.

Table 1.1 shows that about 30% of the villages had a farm credit organization in both years. Over 25% of households are headed by women. The average farm size is about 1.3 hectares but this ranges from 0.4 hectares at the 10^{th} percentile of households to 2.4 hectares at the 90^{th} percentile. There are wide variations in household wealth within the sample. Asset wealth is over 60 times higher at the 90^{th} percentile than it is at the 10^{th} percentile.

Fertilizer prices varied by 30% between the 10^{th} and 90^{th} percentile of fertilizer prices in the first survey year, and by 27% in the second survey year; most of this intra-year spatial variation is likely to be due to transport cost differences. Mean commercial fertilizer price increased by 30% between the first and second waves of the survey, reflecting the surge in the world price of fertilizer over this period. Mean world urea prices rose by 28% between 2003/04 and 2006/07.

There was also major variation in the maize prices recorded by the Ministry of Agriculture within each year, again primarily due to market and transport costs differences. While mean real commercial fertilizer price/kg increased substantially over the two periods, mean real maize prices/kg actually decreased. The decreasing input to output price ratio may have eroded the profitability of applying fertilizer to maize in Malawi during that time.

Realizing that fertilizer coupons are fairly fungible we examined whether or not resale was a significant issue with respondents in the dataset. Of the 716 respondents who said that they received subsidized fertilizer coupons in 2006/07, only 12 households said that they resold the coupons, while one respondent said that he or she gave the coupon away. The small percentage of resale should not significantly influence the results of the study.

Table 1.2 displays the total amount of subsidized and commercial fertilizer that farmers in our sample used in the years before and after the subsidy was scaled up in Malawi. Perhaps not surprisingly people used significantly more subsidized fertilizer after the subsidy program was scaled-up while at the same time they used significantly less commercial fertilizer. Table 1.2 shows that total fertilizer use among sampled households increased by 17,367 kilograms in 2006/07, even though they reported an increase in receipts of subsidized fertilizer of 122,270 kilograms. Farmers reported purchasing 104,903 kilograms less commercial fertilizer in 2006/07 than in the first survey year. This provides *prima facie* evidence of substantial crowding out of commercial fertilizer. However, the results in table 1.2 are bivariate and do not control for the effects of other factors.

Table 1.3 presents the model of factors affecting how much subsidized fertilizer a household receives. The coefficients presented in table 1.3 are the APEs which are computed using the *margins* command in Stata. The *margins* command also computes the standard errors and p-values using the delta method. In table 1.3 the coefficient of the IV, years that the household head has lived in the village, has the expected positive sign and can be interpreted to mean that each additional year lived in a village translates to 0.09 additional kilograms of subsidized fertilizer acquired. The coefficient is statistically significant at the 5% level. Moving from the 25th to the 75th percentiles of years lived in the village raises the predicted quantity of subsidized fertilizer received from 35 kilograms to 42 kilograms, when all other variables are evaluated at the mean 2006/07 levels. This result is evidence that years lived in village is a strong instrument because it is partially correlated with the potentially endogenous variable, receipt of subsidized fertilizer, while not being correlated in any obvious way with the error term in the model of farmer demand for commercial fertilizer after conditioning on covariates.

There are a number of tests for IV strength such as Staiger and Stock (1997) and Stock and Yogo (2005). These tests are based on partial correlation between the IV and the potentially endogenous variable in the first stage/reduced form model and are derived from linear reduced form models. The issue is that the first stage model in this paper is a non-linear corner solution model and we are unaware of a test for IV strength in non-linear models. Therefore in this context the only way to test the strength of our instrument is to look at the partial correlation of the IV "years lived in the village" in the reduced form model. The model yields a Z-statistic of 2.15 and a p-value of 0.03 indicating that the IV is partially correlated with the potentially endogenous variable. Therefore we feel confident that this is a strong instrument.

Note that the number of men over 65 and the age of household head are correlated with the IV years lived in village, with correlation coefficients of 0.25 and 0.60 respectively. This may cause collinearity among the covariates but it does not make the years lived in the village any weaker of an instrument. The IV is still highly correlated with the dependent variable even with the inclusion of the other two variables in the model. Results from table 1.3 indicate that villages with a farm-credit organization receive significantly less subsidized fertilizer than other villages. Households further from a road receive significantly more subsidized fertilizer. These results offer evidence that the government is distributing subsidized fertilizer to farmers in areas with weak access to credit and infrastructure.

Household assets and landholding size are both positively correlated with the quantity of subsidized fertilizer received. These coefficients are significant at the 4% and 1% level respectively. Female-headed households receive nearly 12 fewer kilograms of subsidized fertilizer than male-headed households and the result is statistically significant at the 5% level. Families with more men over 65 years receive significantly more subsidized fertilizer. Perhaps this result is because households with older men have stronger networks and are better connected within the community and to government officials. By contrast, households with more women over 65 years old receive less subsidized fertilizer with the coefficient approaching significance.

It is interesting to note that households receive significantly less subsidized fertilizer in areas where the fertilizer price is relatively high. While we are not aware of any quality issues that may affect commercial and subsidized fertilizer prices, it could be that larger farmers purchase more expensive fertilizer blends and are less likely to pay for subsidized fertilizer. It could also be that the government offers greater quantities of subsidized fertilizer in areas where the fertilizer price is lower because they can acquire more fertilizer at a lower price. Results also show that the allocation of subsidized fertilizer is positively correlated with long-run average rainfall of the district. This might be expected if the government is seeking to target fertilizer to relatively productive agro-ecological areas where the maize-fertilizer response rates are relatively high.

Table 1.4 presents the DH model of factors influencing demand for commercial fertilizer when subsidized fertilizer is treated as endogenous. The coefficients in hurdle 1 of table 1.4 are the conditional APEs obtained from the *margins* command in Stata. The p-values in hurdle 1 are obtained via bootstrapping at 250 repetitions to account for first-stage reduced form estimation of subsidized fertilizer receipt.

The residual from the reduced form model of subsidized fertilizer allocation, $\widehat{\omega}_{it}$, is significant at the 1% level in hurdle 1, indicating that subsidized fertilizer is endogenous in a commercial fertilizer market participation model. The coefficient on subsidized fertilizer is negative and statistically significant at (p=0.00), meaning that subsidized fertilizer has a negative effect on the probability of commercial market participation even after controlling for endogeneity. The economic effect indicates that on average each additional 100 kilograms of subsidized fertilizer makes a farmer about 10 percentage points less likely to participate in the commercial fertilizer market. The magnitude of this coefficient is relatively small most likely because many farmers in Malawi do not participate in the commercial fertilizer market regardless of whether or not they receive the subsidy coupon.

In hurdle 1 the factors such as distance to a paved road makes farmers less likely to participate in commercial fertilizer markets. This is what we would expect *a priori* and supports the idea that infrastructure development promotes market access and fertilizer use. Having a farm credit organization in the village is also positively associated with commercial fertilizer market participation as one might expect, yet this variable may be correlated with differences in suitability of fertilizer use. Region dummies control to some extent for differences in agro-ecology, though intra-regional differences remain.

The coefficient on the variable for expected maize price is positive and statistically significant (p=0.04). This finding makes sense because farmers will be more likely to participate in fertilizer markets if they expect the price of maize to be high. The fertilizer price coefficient has a positive sign and is statistically significant at the 1% level. This result may at first appear anomalous but the economic effect is small which may indicate that, *ceteris paribus,* the people who decide to participate in commercial markets do so regardless of small increases in price.

In hurdle 2, the p-value for the reduced form residual is 0.97, indicating that subsidized fertilizer is not endogenous in the model for commercial fertilizer demand once the market participation decision has been made. Therefore, we drop the residual when estimating the second hurdle and estimate the APEs and p-values using the *margins* command in Stata. Results from this model indicate that once the participation decision has been made, each 100 kilogram of subsidized fertilizer causes the farmer to purchase 15 fewer kilograms of subsidized fertilizer and the results are statistically significant with a p-value of 0.00. The DH results therefore indicate that receipt of subsidized fertilizer crowds out commercial fertilizer by reducing the probability that households will participate in the commercial fertilizer market, and by reducing the amount purchased for those who do participate in the market.

The value of household assets and landholding size positively and significantly affects how much commercial fertilizer a farmer purchases once the participation decision has been made in hurdle 2. Contrary to what we expected, last season's maize price is negatively associated with how much fertilizer a farmer buys this season, although it is positively associated with the decision to purchase fertilizer in hurdle 1 as expected. The fertilizer price coefficient is negative in hurdle 2 as we would expect but the p-value is 0.17. Farmers in areas of relatively high average annual long-run average rainfall tend to purchase more commercial fertilizer (p-value=0.01). The results from hurdle 2 indicate that the quantity of subsidized fertilizer received, assets, farm size, market prices and weather conditions affect the quantity of commercial fertilizer that farmers in Malawi purchase.

The unconditional APE of subsidized fertilizer on commercial fertilizer demand, incorporating the likelihood functions and partial effects of both hurdles is estimated to be -0.22 and is significant at the 1% level. This estimate is obtained using the c*raggit* command in Stata and the standard errors are obtained via bootstrapping. The APE of -0.22 is the overall measure of crowding out and it indicates that on average each additional kilogram of subsidized fertilizer a farmer acquires causes him or her to purchase 0.22 fewer kilograms of commercial fertilizer. The 95% confidence interval on the unconditional APE for subsidized fertilizer indicates a range of displacement between -0.31 and -0.13. Another way to report this finding is that, each additional kilogram of subsidized fertilizer distributed under the targeted input voucher program in Malawi adds between 0.69 and 0.87 kilograms of fertilizer to farmers' fields, after accounting for crowding out.

For robustness we use a likelihood-ratio (LR) test to determine whether the DH model does in fact fit our model of factors influencing demand for commercial fertilizer better than the model estimated by tobit. The LR statistic comparing the two models is 646 giving it a p-value of (0.00), indicating that the tobit can easily be rejected in favor of the DH model.

For additional robustness we compare the average crowding out estimate of -0.22 obtained using the CRE DH estimator with crowding out estimates obtained using a linear fixed-effects estimator and estimates obtained using the CRE tobit estimator. The crowding out estimates are -0.60 using FE, and -0.34 using the tobit. It seems that the DH obtains a more conservative crowding out estimate because it explicitly considers the corner solution problem caused by 73% of farmers in the sample not purchasing commercial fertilizer. The DH estimates demand for commercial fertilizer in two steps, whereas the tobit estimator considers the corner solution issue but estimates demand for commercial fertilizer in one step. The FE estimator ignores the corner solution issue entirely since demand for commercial fertilizer is estimated as a linear model.

Crowding out estimates do not differ significantly for any of the three estimators, FE, CRE tobit, CRE DH, regardless of whether or not the IV control function approach is used. This finding indicates that the choice between the three estimators makes a larger impact on crowding out (-0.60, -0.34, -0.22) than does the bias caused by potential correlation between subsidized fertilizer and time-varying unobservable factors.

Table 1.5 divides the observations in the sample into five groups (quintiles) based on household asset values in 2007 U.S. dollars. Table 5 also compares APES for the CRE tobit, and CRE DH estimator. Findings demonstrate that the magnitude of crowding out of commercial fertilizer purchases by the subsidy increases with the value of household assets. Crowding out increases from -0.18 for the poorest wealth quintile to -0.30 for the highest wealth quintile when the model is estimated using the CRE DH. Crowding out increases from -0.21 for the poorest wealth quintile to -0.42 for the richest quintile in the sample When the model is estimated using the CRE tobit. This finding indicates displacement is 66% greater for the wealthiest farmers than for the poorest farmers using the DH estimate, and 69% greater using the tobit estimate. This is what we might expect as wealthy farmers who are more likely to purchase a larger quantity of fertilizer at commercial prices, are the main source of the crowding out of commercial purchases with subsidized fertilizer.

Table 1.6 shows similar results when the sample is divided into quintiles based on landholding. Crowding out is -0.15 for the smallest quintile of landholders and -0.34 for the largest quintile of landholders when the model is estimated using the CRE tobit. Crowding out is -0.21 for the smallest quintile of landholders and -0.56 for the largest quintile of landholders, when the model is estimated using the CRE tobit. This finding indicates that crowding out is 127% greater for the largest 20% of farmers than it is for the smallest 20% of farmers when using the DH estimator, and 167% greater using the tobit estimator. This result is also not surprising considering the fact that farmers with larger landholdings are likely to purchase greater quantities of fertilizer at commercial price.

Conclusions

In many developing countries, farmer input demand is affected by the interplay of public and commercial input distribution systems. In recent years targeted fertilizer subsidy programs have gained popularity in SSA as a way to select “resource-poor” beneficiaries from the population. However, there are concerns that if targeting cannot be implemented as specified, due to political capture for example, then subsidized fertilizer may crowd out commercial fertilizer markets. To date, however, there has been little empirical investigation of the potential crowding out effect of government fertilizer subsidy programs. Given the renewed attention that fertilizer subsidies are currently receiving as a means to overcome continued low fertilizer use rates in Africa, there would be high payoffs to the development of applied approaches for accurately measuring crowding out effects as well as the estimates derived from such analyses.

This paper provides an overall estimate of how commercial fertilizer purchases are crowded out by subsidized fertilizer programs in Malawi. The study's application may be of broader relevance for modeling input demand in a two-channel system in which endogeneity and corner solutions feature prominently. This situation would apply to numerous problem contexts where the state and private sector operate in parallel marketing channels, where the actions of one channel affect farm behavior in the other, and where a large fraction of farmers do not participate in either market.

We use the correlated random effects procedure to control for correlation between time-constant unobserved heterogeneity and the covariates. We use the control function approach with an IV, number of years that the household head has lived in the village, to control for potential endogeneity caused by correlation between time-varying unobservable factors and the quantity of subsidized fertilizer received by farm households.

Our main empirical findings are as follows: First, subsidized fertilizer has a significant negative impact on farmers' commercial fertilizer purchases. Results from the double-hurdle model show that overall receipt of subsidized fertilizer is found to reduce farmers' purchases of commercial fertilizer at an average rate of 0.22. This means that each additional kilogram of subsidized fertilizer contributes an additional 0.78 kilograms to total fertilizer use after accounting for crowding out. This relationship is statistically significant at the 1% level. The 95% confidence interval on the unconditional APE for subsidized fertilizer indicates that each additional kilogram of subsidized fertilizer distributed under the targeted input voucher program in Malawi adds between 0.69 and 0.87 kilograms of fertilizer to farmers' fields. These findings pertain to a year in which the Malawi government incorporated the private sector in its distribution process through the issuing of targeted input vouchers. It is also worth noting that a crowding out rate of 22% could represent a lower bound, as this estimate only considers displacement at the household level. This estimate does not directly account for leakages of subsidized fertilizer that may have occurred further up in the distribution system (Holden and Lunduka 2010).

Furthermore despite targeting guidelines to the contrary, greater quantities of subsidized fertilizer went to households with higher assets and more land. Female headed households also received disproportionately less subsidized fertilizer, while households whose head has lived in the village for a relatively long time received significantly more subsidized fertilizer. These findings indicate that the level of social and political connections affect how much subsidized fertilizer households receive. Some aspects of voucher targeting did favor resource-poor households; those in areas with limited credit availability and poor infrastructure were given more subsidized fertilizer.

The main policy implication from this study is that targeting fertilizer vouchers more effectively to resource-poor farmers would improve the subsidy program's contribution to overall fertilizer use and mitigate the adverse effects on the development of commercial fertilizer markets. More focused targeting to the poor would also raise the net household incomes and food security of the poor more directly through the contribution of the subsidized fertilizer to their own crop output. The results indicate that for every voucher transferred from a household in the top asset quintile to a household in the bottom asset quintile, overall fertilizer use would rise by 12 percentage points.

However, many other factors would need to be taken into account to understand the full impacts of targeting the poor, including how targeting differences would affect the magnitude and distributional effects of the benefits of the subsidy program. One major question is whether poor farm households use fertilizer as efficiently as larger and better off farmers? Evidence to date is spotty but suggests that this may indeed be the case (Minde et al. 2008). If we assume that smaller and resource poor farms use fertilizer as efficiently as larger farms, then more effective targeting to the poor would contribute more to national crop output per voucher distributed. At mean commercial maize and fertilizer prices prevailing in the 2006/07 season and assuming a maize to fertilizer response rate[4] of 4:1

(based on Dorward et al., 2008) and displacement effects like those presented in table 5, the overall contribution to net farm income rises from $0.90 for every dollar of subsidy targeted to households in the wealthiest asset quintile to $1.05 for every dollar targeted to households in the poorest asset quintile. When considering only the cost that farmers themselves pay for subsidized fertilizer (25% of the full price in the 2006/07 season), every dollar spent on the voucher program raises net farm income by $3.60 when targeted to households in the wealthiest asset quintile and by $4.22 when targeted to households in the poorest asset quintile.

A more comprehensive assessment of fertilizer subsidy programs would need to consider general equilibrium effects, such as how the targeted voucher program affects maize and fertilizer prices and the demand for labor and wage rates. While these issues are beyond the scope of this study, they, along with estimates of crowding out, are needed to fully assess the returns to fertilizer subsidy programs compared to other types of public programs and investments. Given that Malawi's input subsidy program accounted for 80% of its agricultural budget and 15% of its national budget in 2008/09, answers to these questions could make a big difference in helping African governments achieve their poverty reduction and food security goals**.**

Endnotes

[1] Corner solution variables represents some "observable choice or outcome by some economic agent where the variable takes on a zero value with positive probability but is a continuous random variable over strictly positive values." (Wooldridge 2002, pg. 518)

[2] Hurdle 1 of the DH model for commercial fertilizer demand is run conditional on $S_{it}>0$. Doing so conditions on the part of the sample where the error terms are observed and normal. When both parts of the DH model are run simultaneously to get the overall measure of displacement we observe the full distribution of S_{it} so the entire sample is used (for more information on the control function see Lewbel 2004; Imbens and Wooldridge 2007).

[3] The APE for the DH model can be obtained with the "Craggit" command in Stata, described in Burke (2009). This command allows us to jointly obtain the unconditional APE from the first and second stage of the DH model. Standard errors are available via bootstrapping.

[4] Fertilizer response rate means the additional kgs of maize obtained per kg of fertilizer applied.

[5] elasticity of fertilizer price is estimated as APE for fertilizer price wrt commercial fertilizer * (mean fertilizer price / mean kilograms of commercial fertilizer purchased). Average elasticity at the household-level for fertilizer price could not be estimated because nearly 73% percent of the households in the sample did not purchase commercial fertilizer.

[6] elasticity of maize price is estimated as APE for maize wrt commercial fertilizer * (mean maize price / mean kilograms of commercial fertilizer purchased). Average elasticity at the household-level for maize price could not be estimated because nearly 73% percent of the households in the sample did not purchase commercial fertilizer.

Table 1.1 Descriptive Statistics of Variables Used in the Analysis

	First Survey Year (2002/03 & 2003/04)					
	value at i^{th} percentile in distribution					
VARIABLE	**10th**	**25th**	**50th**	**75th**	**90th**	**Mean**
Dep. Var. Hurdle 1: Use comm. fertilizer	0	0	0	1	1	0.4
Dep. Var. Hurdle 2: Qty comm. fert. purchased (kg/hh)	0	0	0	50	175	63.3
Endogenous Var.: Subsidized fert. acquired (kg/hh)	0	0	0	10	10	4.2
Received subsidized fertilizer (=1)	0	0	0	1	1	0.31
Fixed Costs: Km from village to nearest paved road	0	2	11	30	43	18.9
Farm credit organization in the village (=1)	0	0	0	1	1	0.27
HH Attributes: Asset value (‘000 kw/hh)	0.5	1.9	6	12.7	31	18.6
Landholding size (ha/household)	0.4	0.6	1	1.5	2.4	1.3
Age of hh head during first survey year	25	31	42	57	70	45.2
Female headed household (=1)	0	0	0	0	1	0.24
# of males over 65 in household	0	0	0	0	1	0.11
# of females over 65 in household	0	0	0	0	1	0.12
# of adult males under 65 in household	0	1	1	2	3	1.33
# of adult females under 65 in household	1	1	1	2	3	1.39
# of children under 12 in the household	0	1	2	3	4	1.91
Adult death in family: past two years (=1)	0	0	0	0	1	0.15
Prices: Naïve expectation of average real maize price for 6 mo’s prior to planting season: (kw/kg) at district level: (May - Oct)	15.3	18.3	19.8	26.3	28.1	21.9
Observed **r**eal commercial fert. price: (kw/kg) during planting season (Oct-Dec)	48.5	50.1	52.7	56.3	62.7	54.1
Rainfall: Long-run avg. cum. rainfall (during past five growing seasons) at district level (in 100 cm)	767	825	888	1,203	1,293	985
Std. deviation of avg. rainfall over the past five growing seasons at district level (in 100 cm)	115	145	2,177	270	403	221
Reduced Form IV: # of years hh head has lived in village during 1st yr of survey	4	13	28.5	45	62	30.9

Table 1.1 Continued

VARIABLE	Second Survey Year (2006/07) value at i^{th} percentile in distribution 10th	25th	50th	75th	90th	Mean
Dep. Var. Hurdle 1: Use comm. fertilizer	0	0	0	0	1	0.16
Dep. Var. Hurdle 2: Qty comm. fert. purchased (kg/hh)	0	0	0	0	50	19.7
Endogenous Var.: Subsidized fert. acquired (kg/hh)	0	0	50	100	100	55
Received subsidized fertilizer (=1)	0	0	1	1	1	0.57
Fixed Costs: Km from village to nearest paved road	0	2	11	30	43	18.9
Farm credit organization in the village (=1)	0	0	0	1	1	0.3
HH Attributes: Asset value (‘000 kw/hh)	0.8	2.5	9	24.7	72.1	39.9
Landholding size (ha/household)	0.4	0.6	1	1.6	2.4	1.3
Age of hh head during first survey year	25	31	42	57	70	45.2
Female headed household (=1)	0	0	0	1	1	0.26
# of males over 65 in household	0	0	0	0	1	0.12
# of females over 65 in household	0	0	0	0	1	0.14
# of adult males under 65 in household	0	1	1	2	3	1.51
# of adult females under 65 in household	1	1	1	2	3	1.67
# of children under 12 in the household	0	1	2	3	4	1.94
Adult death in family: past two years (=1)	0	0	0	0	0	0.09
Prices: Naïve expectation of average real maize price for 6 mo’s prior to planting season: (kw/kg) at district level: (May - Oct)	15.5	19.3	20.3	22.3	23.4	20.1
Observed real commercial fertilizer price: (kw/kg) during planting season (Oct-Dec)	63	66	70	70	80	69.7
Rainfall: Long-run avg. cum. rainfall (during past five growing seasons) at district level (in 100 cm)	703	803	864	1,021	1,188	908
Std. deviation of avg. rainfall over the past five growing seasons at district level (in 100 cm)	125	149	216	279	382	232
Reduced Form IV: # of years hh head has lived in village during 1st yr of survey	4	13	28.5	45	62	30.9

Note: kw = Malawian Kwacha (US $1 roughly equal to 140 Kwacha)
prices are in real values (2006/07)

Table 1.2 Quantity of Fertilizer Used by Malawian Farmers in Survey, by Source; Full Sample (in Kilograms)

Source of Fertilizer	First survey year (2002/03, 2003/04)	Second survey year (2006/07)	Difference
Subsidized	9,993	132,262	+122,270
Commercial	152,382	47,479	- 104,903
Total fertilizer Used	**162,375**	**179,741**	**+17,367**

Source: Integrated Rural Household Survey-II (2004) and Agricultural Inputs Subsidy Survey (2007), both collected by National Statistical Office.

Table 1.3 Factors Influencing the Quantity of Subsidized Fertilizer Acquired by Households, Using Tobit Estimator

	N = 4,812 Pseudo R^2 = .03	
Independent Variables: The coefficients displayed are the Average Partial Effects (APE)	Coefficient	P-Value
Years household head has lived in village during first survey[1,2]	0.09**	(0.03)
Farm credit organization in the village (=1)	-10.78***	(0.00)
Distance to nearest paved road (km)[1]	0.08**	(0.014)
Value of Assets ('000 Malawian Kwacha)	0.02**	(0.04)
Landholding size (hectares)	3.29***	(0.00)
Female headed household (=1)	-11.82**	(0.04)
Age of household head in first survey year[1]	-0.01	(0.88)
# of males over 65 in household	12.84**	(0.05)
# of females over 65 in household	-9.32	(0.104)
# of adult males under 65 in household	-0.84	(0.64)
# of adult females under 65 in household	0.35	(0.84)
# of children under 12 yrs in household	-1.24	(0.27)
Death in the family in the past two years (=1)	5.31*	(0.09)
Naïve expectation of average real maize price for 6 mo's prior to planting season: (kw/kg) at district level: (May - Oct)	-0.93***	(0.00)
Observed commercial fertilizer price during planting season (kwacha/kg)	-0.45***	(0.00)
Long run-annual average cumulative rainfall (mm)	0.08***	(0.00)
Standard deviation of long run cumulative rainfall	-0.02	(0.30)
North Region[1] (=1)	-7.37***	(0.00)
Central Region[1] (=1)	-0.42	(0.81)
First survey (Year 1) dummy (=1)	-55.20***	(0.00)
First survey (Year 2) dummy (=1)	-51.55***	(0.00)

Note: *, **, *** indicates that the corresponding coefficients are significant at the 10%, 5% and 1% level respectively; coefficients and p-values obtained by *margins* command in Stata; [1] indicates variable does not vary over time. [2] indicates that variable is used as instrument and is not included in the structural model results presented in table 4; model includes time averages of all time-varying explanatory variables except the year dummies.

Table 1.4 Double Hurdle Model of Factors Influencing Demand for Commercial Fertilizer (Subsidized Fertilizer Treated as Endogenous)

	Hurdle 1 Probability of Participating in Commercial Fertilizer Market **Probit Estimator**		**Hurdle 2** Demand for Commercial Fertilizer Upon Participation **Truncated Normal Estimator**	
	N = 2,126 Pseudo R^2 = .14		N = 1,339 Correlation^2 = .12	
Independent Variables: The coefficients displayed are the conditional Average Partial Effects (APE)	**Coefficient**	**P-value**	**Coefficient**	**P-value**
Residual from reduced form equation, $\widehat{\omega}_{it}$	-0.007***	(0.00)	-	
Quantity of subsidized fertilizer acquired by household in kgs. * 100	-0.10***	(0.00)	-15***	(0.00)
Distance to nearest paved road[1] (km)	-0.002***	(0.00)	-	
Farm credit organization in the village (=1)	0.158**	(0.01)	-	
Value of Assets ('000 kw/hh)	-0.0004	(0.13)	0.05***	(0.01)
Landholding size (hectares)	-0.024	(0.26)	5.16***	(0.00)
Female headed household (=1)	0.11	(0.21)	-15.28	(0.66)
Age of household head in first survey year[1]	-0.002**	(0.05)	-0.09	(0.85)
# of males over 65 in household	-0.166*	(0.09)	21.11	(0.48)
# of females over 65 in household	0.266***	(0.00)	-12.09	(0.67)
# of adult males under 65 in household	-0.003	(0.90)	5.54	(0.60)
# of adult females under 65 in household	-0.020	(0.24)	1.09	(0.91)
# of children under 12 yrs in household	0.017	(0.22)	3.48	(0.59)
Death in the family in the past two years (=1)	0.054	(0.22)	1.06	(0.96)
Naïve expectation of average real maize price for 6 mo's prior to planting season: (kw/kg) at district level: (May - Oct)	0.012**	(0.04)	-3.94***	(0.01)
Observed Commercial fertilizer price at district level at planting season (kw/kg)	0.012***	(0.00)	-1.03	(0.17)
Long run annual average cumulative rainfall (mm)	-0.001**	(0.04)	0.28***	(0.01)
Standard deviation of long run cumulative rainfall	0.0000	(0.84)	0.10	(0.22)
North Region (=1)	0.132***	(0.01)	85.51***	(0.00)
Central Region (=1)	0.07***	(0.00)	95.89***	(0.00)
First survey (Year 1) dummy (=1)	1.136***	(0.00)	50.75***	(0.01)
First survey (Year 2) dummy (=1)	0.969***	(0.00)	3.87	(0.83)

Table 1.4 Continued

Note: *, **, *** indicates that the corresponding coefficients are significant at the 10%, 5% and 1% level respectively; p-values in parentheses; p-values obtained via bootstrapping at 250 repetitions in hurdle 1 to account for first stage estimation; coefficients in hurdle one along with coefficients and p-values in hurdle two obtained using *margins* command in Stata; [1] indicates variable does not vary over time; both hurdles include time averages of all time varying explanatory variables except the year dummies.

Table 1.5 Average Partial Effects (APE) of Subsidized Fertilizer on Commercial Fertilizer Demand at Different Quintiles of Asset Distribution with Different Estimators, Using the Full Sample

		Estimator				
		CRE Tobit		CRE DH		Mean Asset
Asset Quintile		Coefficient	P-value	Coefficient	P-value	Value in US $
Poorest	1	-0.29	(0.00)	-0.18	(0.00)	$5
	2	-0.31	(0.00)	-0.19	(0.00)	$21
	3	-0.35	(0.00)	-0.22	(0.00)	$51
	4	-0.36	(0.00)	-0.23	(0.00)	$107
Richest	5	-0.42	(0.00)	-0.30	(0.00)	$862
Mean		-0.34	(0.00)	-0.22	(0.00)	$209

Note: p-values estimated via bootstrap at 250 repetitions for Tobit and 100 repetitions for DH; exchange rate in 2007 estimated to be US $1.00 = 140 Malawian Kwacha; models include reduced form residual.

Table 1.6 Average Partial Effects (APE) of Subsidized Fertilizer on Commercial Fertilizer Demand at Different Quintiles of Landholding Distribution with Different Estimators, Using the Full Sample

	Estimator				mean landholding, in ha
	CRE Tobit		CRE DH		
Landholding Quintile	Coefficient	P-value	Coefficient	P-value	
Smallest 1	-0.21	(0.00)	-0.15	(0.00)	0.35
2	-0.26	(0.00)	-0.18	(0.00)	0.72
3	-0.32	(0.00)	-0.21	(0.00)	1.07
4	-0.41	(0.00)	-0.26	(0.00)	1.48
Largest 5	-0.55	(0.00)	-0.34	(0.00)	3.06
Mean	-0.34	(0.00)	-0.22	(0.00)	1.29

Note: p-values estimated via bootstrap at 250 repetitions for Tobit and 100 repetitions for DH; exchange rate in 2007 estimated to be US $1.00 = 140 Malawian Kwacha; models include reduced form residual.

REFERENCES

REFERENCES

Alwang, J., and P.B. Siegel. 1999. “Labor Shortages on Small Landholdings in Malawi: Implications for Policy Reforms.” *World Development* 27(8): 1461-1475.

Barro, R.J. 1997. *Macroeconomics 5th ed*. Cambridge MA: MIT Press.

Bartus, T. 2005. “Estimation of Marginal Effects Using Margeff.” *Stata Journal* 5(3): 309-329.

Bellemare, M., and C. Barrett. 2006. “An Ordered Tobit Model of Market Participation: Evidence from Kenya and Ethiopia.” *American Journal of Agricultural Economics* 88(2): 324-337.

Brooks, J., G. Dyer, and E. Taylor (2008). “Modelling Agricultural Trade and Policy Impacts in Less Developed Countries.” *OECD Food, Agriculture and Fisheries Working Papers* 11.

Bryceson, D.F. 2006. “Ganyu Casual Labour, Famine and HIV/AIDS in Rural Malawi: Causality and Casualty.” Jou*rnal of Modern African Studies* 44(2): 173-202.

Burke, W.J. 2009. “Fitting and Interpretting Cragg’s Tobit Alternative Using Stata.” *Stata Journal* 9(4): 584-592.

Cebula, R.J. (1987). “Federal deficits and the real rate of interest in the United States: A note.” *Public Choice* 1: 97–100.

Chamberlain, G. 1984. “Panel data”. In Grilliches, Z., Intriligator, M.D., eds. *Handbook of Econometrics*, Vol. 2 North Holland, Amsterdam. 1247-1318.

Coady, D.P. 1995. “An Empirical Analysis of Fertilizer Use in Pakistan.” *Econometrica* 62(246): 213-224.

Cragg, J.G. 1971. “Some Statistical Models for Limited Dependent Variables with Application to the Demand for Durable Goods.” *Econometrica* 39(5): 829-844.

Croppenstedt, A., M. Demeke, and M.M. Meschi. 2003. “Technology Adoption in the Presence of Constraints: The Case of Fertilizer Demand in Ethiopia.” *Review of Development Economics* 7: 58-70.

Cutler, D.M., and J. Gruber. 1996. “Does Public Insurance Crowd Out Private Insurance?” *Quarterly Journal of Economics*, 111(2): 391-430.

de Janvry, A., M. Fafchamps, and E. Sadoulet. 1991. “Peasant Household Behaviour with Missing Markets: Some paradoxes Explained.” *The Economic Journal* 101(409): 1400-1417.

de Janvry, A., and E. Sadoulet. 2006. “Progress in Modeling of Rural Household’s Behavior Under Market Failures.” In de Janvry, A., R. Kanbur, eds. *Poverty, Inequality and Development* Vol. 2 Springer, New York. 155-181.

Dorward, A. 2006. “Markets and Pro-Poor Agricultural Growth: Insights from Livelihood and Informal Rural Economy Models in Malawi.” *Agricultural Economics* 35:157-169.

Dorward, A., E. Chirwa, V. Kelly, T.S. Jayne, R. Slater, and D. Boughton. 2008. “Evaluation of the 2006/07 Agricultural Input Subsidy Programme, Malawi.” Final Report. Lilongwe, Malawi.

Dugger, C. W. 2007. Ending Famine, Simply by Ignoring the Experts. *New York Times,* December 2, 2007, p. 1.

Easterly, W. 2006. *White Man’s Burden. Why the West's Efforts to Aid the Rest Have Done So Much Ill and So Little Good*. New York, Penguin Press.

Fitzgerald, J., P. Gottshalk, and R. Moffitt. 1998. “An Analysis of Sample Attrition in Panel Data: The Michigan Panel Study on Income Dynamics.” *Journal of Human Resources* 33(2):251–99.

Garcia, J., and J.M. Labeaga. 1996. “Alternative Approaches to Modeling Zero Expenditure: An Application to Spanish Demand for Tobacco.” *Oxford Bulletin of Economics and Statistics.* 58(3): 489-504.

GRAIN. 2010. *Unraveling the “Miracle” of Malawi’s Green Revolution.* Barcelona, Spain.

Harrigan, J. 2008. “Food Insecurity, Poverty and the Malawian Starter Pack: Fresh Start or False Start?” *Food Policy* 3: 237-49.

Holloway, G., C. Barrett, and S. Ehui. 2005. “The Double-Hurdle Model in the Presence of Fixed Costs.” *Journal of International Agricultural Trade and Development* 1:17-28.

Holloway, G., S. Ehui, and A. Teklu. 2008. “Bayes Estimates of Distance-to-Market: Transactions Costs, Cooperatives and Milk-Market Development in the Ethiopian Highlands.” *Journal of Applied Econometrics* 23:683-696.

Holden and Lunduka. 2010. “The Political Economy of Targeted Input Subsidies in Malawi.” Paper Presented at the NFU Conference, Oslo Norway, November 25-26.

Imbens, G., and J.M. Wooldridge. 2007. “Control Function and Related Methods.” NBER Summer Lecture Series 6.

Jones, A.M. 1992. “A Note on Computation of the Double-Hurdle Model With Dependence With An Application to Tobacco Expenditure.” *Bulletin of Economic Research* 44(1): 67-74.

Key, N., E. Sadoulet, and A. de Janvry. 2000. “Transactions Costs and Agricultural Household Supply Response.” *American Journal of Agricultural Economics* 82:245-59.

Kronick, R., and T. Gilmer, 2002. “Insuring Low-Income Adults: Does Public Coverage Crowd out Private?” *Health Affairs* 21(1): 225-239.

Lewbel, A. 2004. “Simple Estimators for Hard Problems: Endogeneity in Discrete Choice Related Models.” Unpublished, Boston College.

Minde, I., T.S. Jayne, E. Crawford, J. Ariga, J. Govereh. 2008. "Promoting Fertilizer Use in Africa: Current Issues and Empirical Evidence from Malawi, Zambia, and Kenya." Working Paper 13, Regional Strategic Analysis and Knowledge Support System, Pretoria, South Africa.

Mundlak, Y. 1978. "On the Pooling of Time Series and Cross Section Data." *Econometrica* 46: 69-85.

Odhiambo, J.J., V.N. Magandini. 2008. "An Assessment of the Use of Mineral and Organic Fertilizer by Smallholder Farmers in Vhembe District, Limpopo Province, South Africa." *African Journal of Agricultural Research* 3(5): 357-362.

Papke, L.E., and J.M. Wooldridge. 2008. Panel Data Methods for Fractional Response Variables with an Application to Test Pass Rates. *Journal of Econometrics* 145: 121-133.

Robins, J.M., A. Rotnitzky, and L.P. Zhao. 1995. "Analysis of Semiparametric Regression Models for Repeated Outcomes in the Presence of Missing Data." *Journal of the American Statistical Association* 90(429):106–21.

Rivers, D., and Q.H. Vuong. 1988. "Limited Information Estimators and Exogeneity Tests for Simultaneous Probit Models." *Journal of Econometrics* 39: 347-366.

Singh, I., L. Squire, and J. Strauss. 1986. *Agricultural Household Models*. Baltimore: Johns Hopkins University Press.

Smith, R.J., and R.W. Blundell. 1986. "An Exogeneity Test for a simultaneous Equation Tobit Model with and Application to the Labor Supply." *Econometrica* 50(3):679-685.

Spencer, R.W., and W.P. Yohe. 1970. "The 'Crowding Out' of Private Expenditures by Fiscal Policy Actions." *Federal Reserve Bank of St. Louis Review,* 10: 12-24.

Tobin, J. 1958. "Estimation of Relationships for Limited Dependent Variables." *Econometrica* 26: 24-36.

Vella, F. 1993. "A Simple Estimator for Simultaneous Models with Censored Endogenous Regressors." *International Economic Review* 34(2): 441-457.

Wooldridge, J.M. 2002. *Econometric Analysis of Cross Section and Panel Data*. London: MIT Press.

Wooldridge. J.M. 2009. "Sample Selection and Missing Data" Unpublished Lecture Notes EC 822B, Michigan State University.

Xu, Z., W.J. Burke, T.S. Jayne., and J. Govereh. 2009. "Do Input Subsidy Programs "Crowd In" or "Crowd Out" Commercial Market Development? Modeling Fertilizer Use Decisions in a Two-Channel Marketing System." *Agricultural Economics* 40(1): 79-94.

CHAPTER 2
MEASURING THE SPILL-OVER EFFECTS FROM SUBSIDIZING FERTILIZER: THE IMPACT ON THE AGRICULTURAL LABOR MARKET IN MALAWI

Due to a renewed emphasis on raising smallholder agricultural productivity, fertilizer subsidies are currently receiving a great deal of attention and funding from policy-makers and donors in Sub-Saharan Africa (SSA). Over the past several years numerous countries including Senegal, Mali, Nigeria, Kenya, Tanzania, Zambia, and Malawi have re-introduced programs that provide inorganic fertilizer and often hybrid maize seeds to farmers below commercial market prices. In an effort to overcome inefficiencies created by universal fertilizer subsidies in the past, several of these countries have implemented programs that distribute fertilizer to farmers via targeted input vouchers. Under such programs government distributes vouchers to farmers who meet certain criteria, and these “targeted” farmers can then redeem the vouchers in exchange for the right to buy inorganic fertilizer at a reduced price.

The ultimate goal of subsidizing fertilizer is to improve the well-being and food security of rural households through boosting production of staple crops such as maize. However the costs of financing large scale fertilizer subsidy programs are high. For example, in 2008 Malawi spent roughly 70% of the ministry of agriculture’s budget or almost 16% of the government’s total budget subsidizing fertilizer and seed (Dorward and Chirwa 2011). In Zambia, 57% of total government spending on agriculture was devoted to fertilizer and maize subsidies in 2010, equivalent to 2% of the nation’s gross domestic product (Nkonde et al. 2011, IMF 2010). Despite their relatively high costs, to date little empirical research has been conducted to weigh the benefits of fertilizer subsidies against their costs.

The objective of this study is to determine how the presence of a fertilizer subsidy program affects the agricultural labor market in Malawi. Off-farm agricultural labor in Malawi is known as *ganyu*. In this study we first estimate a community-level agricultural wage equation. Second we estimate a household-level labor supply function for *ganyu* labor. Third, demand for *ganyu* labor is estimated in order to obtain a complete picture of the impact of fertilizer subsidies on the agricultural labor market.

Understanding how a large scale fertilizer subsidy program impacts the agricultural labor market is a critical question because substantial evidence from Malawi and SSA demonstrates that the majority of small farmers are net consumers of staple crops (Alwang and Siegel 1999; Levy et al 2004; Harrigan 2008; Jayne et. al 2010). Many of these households supplement their own-farm food production deficit by engaging in off-farm labor activities in order to earn cash to buy inputs, and purchase staple food to feed themselves (Whiteside 2000; Bryceson 2006). Some have argued that the general equilibrium effects of fertilizer subsidy programs and their ability to lower maize prices and increase *ganyu* wage rates could have a more pronounced effect on the welfare of the poor than the effect of receiving the subsidy directly (Dorward et al., 2010). Therefore the effect of fertilizer subsidies on the agricultural labor market could potentially have a major impact on the well-being of millions of rural households in SSA.

It seems *ex ante* that the supply-side impacts of fertilizer subsidies could help smallholders who supply *ganyu*. If farmers who would otherwise have been forced to work *ganyu* in order to earn cash to buy fertilizer or earn maize to feed their families, receive subsidized fertilizer and apply it on their own farm, then those farmers may spend more time working on their own farm, rather than working off-farm as a *ganyu* laborer. This contraction of labor supply could provide more ganyu labor opportunities for non-recipients of subsidized fertilizer and wage rates could also increase due to the contracting of labor supply.

Fertilizer subsidies could possibly have off-setting positive and negative effects on demand for hired labor. On the positive side, if area planted and staple crop production increases for less poor farmers who receive subsidized fertilizer, then the subsidy may cause an increase in demand for *ganyu* labor, as households who receive the subsidy may hire-in labor to work on their farms. Conversely it could be that by lowering fertilizer price relative to labor price, the subsidy may cause *ganyu* demanding farmers to apply more fertilizer and be less interested in hiring *ganyu* to engage in composting or other labor intensive activities. Based on these offsetting conjectures the impact of fertilizer subsidies on the agricultural labor market is an empirical question.

Effects on supply and demand for *ganyu* labor from the subsidy should be reflected in agricultural wage rates. Should the subsidy program boost the *ganyu* wage rate, it would provide some evidence that the program is generating positive spill-over benefits that affect poorer non-recipient households who supply *ganyu* labor. It is also important to recognize that higher wage rates could reduce the welfare of less poor households who hire in *ganyu* labor. To our knowledge this is the first study to use household-level data to measure the impact of a fertilizer subsidy program on the agricultural labor market. We use a panel consisting of three waves of household-level survey data in Malawi. Malawi makes for an interesting case study because since 2005/06 the country has implemented an innovative targeted input voucher program. The program received popular acclaim in a front-page New York Times article (Dugger 2007) and is widely being perceived as a test case for possible broader implementation elsewhere in Africa. However, more evaluation needs to be conducted in order to help policy makers understand the overall impacts of the subsidy.

By providing insight on how fertilizer subsidies affect agricultural labor markets this study adds an important dimension to the literature that evaluates fertilizer subsidy programs. Two recent studies look at how much commercial fertilizer is crowded-out in the presence of a fertilizer subsidy program. In Malawi, Ricker-Gilbert, Jayne and Chirwa (2011) estimate that after controlling for other factors, one kilogram of subsidized fertilizer crowds out 0.22 kilograms of commercial fertilizer on average. The authors find that wealthier farmers who receive subsidized fertilizer displace a greater proportion of their commercial purchases with the subsidy than do poorer farmers. Another study based in Zambia by Xu et. al (2009) finds that subsidized fertilizer crowds out commercial fertilizer in areas where the private fertilizer sector is relatively established but crowds in commercial fertilizer in areas where the private sector is weak.

Several studies have looked at how recipients of fertilizer subsidies are targeted. These studies generally find that subsidy programs have difficulty targeting resource poor beneficiaries who would otherwise be unable to purchase fertilizer at commercial market prices. Evidence suggests that in Malawi subsidized fertilizer often goes to wealthier households with better community and political connections (Holden and Lunduka 2010a, Chibwana et. al 2010, Ricker-Gilbert, Jayne and Chirwa 2011). A recent study in Ghana finds that greater quantities of subsidized fertilizer are distributed in districts where the ruling party has lost the previous presidential election (Banful 2010). Poorly implemented targeting reduces the efficiency of fertilizer subsidies at increasing total fertilizer use and thereby the program's ability to boost agricultural productivity.

In addition to targeting and displacement issues, several recent studies address the farm level impacts of fertilizer subsidies. Holden and Lunduka (2010b) use plot-level data from households in central and southern Malawi to look at the impact of fertilizer subsidies on cropping decisions and fertilizer use efficiency. The authors find that maize area has decreased during the years of the subsidy while maize yield has increased over the same period. Chibwana, Fisher and Shively (2010) use plot-level data from two districts in the central region of Malawi and find that the share of total area planted to maize and tobacco has gone up, while the share of area planted to other crops has gone down. Another study using experimental evidence from Kenya finds that offering small, time-limited fertilizer subsidies during harvest (while farmers have cash) can substantially increase fertilizer use the next season (Duflo, Kremer and Robinson 2009). The authors argue that small, timely discounts increase welfare more than large-scale fertilizer subsidies or *laissez-faire*.

Two other papers (Dorward 2007, Dorward et al. 2008) use a set of household programming models to estimate the impacts of fertilizer subsidies on the rural economy, and household labor allocation decisions in Malawi. Through simulation, these studies find that fertilizer subsidies increase smallholder production and thus cause maize prices to decrease. The subsidy is also found to decrease labor supply and increase demand for *ganyu* labor, thus raising *ganyu* wage rates. These studies provide useful information on the subsidy's impact however results depend on assumptions about elasticities of supply and demand for labor and fertilizer.   A recent study using a field experiment estimates that the elasticity of labor supply in Malawi during the dry season is very inelastic at 0.15 (Goldberg 2010). Results from Goldberg's study would indicate that if the subsidy increases agricultural wages, households are not likely to change their allocation of time supplied to off-farm labor. Our analysis, which is based on household-level panel data can compliment previous modeling work and provide new insights on how fertilizer subsidies affect the agricultural labor market.

The contribution of this paper is mainly empirical as we determine how fertilizer subsidies impact the agricultural labor market in Malawi. We use a basic Singh, Squire, Strauss (1986) agricultural household model to understand smallholder labor and fertilizer allocation decisions. This study controls for other factors that may affect labor market decisions, such as other input and output prices, and rainfall.

We also recognize that targeted fertilizer subsidies are not distributed randomly, so dealing with this issue is a major part of the article's modeling effort. It is likely that the amount of subsidized fertilizer that a household receives is endogenous in a model of household level labor supply or demand because it is likely correlated with factors in the error term of that model. Another issue is that in this study, both the dependent variable of interest, quantity of *ganyu* labor supplied by the household and the key right-hand side variable of interest, quantity of subsidized fertilizer received take on the properties of a corner solution variable.[1]

Wage rates suffer from incidental truncation in this application because they are only observed for those households who participate in the labor market. We control for this issue by estimating the median community-level predicted wage and including the predicted community wage rate in the labor supply and demand models. In appendix 1 we compare the results of the labor supply model using predicted community-level wage with results obtained using the *heckit* procedure following Heckman (1980) that uses a predicted household-level wage. Results for the effect of subsidized fertilizer on agricultural labor supply are similar regardless of whether household-level predicted wage or community-level predicted wage is used. By making a serious attempt to address endogeneity, corner solution variables and truncation issues, this paper should be a useful application for researchers dealing with non-random program selection where the potentially endogenous variable of interest is non-linear. This study will be useful to policy makers in SSA by providing an accurate estimate of the effect of fertilizer subsidies on the agricultural labor market in Malawi.

Results from this study indicate that each additional kilogram of subsidized fertilizer acquired by a household causes the average household to supply 9.6% fewer days in the off-farm agricultural labor market. This finding indicates that subsidy recipients may move back towards own farm production. The supply-side effect of the subsidy program is small however, as the average household that acquires subsidized fertilizer only reduces *ganyu* supply by 2.5 days on average. Therefore, the reduction in labor supply from the subsidy likely has a limited effect on household income. Results also indicate that fertilizer subsidies do not have a significant effect on demand for hired-in *ganyu* labor. This result provides some evidence that the subsidy program could have off-setting effects on the demand side, as increased demand for hired-in labor caused by boosts in production could be offset by a decrease in demand for labor as the subsidy decreases fertilizer price relative to labor price. Finally, a one kilogram increase in the amount of subsidized fertilizer received on average by households in a community boosts median off-farm wage by 0.2%.

The rest of the paper is organized as follows. The next section gives a brief background on the recent fertilizer subsidy program in Malawi then a short discussion about the place of *ganyu* labor in the

Malawian economy. Next is the conceptual framework, followed by methodology and identification strategy. Subsequent sections present data, results and conclusions.

Fertilizer Distribution and Subsidies in Malawi

Small-scale fertilizer subsidy programs have existed for decades in Malawi. However, after experiencing a drought-affected poor harvest in 2004/05, the Government of Malawi decided to embark on a large-scale fertilizer subsidy program to promote maize and tobacco production. During the 2005/06 season coupons for around 131,000 metric tons of fertilizer (2.63 million 50kg bags) were distributed to farmers. The subsidy program cost US $48 million during the 2005/06 growing season (Dorward and Chirwa 2011).

The rains were good in 2005/06 and yields were high, making the subsidy program very popular. Consequently it was extended and scaled up for the 2006/07 growing season. During that year the government procured and distributed 175,000 metric tons of fertilizer to farmers for maize and tobacco production. Coupons for subsidized maize seed were available as well. Coupon recipients paid the rough equivalent of US $6.75 for a 50 kg bag of fertilizer. The same 50 kg bag of fertilizer cost the government US $24.50 delivered at market, for a subsidy rate of about 72% (Dorward and Chirwa 2011). Officially each household was eligible to receive two coupons good for two 50 kilogram bags of fertilizer at a discounted price. In reality, the actual amount of subsidized fertilizer that households acquired varied greatly. The program cost nearly US $85 million (Dorward and Chirwa 2011) with most of the bill being paid by the Malawian government and a minority by the UK's Department for International Development (DFID).

Fertilizer was also available for purchase from private suppliers at commercial prices during both the 2005/06 and 2006/07 growing season. Six private firms won the right to procure and distribute subsidized fertilizer through their retail networks. Farmers who received coupons could redeem them at participating retail stores along with US $6.75 to obtain their fertilizer. Retailers would then submit the coupon and receipt to the government for payment.

The subsidy program was scaled up even further in 2007/08 when 216,500 metric tons of fertilizer was procured by the Malawian government at an estimated cost of nearly US $117 million. The government made 202,000 metric tons of subsidized fertilizer available in the 2008/09 season and spent an estimated US $265 million on the program. The higher cost was due to an increase in fertilizer prices and an expansion of the subsidy to small holder tea and coffee crops (Dorward, Chirwa and Slater 2010; Dorward and Chirwa 2011). The private sector was excluded from distributing subsidized fertilizer in 2008/09, however a seed subsidy was scaled up in that year which involved private retailers. The proportion of the fertilizer cost that was paid by the government increased to greater than 90% in 2008/09. Farmers were officially required to pay the equivalent of US $5.33 for a 50 kg bag of fertilizer that cost between US $40 to $70 at commercial prices.

Throughout the years of the subsidy's implementation, the process of determining who received coupons for fertilizer subsidies was subject to a great deal of local idiosyncrasies. At the regional level, coupons were supposed to have been allocated based on the number of hectares under cultivation. At the village level, subsidy program committees and the village heads were supposed to determine who was eligible for the program. The general program eligibility criteria was that beneficiaries should be "full time smallholder farmers who cannot afford to purchase one or two bags of fertilizer at prevailing commercial prices as determined by local leaders in their areas" (Dorward et al. 2008). However, numerous unofficial criteria may have been used in voucher allocation, such as households' relationship to village leaders, length of residence and social and/or financial standing of the household in the village. Along the same lines it is also possible that factors which are unobservable to us as researchers and affect household production and income such as health shocks could also influence how much subsidized fertilizer a household receives. Therefore, we consider the fact that subsidized fertilizer could potentially be endogenous in our model of household agricultural labor supply and labor demand.

Ganyu Labor in Malawi

Malawi is one of the most densely populated countries in Africa with approximately 129 people per square kilometer. Population density is extremely high in southern Malawi where the mean farm size is around 0.88 hectares, compared to a mean farm size of 1.32 hectares in less-densely populated north. The agricultural sector in Malawi is made up of a commercialized estate sector and millions of smallholder households, many of whom are net consumers of staple crops. Many of these net maize consuming smallholders are forced to work *ganyu* on estate farms or on the farms of less-poor small holders in order to make up for their own production short fall. According to Whiteside (2000) *ganyu* labor in Malawi is mainly done out of necessity. Once enough income is generated to meet consumption needs, *ganyu* usually stops.

Various studies have looked at the relative importance of *ganyu* in Malawian smallholder livelihoods. These studies find that the importance of *ganyu* work varies from region to region in Malawi. In some areas, particularly the densely populated south, *ganyu* work may contribute up to as much as 50% of total rural household livelihoods in some villages (Whiteside 1998; Peters 1998). Data from 2007 in Malawi show that nationwide, *ganyu* makes up roughly 13% of rural household income (Jayne et. al 2010a, p.34). In this study we refer to *ganyu* as agricultural employment where poor smallholders work as unskilled laborers on less poor smallholder farms or on large estate farms for payment in cash or in kind.

Evidence suggests that many of the less poor households who hire in *ganyu* do not necessarily have significantly larger landholdings than households who supply *ganyu*. Table 2.1 indicates that in 2008/09, the median landholding for ganyu supplying households is 0.81 hectares, and 1.01 hectare for *ganyu* demanding households. However, during the 2008/09 season in Malawi, 2% of smallholders provide 50% of total maize sales. The households that sell 50% of all maize have an average landholding of 1.94 hectares compared to an average landholding of 1.19 hectares for the 80% of smallholders who do not sell maize (Jayne et al. 2010b, pg.11). Furthermore, table 2.1 from our study indicates that households who hire in *ganyu* labor have much higher livestock and durable assets on average than do households who supply *ganyu*. *Ganyu* demanding households also have a much higher level of non-farm income than do households who supply *ganyu*. This indicates that even though their farms may not be extremely large, *ganyu* demanding households may have a higher opportunity cost of on-farm work, as they can engage in more productive activities outside of agriculture. These ganyu demanding households then hire in poorer households to work on their farm, mainly during important times of the year, which include planting from October to December, and harvest from April to June.

One of the major concerns about households going out for *ganyu* is that the main times when ganyu opportunities are available are also the main times of year when labor is needed on their own plots. Therefore *ganyu* supplying households may be forced to neglect their own plots at crucial times during the season in order to earn cash or in kind payments working on other peoples' farms (Mkandawire and Ferguson, 1990). Maize prices are generally higher at planting time than they are in the months immediately following the previous harvest, and prices usually continue to rise after the planting season while the current year's crop is being cultivated. Households that run out of their own maize before the next harvest are forced to work ganyu during times when prices are high, in order to earn cash or receive in kind payment to meet their consumption needs. Alwang and Siegel (1999) find that many poor in Malawi lack credit and face food security constraints due to their small plot size. Therefore many smallholders are locked into a cycle where year after year they are forced to neglect their own plot and engage in low paying *ganyu* labor on other farms.

Conceptual Framework

In order to conceptualize the impact of a large-scale fertilizer subsidy program on the agricultural labor market, we start with the basic Singh, Squire, Strauss (1986) household model where the household maximizes utility as a function of leisure (l) and good (X); U(l, X; **B**) where B is a vector of household taste shifters. The household chooses to either produce some quantity of X on farm (X_H) and/or purchase some quantity of X at market (X_m) for per unit price P_x; $X = X_H + X_m$. The household must choose to allocate its time between own-farm production of X, off-farm wage labor activities, and leisure. When a household works off farm it earns a wage ω_m. Income earned from off-farm labor may be used to purchase X directly from the market or to purchase fertilizer F at price P_f that can be used in the production of X on farm. The production function for X is:

1) $X_H = f(F, L, A, \varepsilon)$

Where *F* represents the quantity of fertilizer applied to the production of *X*, and *L* represents the quantity of labor applied to its production. Land is represented by *A*, and *ε* represents the stochastic nature of production. Labor can be hired in L_m at wage rate $\omega_m$or supplied by the farm household L_H at shadow wage rate ω_H; $L = L_H + L_m$.

In a situation where household production decisions can be separated from consumption decisions, $\omega_H = \omega_m$ and on-farm work is a perfect substitute for off-farm work. Therefore the household is indifferent between off-farm and own-farm labor. Under the assumption of separability, the household first decides how much labor to use on farm to maximize profits. Second, the household decides how much *X* and *l* to consume and how much labor to supply off-farm.

Separability is unlikely to hold in a country like Malawi, with its imperfect credit, fertilizer, and land markets. When separability fails, labor supply decisions and labor needs of the household are dependent on one another. In the non-separable context, shadow wages determine the household's labor supply decision (Jacoby 1993, Skoufias 1994). Shadow wages are determined by the marginal product of a household's own labor in the farm production function.

With the existence of a fertilizer subsidy program, the non-separable household's off-farm labor supply (L_S) decision can be modeled as a function of the following factors:

2) $L_S = f(S, T, C, Z, P_X, P_f, \omega_H, A)$

Here S represents the quantity of subsidized fertilizer the household receives. Subsidized fertilizer can be thought of as a quasi-fixed input as the amount that households can receive is officially limited and not every household is eligible to receive the subsidy. Transfer costs of using fertilizer, such as distance to a paved road are represented by *T*. Credit availability is denoted by *C*. Household socio-demographic characteristics which are known to affect household's labor supply decisions such as non-farm income, are represented by *Z* (de Janvry and Sadoulet 2006). Price of staple good X (P_X) also affects the household labor supply decision. Price of fertilizer (P_f), wage rate ω_H, and land (A) also affect household off-farm labor supply.

The key relationship of interest in equation 2) is how does the presence of a fertilizer subsidy program affect the household's decision to supply labor off-farm? In a non-separable household context any change in input price that affects production will influence a household's labor supply decision (Skoufias). Therefore if the subsidy program decreases the price that households pay for fertilizer, then the following relationship may occur:

3) $\frac{\partial LS}{\partial S} < 0$

and the subsidy program may in fact help relieve the credit constraint, permitting households to decrease the quantity of ganyu-labor supplied off-farm, allowing the household to allocate more time towards own-farm production.

The relationship between L_S and ω_H seems theoretically ambiguous. Some have hypothesized that that higher wages for *ganyu* may cause households to work less, implying a backwards bending supply curve (Dorward 2006). This assumption would fit with the characterization that ganyu work is done out of necessity to earn cash. When the need for cash is fulfilled, *ganyu* work generally stops (Whiteside 2000). Empirical studies from developing countries that estimate elasticity of off-farm labor supply have obtained varying results in different contexts. Goldberg finds a positive and very inelastic elasticity of labor supply for *ganyu* labor in Malawi. Bardhan (1979) finds a positive elasticity of supply in India, while Rosenzweig (1978) estimates a positive elasticity of supply for women but a negative elasticity of supply for men in India. Abdouli and Delgado (1999) also estimate a positive elasticity of supply for men and women in Ghana.

The effect of a fertilizer subsidy program on demand for *ganyu* labor (L_d) is illustrated as follows

4) $L_d = f(S, T, C, Z, P_x, P_f, \omega_m, A)$

Should the fertilizer subsidy program lead to an increase in production and area planted for those hiring in *ganyu* labor we may expect to see the following relationship:

5) $\frac{\partial Ld}{\partial S} > 0$

where additional kilograms of subsidized fertilizer received by a household increases its demand for hired-in *ganyu* labor. Conversely if, the subsidy program decreases the effective price of fertilizer relative to the price of labor than we may see the following relationship:

6) $\frac{\partial Ld}{\partial S} < 0$

where the decrease in price of fertilizer causes a decrease in demand for hired-in *ganyu* labor. The relationship may occur because fertilizer could be a partial substitute for land and labor, so the household may find it optimal to apply more fertilizer and hire in less labor to engage in labor intensive activities such as compositing .

The aggregate effects of the subsidy program on supply and demand for agricultural labor can be captured by examining the subsidy program's impact on community-level wages. It seems possible that an increase in the average amount of subsidized fertilizer acquired in a community could boost agricultural wage rates through contracting labor supply, as a greater number of households receive subsidized fertilizer, and those households move back towards own-farm production. Wage rates could also be affected by how evenly or unevenly subsidized fertilizer is distributed to households in a community. If nearly everyone in a community receives similar quantities of subsidized fertilizer then a larger labor supply contraction and upward boost in wage rates may occur, relative to what might happen if most of the subsidized fertilizer went to just a few people in the community. Under a scenario where fewer people receive subsidized fertilizer, a large part of the population would still be left to engage in the *ganyu* labor market, putting downward pressure on wages.

Consider the reduced from model for median ganyu wage rate in a community ω_C as a function of the following factors:

7) $\omega_C = f(S_A, \sigma_C, Z, P_X, P_f)$

where S_A represents the average amount of subsidized fertilizer acquired by households in the community. The standard deviation of the average amount of subsidized fertilizer received by households in a community is represented by $\sigma_{C.}$ The standard deviation of the average amount of subsidized fertilizer acquired in a community serves as a proxy for how evenly the subsidy is distributed to individuals in that area. We would hypothesize that a higher standard deviation in the distribution of subsidized fertilizer may have a negative effect on ganyu wage rates, because it indicates that the distribution of the fertilizer is more uneven in that community. Household characteristics that affect *ganyu* wage rates are denoted by Z, while the price of fertilizer (P_f) and price of agricultural good (P_X) also affect *ganyu* wage rates in the community.

Empirical Model

To estimate the degree to which subsidized fertilizer affects the number of days of *ganyu* labor supplied and demanded by household (i) at time (t), the conceptual labor supply and labor demand models are estimated as follows:

(8) $L_{it} = \alpha S_{it} + \beta \omega_{it} + \mathbf{X_{it}\delta} + \varepsilon_{it}$

(9) $\varepsilon_{it} = c_i + \mu_{it}$

The coefficient estimates and standard errors from α provide the estimate of how the subsidy affects *ganyu* labor supply, and labor demand at the household level. Another key variable to consider is $\omega_{\mathbf{it}}$ the wage rate per day of *ganyu* labor and the corresponding parameter β. In the empirical specification of this model we explicitly estimate the marketed wage rate ω_m using observed data from households who supply and demand *ganyu* labor. This is the incidental truncation (data censoring) issue, and in the following section we discuss how we deal with this issue in order to proxy for the household's own farm wage rate ω_H.

The vector of other explanatory variables which affect labor supply, and demand are represented by $\boldsymbol{X_{it}}$, while $\boldsymbol{\delta}$ represents the vector of corresponding parameters. These factors include household financial and demographic characteristics, such as area cultivated, livestock and durable assets, credit access, and age structure in the household. Non-farm income is also included in $\boldsymbol{X_{it}}$ as a way to consider the amount of cash that the household must have, in order to purchase inputs at planting. Other factors in $\boldsymbol{X_{it}}$ include maize and tobacco prices, fertilizer prices, and rainfall, which may affect supply and demand for *gany*u labor.

The error term ε_{it} in equation (9) is a function of two components. The first component is unobserved time-constant factors, also called unobserved heterogeneity c_i, which affect household *i*'s labor supply, and labor demand decision. These factors might include a household's farming ability and/or degree of risk aversion. The second component of the error term is unobserved time-varying shocks affecting labor supply and labor demand. These factors might include political turmoil and health shocks, as represented by μ_{it}.

The median community wage, ω_c, is estimated for community j at time t as a function of the following factors,

10) $\omega_{cjt} = \alpha S_{Ait} + \rho\sigma_{Ait} + \beta Z_{it} + v_{it}$

where S_A represents the average quantity of subsidized fertilizer that households in a community receive in a given year. The "community" in this study is defined as a group of villages, called a traditional authority in Malawi. The standard deviation for the amount of subsidized fertilizer acquired by households in the community is represented by σ. Other household-level factors that affect median wage such as landholding, value of livestock and durable assets, fertilizer prices, maize and tobacco prices, along with maize production, tobacco production, and rainfall are denoted by Z in equation 10.

The composite error term that includes time constant and time varying error terms like the one presented in equation 9) is represented by v.

The community wage equation presented in 10) and the labor supply and demand equations presented in 8) are estimated individually rather than in a system. The equations are estimated individually because the wage model is a community-level equation, while the labor supply and demand models are household level equations.

Identification Strategy

The objective of this paper is to determine how an additional kilogram of subsidized fertilizer affects the amount of *ganyu* labor that households in Malawi supply, and demand while controlling for other factors. We also estimate a wage equation to determine how increasing the distribution of subsidized fertilizer acquired by households in a community affects the median wage. In order to estimate a causal effect of subsidized fertilizer on labor allocation decisions, there are several modeling challenges that we must address. First, subsidized fertilizer S_{it} and is potentially endogenous in the labor supply and demand equations as unobservable factors affecting labor allocation decisions, such as ability may also affect how much subsidized fertilizer a household receives. Second, wage rates ω_{it} are truncated in the labor supply equation, because they are only observed for those households who supply and demand *ganyu* labor. The following sub-sections discuss how we deal with these modeling issues, in order to generate consistent estimates of the subsidy program's impact on household labor allocation decisions.

Controlling for Endogeneity of Subsidized Fertilizer

The first challenge to obtaining consistent parameter estimates is that the observed covariates such as S_{it} may be correlated with the unobserved heterogeneity c_i in the labor supply model. Quantity of labor supplied and demanded is non-linear, so in order to obtain consistent estimates in non-linear panel models, the covariates must be independent of unobserved heterogeneity c_i. This is often a strong assumption, but it can be relaxed by modeling c_i using a framework known as either correlated random effects (CRE) or the Mundlak–Chamberlain device, following the works of Mundlak (1978) and Chamberlain (1984). To implement the CRE framework in equation (8), we include a vector of variables containing the means for household *i* of all time-varying covariates. These variables have the same value for each household in every year but vary across households (for more on the CRE framework, see Wooldridge 2011).

Controlling for Unobserved Shocks, μ_{it}

We also need to consider the fact that estimates of subsidized fertilizer's impact on labor supply and labor demand will still be inconsistent if S_{it} is correlated with unobservable time-varying shocks μ_{it} in equation (8). Many panel studies simply assume zero correlation between covariates and the time varying error, a potentially unrealistic assumption that can lead to biased coefficient estimates, particularly when the covariate of interest is not determined randomly. In this study, the amount of subsidized fertilizer acquired is likely to be correlated with unobserved time-varying factors affecting labor supply and demand due to its non-random distribution process.

Subsidized fertilizer, the potentially endogenous explanatory variable of interest in this study is a non-linear corner solution variable, because many households do not receive subsidized fertilizer, but beyond that the quantity households receive is relatively continuous. Therefore, we use the control function (CF) method to deal with correlation between S_{it} and μ_{it}. The CF method entails taking the residuals from a reduced form model where kilograms of subsidized fertilizer acquired by the household is the dependent variable, and then including the residuals from that model as a covariate in the structural models of labor supply and demand in equation (8). The significance of the coefficient on the residual both tests and controls for correlation between S_{it} and μ_{it}. Should the reduced form residual be found to be statistically significant when using the CF approach, bootstrapping should be used to obtain accurate standard errors that take estimation of the reduced form model into account (for more information on the CF approach see Rivers and Vuong 1988, Smith and Blundel 1986, Papke and Wooldridge 2008).

In order to implement the CF approach one needs an instrumental variable (IV) that is correlated with the potentially endogenous variable S_{ijt} but not correlated with the error term in the structural model of labor supply and demand. A good IV for our study is a variable for whether or not a member of parliament (MP) resides in the community. This seems like a strong instrument *ex ante* because it is a measure of socio-political capital that could influence the quantity of subsidized fertilizer available in a community. Also, there is little reason to believe that this IV is endogenous at the household-level for the following reasons; 1) the IV is a community level variable that does not affect the household directly; 2) we condition on other covariates $\mathbf{X}_{it}$, which control for village-level factors such as distance to the main district town and road access that may affect where a member of parliament lives and also household labor supply, and labor demand decisions; 3) we use a CRE framework that controls for time constant unobservable factors at the village and household level in the labor supply and demand models, which could be correlated with our instrument. Therefore the IV, having a member of parliament in the village need only be uncorrelated with the time-varying factors in the error term of the structural models; 5) in order to make a stronger case that our IV is exogenous we use an indirect test, where we regress a variable as to whether or not a household head attended school on the IV and other variables in our structural model. The idea is that perhaps members of parliament live in villages where the population is more educated and likely to vote. Since attending school is a predetermined factor, if the IV shows up as not having a statistically significant affect on education, then it strengthens our argument that it is exogenous. Results from this model indicate that the p-value for the MP variable is 0.27 when estimated as a linear probability model, so having an MP in the village does not affect whether or not household heads attend school. Ultimately the exogeneity of our instrument, whether or not a member of parliament lives in the village, is a maintained hypothesis, but for the reasons state above we feel confident that the assumption is reasonable.

Incidental truncation of wages

Wage rate $\omega_{it,}$ is only observed when L_{it}> 0 for the households that supply ganyu labor. When L_{it}=0, ω_{it} is unobserved, because for those households their individual wage offer ω_{oit} is below their reservation wage ω_{rit}. This is the common incidental truncation or data censoring problem, and we solve it by including the predicted median community wage rate, estimated in equation 10), in the structural labor supply and demand models estimated in equation 8). Bootstrapping is used to compute standard errors, in order to account for first stage estimation of the median community-level *ganyu* wage rate equation.

On the supply side, wage rates are an average calculated by dividing the total income from *ganyu* earned by the household by total days of *ganyu* labor supplied by the household. On the demand side, wage rates are calculated as total expenditure on hired labor divided by number of days of hired labor on the farm. The benefit of using predicted median wages is that by aggregating to a community-level we may obtain a more accurate indication of wage rates than we would trying to estimate a household-level wage rate. In appendix A, labor supply is estimated using the predicted household wage obtained via the *heckit* method following Heckman (1980). Comparing results using the household-level predicted wage and community-level predicted wage increases the robustness of our estimates on the impact of subsidized fertilizer on off-farm agricultural labor supply and labor demand in Malawi.

Data

Data used in this study come from three waves of farm household surveys conducted by the Government of Malawi's National Statistical Office. The first wave of data comes from the Second Integrated Household Survey (IHHS2) in Malawi collected during the 2002/03 and 2003/04 growing seasons. The IHHS2 surveyed households in 26 districts in Malawi and in total 11,280 households were interviewed. The second wave of data comes from the 2007 Agricultural Inputs Support Survey (AISS1) conducted after the 2006/07 growing season. The budget for AISS1 was much smaller than the budget for IHHS2, and of the 11,280 households interviewed in IHHS2 only 3,485 of them lived in enumeration areas that were re-sampled in 2007. Of these 3,485 households 2,968 were re-interviewed in 2007, which gives us an attrition rate of 14.8%.

The third wave of data comes from the 2009 Agricultural Inputs Support Survey II (AISS2) conducted after the 2008/09 growing season. The AISS2 survey had a subsequently smaller budget than the AISS1 survey in 2007, so of the 2,968 households first sampled in 2003 and again in 2007, 1,642 of them lived in enumeration areas that were revisited in 2009. Of the 1,642 households in revisited areas, 1,375 were found for re-interview in 2009, which gives us an attrition rate of 16.3% between 2007 and 2009.

Note that the first year of the panel, while drawn from the same survey IHHS2, covers two different years. Since we know in which of the two years each household was surveyed, we address this issue by including a year dummy for each of the two years in the first survey and using the second survey as the control year. Furthermore since the time difference is just a single year one would not expect there to be many unobservable changes that vary over that time.

Attrition Bias

Potential attrition bias caused by households leaving the panel in different waves for systematic reasons is a major issue that must be addressed. We recognize that the attrition rate is fairly high in this data set at nearly 16% between each survey. To ensure that the results using our balanced panel are robust to attrition bias, we compare our base results with those using inverse probability weights (IPW). The IPW technique involves three steps: (i) use probit to measure whether observable factors in one wave affect whether a household is re-interviewed in the next wave; (ii) obtain the predicted probabilities (Pr_{it}) of being re-interviewed in the following wave; (iii) compute the IPW = ($1/Pr_{it}$) and apply it to all models estimated. For households originally sampled in 2004, the IPW for household i in 2007=$1/Pr_{i2007}$ and the IPW in 2009= $1/(Pr_{i2007}*Pr_{i2009})$. (For more information on IPW see Wooldridge 2011). We multiply the IPW by the survey sampling weights in the first wave to control for the probability of the household being selected for interview from the population. Using the IPW's do not significantly change the estimation results, so they are not included in the final estimation because we use the CRE procedure. We include the survey weights in the final analysis however. In addition, because we use the CRE procedure, we do not include households who were only interviewed in the first wave. Therefore, we end up using the 1,593 households who were surveyed in wave 1 and wave 2 along with the 1,375 households who were surveyed in all three waves. Ultimately we end up with 7,311 household observations for the analysis of this unbalanced panel.

Wage rate calculations

On the supply side wage rates are calculated as the average of total income from *ganyu* earned by the household divided by total days of *ganyu* labor supplied by the household. On the demand side wage rates are calculated as total expenditure on hired labor divided by number of days of hired labor on the farm. Households are also asked in the survey to monetize the value of any in kind payment.

We recognize that wage rates vary across the growing season, but due to how and when respondents were interviewed we are only able to calculate one average wage for the households over the entire year. The majority of households in the survey state that they do most of their ganyu work at planting and at harvest, with relatively little work done during the dry season. Households were surveyed at different points during the year depending on when the enumerators reached their village. Variation in month surveyed is controlled by including dummy variables for month of interview in the model.

Ganyu labor questions are asked at the household-level rather than at the individual level in our survey, so the labor supply decisions and wage rates cannot be separated within a household. Using our data, the best way that we can proxy for individual labor supply and labor demand decisions within a household is to include covariates for the demographic composition of the household in the model. These variables include the number of children under six years old in the household, who would be considered too young to work as agricultural laborers, but need to be supported by other family members. A variable for number of children between 6 and 14 years old, who could be child laborers, is also included. Variables for number of males between 15 and 65, and number of females between 15 and 65 are also included to proxy for working age adults. Variables for the number of males over 65 and number of females over 65 years old in the household are also included to represent the number of elderly.

Income variables

Non-farm income is measured by considering income earned from sources such as non-farm enterprises, rental income, remittances, and pensions. Obviously income earned from working as a *ganyu* laborer is not included in the calculation of non-farm income. Non-farm income is an important variable that may affect labor supply as non-farm income could indicate how much cash households have to purchase inputs, which in turn affects their *ganyu* labor decision. Non-farm income also indicates the extent of a household's opportunity cost for working *ganyu* labor.

Fertilizer Prices

Commercial fertilizer prices used in the study are calculated as Malawian Kwacha per kilogram of fertilizer. The price is an aggregation of Urea and Nitrogen/Phosphorus/Potassium (NPK) prices. These prices are based on what respondents in the survey say they pay for commercial fertilizer during the planting season from October to December. For those buying commercially we use the observed price that they pay, while for those who do not buy commercially we use the district median price to proxy for the price that the farmer faces for the input. Fertilizer prices are in Malawian Kwacha per kilogram and are in real 2009 terms, which is calculated by dividing the nominal price of fertilizer by the CPI.

Maize and Tobacco Prices

Maize prices used in this study are calculated as the median district price received by households in the survey. We recognize that maize prices vary throughout the season and the purchase price of maize is important to households who are net consumers of maize. Unfortunately, maize sale prices at harvest are the only prices available from the survey. Using sale price instead of purchase price for maize in our analysis should not be a problem as it will only bias the subsidized fertilizer coefficient if the wedge between sale and purchase prices is systematically related to how much subsidized fertilizer a household acquires. Tobacco prices are calculated as the median regional price received by households in the survey because fewer households sell tobacco than sell maize in Malawi.

Maize and tobacco prices used in this study are the observed prices received by households after harvest, and may not be known to farmers at the time of planting. In order to use these prices in our labor supply and demand models, we make the assumption that farmers know the price they are going to receive at harvest time. Prices for maize and tobacco are in Malawian Kwacha per kilogram and are in real 2009 terms, which is calculated by dividing the nominal price by the CPI.

Rainfall

The rainfall variables come from district-level experiment station records. We include the average cumulative annual rainfall over the previous five growing seasons to model farmer expectation. The coefficient of variation for rainfall over the past five years is also included to give an estimate of rainfall variability. We also include cumulative rainfall over the growing season to account for rainfall's impact on production, which may affect household labor supply and demand decisions throughout the growing season.

All other explanatory variables are constructed from the household surveys.

Results

Table 2.1 presents the characteristics of households who supply *ganyu* and the characteristics of those who demand *ganyu* in each wave of the survey. It is evident and not surprising from table 2.1 that households who supply *ganyu* are much poorer than those who demand *ganyu* in all years of the survey. *Ganyu* supplying households have a much lower value of livestock and durable assets than *ganyu* demanding households. *Ganyu* supplying households also have somewhat lower crop income, and slightly smaller landholdings than do *ganyu* demanding households. *Ganyu* demanding households have much higher non-farm incomes than *ganyu* supplying households, which indicate that *ganyu* demanding households are engaged in other activities outside of agriculture, and may thus hire in labor to work their fields. *Ganyu* supplying households also have a lower ratio of landholding to adult equivalent (AE) than do *ganyu* demanding households. The lower ratio of landholding/AE means that *ganyu* supplying households must support more people on less land.

Table 2.2 presents the number and percentages of households who supply and demand *ganyu* labor across the three survey waves. From table 2.2 it is evident that the percent of households demanding *ganyu* increases from 23% in 2003/04 and 22% in 2006/07 to 30% in the 2008/09 growing season. The mean and median number of days demanded drops from the first wave to the second wave, and then drops again between the second and third wave. This is an interesting pattern that shows that while a higher percentage of households hire in labor in the most recent wave, the amount of hired-in labor per household has decreased in that same time period. On the supply side, the percent of households supplying *ganyu* labor decreases between the first wave and the second wave but increases in the third wave. The mean and median number of days of *ganyu* labor supplied follows the same pattern throughout the survey years.

Table 2.3 indicates that *ganyu* demanding households acquire significantly greater quantities of subsidized fertilizer throughout the three survey waves, than do *ganyu* supplying households. Table 2.1 demonstrates that the *ganyu* demanding population has much higher non-farm incomes on average than *ganyu* supplying households. Therefore targeting *ganyu* demanding households may not be efficient, at least in terms of increasing total fertilizer use, because these people would be more likely to have the cash and resources to purchase fertilizer at commercial prices, than would *ganyu* supplying households. Therefore targeting subsidized fertilizer to *ganyu* demanding households would likely increase crowding-out of commercial fertilizer by the subsidy and a reduction of new fertilizer that enters the system.

Table 2.4 presents the results for factors affecting how much subsidized fertilizer a household acquires. The instrumental variable (IV), if a member of parliament resides in the village, indicates that during the 2002/03 season having a member of parliament (MP) in the community got the average household significantly more subsidized fertilizer than it did in the control year, 2008/09. Having an MP in the community got the households significantly less subsidized fertilizer in 2003/04 than it did in 2008/09. Significance of the interaction effect provides evidence that political connections affect subsidized fertilizer acquisition. Households in villages further from a paved road and households in villages further from the district capital receive significantly more subsidized fertilizer, as an additional kilometer from a paved road or main town gets the household 0.13 kilograms or 0.10 kilograms more subsidized fertilizer on average respectively. There is also evidence that poorer households with fewer assets and less land do not receive significantly more subsidized fertilizer than other households. Households where the head attended school receive significantly more subsidized fertilizer than others. Households with more men over 65 also receive significantly more subsidized fertilizer. These findings indicate that social connections affect how much subsidized fertilizer households acquire.

Table 2.5 presents the factors affecting median community-level *ganyu* wage rates. Column 1 presents results using a pooled OLS (POLS) estimator and column 2 shows results using a fixed-effects (FE) estimator. Results from column 2 indicate that boosting the average amount of subsidized fertilizer in a community raises median ganyu wage by 0.2%. A one standard deviation increase in the distribution of subsidized fertilizer in a village reduces median community wage rates by 0.1%. This finding indicates that while greater average quantities of subsidized fertilizer in a community boost wage rates, the more unevenly that the fertilizer is distributed, the less of a positive impact it has on wage rates. These results provides some evidence that those households who did not receive subsidized fertilizer may have gained some spill-over benefit from the program as additional kilograms of subsidized fertilizer acquired per household in the community pushes up agricultural wages for those who supply *ganyu* labor. It should be noted that less poor households who hire in ganyu may have their welfare reduced by this increase in agricultural wage rates.

Table 2.6 displays the results for factors affecting the number of days households supply *ganyu* labor throughout the year. Columns 1-3 present results for the entire population, while columns 4-6 present results for the ganyu supplying population, defined as those who supplied *ganyu* labor in the first survey, before the subsidy program was scaled up. Columns 1 and 4 from table 2.6 show the results using a pooled tobit estimator, where covariates and the error term are assumed to be uncorrelated. Columns 2 and 5 display results using a correlated random effects (CRE) tobit estimator that controls for correlation between covariates and time-constant unobserved heterogeneity. Columns 3 and column 6 present results using the CRE tobit with the reduced form residual from the model presented in table 2.4 on how much subsidized fertilizer a household receives. By including the reduced form residual we control for potential correlation between the subsidized fertilizer variable and any unobserved time-varying factors that affect labor supply.

Results from column 2 and 3 in table 2.6 indicate that an additional kilogram of subsidized fertilizer acquired by households across the sample reduces the number of days of *ganyu* labor supplied by 0.06 days. The average household acquires 40 kilograms of subsidized fertilizer and supplies 25 days of *ganyu* so the average recipient of subsidized fertilizer reduces the number of *gany*u days supplied by 9.6%. Columns 5 and 6 indicate that the contraction in labor supply from receiving subsidized fertilizer is slightly larger for the population of *ganyu* supplying households, defined by their participation in the initial survey wave. Results indicate that an additional kilogram of subsidized fertilizer reduces *ganyu* days supplied by 0.12 days. As the average household in the *ganyu* supplying population receives 35 kilograms of subsidized fertilizer and works 42 days of *ganyu*, participating in the subsidy program causes the average household in the *ganyu* supplying population to reduce ganyu days worked by 10%. This finding indicates that recipients of the subsidy program reduce participation in the agricultural labor market and may devote significantly more time to own farm production and/or consume significantly more leisure rather than work off-farm as *ganyu* laborers.

The elasticity of the community wage variable is estimated by dividing the coefficient by the mean number of *ganyu* days supplied. The elasticity for wage is slightly larger than -1 for both the whole population and for the *ganyu* supplying population as the mean number of days supplied is 25 days and 42 days for each population respectively. This finding indicates that a 1% increase in the *ganyu* wage rate causes the household to reduce number of days of *ganyu* labor supply by about 1% throughout the year. The results are marginally significant for the whole population in columns 2) and 3). The results are marginally significant in column 5 and insignificant in column 6 for the ganyu supplying households. The finding on wage elasticity indicates a strong preference by households towards not working *ganyu*. This result differs from Goldberg's finding of an inelastic labor supply curve of 0.15 in Malawi, but it fits with Whiteside's characterization of *ganyu* being done out of necessity to earn cash or in kind payment. The elasticity of labor supply undoubtedly varies across the season in Malawi, but findings here indicate that on average the *ganyu* labor supply curve is backwards bending. Results in table 2.6 also indicate that households with older heads are less likely to supply *ganyu*. Households with more assets and households where the head has attended school are also less likely to supply *ganyu*, probably because they have the opportunity to engage in other activities.

Table 2.7 presents the Average Partial Effects (APE) and the average percentage change in *ganyu* labor supplied by households at different quintiles in the asset distribution. From the table it is evident that receiving subsidized fertilizer induces a much smaller response in terms of reduction in *ganyu* labor supply for the average household in the poorest quintile. For the poorest group of people, participating in the subsidy program reduces the average number of *ganyu* days supplied by 5.9%. The negative *ganyu* labor supply response to subsidized fertilizer increases as households get wealthier. Participating in the subsidy program reduces the number of ganyu days supplied by 17.9% for the richest 20% of households on average. The response to receiving subsidized fertilizer is more elastic for relatively wealthy households than it is for poor households, probably because wealthier farmers have more opportunities to find productive uses for subsidized fertilizer on their own farm.

Table 2.8 presents results for the factors affecting demand for hired-in *ganyu* labor. Columns 1-3 present results for the entire population. Columns 4-6 present results for the population of households who hired in *ganyu* labor in the first survey, before the subsidy program was scaled up. The subsidized fertilizer coefficient indicates that acquiring subsidized fertilizer does not produce any statistically significant effect on demand for hired-in ganyu labor, either for the whole population or for the sub-population of households who hired in *ganyu* during the first survey wave. This result provides some evidence that the subsidy program could have off-setting effects on the demand side. Although the subsidy may increase production which could boost demand for hired-in labor, that effect could be offset because as the subsidy lowers the price of fertilizer, there may be a substitution effect by households who demand *ganyu* towards applying more fertilizer and away from hiring labor to engage in labor intensive activities, such as composting . In addition, there is some evidence to suggest that households in villages that have farm credit organization hire in more labor, probably because they are less cash constrained. In addition households where the head has attended school hire in more labor, possibly because these households have more non-farm opportunities, so they hire-in others to tend their plots.

Conclusions

Fertilizer subsidies are regaining support as a popular policy tool to increase fertilizer use and boost agricultural production for small farmers in Africa. To date there has been little empirical evidence to measure the impacts of subsidized fertilizer on recipient households. This study uses three waves of panel data to address how subsidizing fertilizer affects the agricultural labor market in Malawi. In doing so this study takes key steps towards quantifying some of the general equilibrium benefits of the subsidy program, such as how does it affect labor supply, labor demand, and agricultural wages?

The main findings of this study are as follows; first subsidized fertilizer has a significant negative effect on the amount of off-farm agricultural labor, called *ganyu* that households supply. Each additional kilogram of subsidized fertilizer causes the average household to supply 0.06 fewer days in the agricultural labor market across the sample. The average household who participates in the fertilizer subsidy program reduces days supplied in the agricultural labor market by 9.6% across the sample. This result indicates that the labor supply curve contracts as a result of the subsidy because households who receive subsidized fertilizer allocate more of their time to own-farm production and away from supplying *ganyu* labor. The shift in labor supply could be due to the fact that the subsidy decreases household expenditure on fertilizer, which lessens the household's credit constraint, freeing them from working *ganyu* at planting time in order to earn cash to buy fertilizer. In addition if the subsidy increases fertilizer use and boosts own-farm production, the household may spend more time on farm during the growing season and less time working *ganyu* on other farms. It should be noted, that the average household supplies 25 days of ganyu labor so the subsidy program reduces days supplied off-farm by only about 2.5 days on average. This result indicates that reductions in *ganyu* labor supply are small and therefore unlikely to have large effects on household income, either in terms of reduction in off-farm wage income or through increases in own farm agricultural income for households who spend the extra time tending their own plots.

The second major finding is that fertilizer subsidies do not have a significant effect on demand for hired-in *ganyu* labor. This result provides some evidence that the subsidy program could have off-setting effects on the demand side, as increased demand for hired-in labor caused by boosts in production could be offset by a decrease in demand for labor as the subsidy decreases fertilizer price relative to labor price.

The third major finding from the study is that at an increase in average amount of subsidized fertilizer acquired per household in a community causes the median *ganyu* wage rate in the community to increase slightly. A one kilogram increase in the average amount of subsidized fertilizer in a community boosts median *ganyu* wage rate by 0.2%. A one standard deviation increase in the distribution of subsidized fertilizer in a village reduces median community wage rates by 0.1%. This finding indicates that while greater average quantities of subsidized fertilizer in a community boost wage rates, the more unevenly that the fertilizer is distributed, the less of a positive impact it has on wage rates.

Through increasing agricultural wage rates, the subsidy may provide some spill-over benefits to those who do not participate in the program and supply *ganyu* labor. Higher *ganyu* wage rates could have a negative effect on less poor households who hire in *ganyu* labor. Evidence from this study indicates that the increase in *ganyu* wage rate is mainly due to a contraction in labor supply from the subsidy as recipients supply less *ganyu* labor off-farm.

Endnotes

[1] These variables are considered corner solutions because a significant number of people do not supply *ganyu* labor and many do not receive subsidized fertilizer. For those who do supply *ganyu* labor or receive subsidized fertilizer, the distribution of days worked and kilograms of fertilizer received are relatively continuous because many people receive no subsidized fertilizer, but for those who receive subsidized fertilizer, the quantity they obtain takes on a relatively continuous positive distribution.

Table 2.1 Comparison Statistics for *Ganyu* Supplying and *Ganyu* Demanding Households

Ganyu Supplying HH			*Ganyu Demanding HH*	
		2003/04		
variable	mean	median	mean	median
real net crop income (in MK)	11,643	8,252	23,368	11,259
real non-farm income (in MK)	12,692	2,859	61,122	14,088
real value of livestock & durable assets (in MK)	20,292	7,987	68,814	24,231
land holding	0.99	0.81	1.38	1.06
land holding /AE	0.31	0.24	0.43	0.30
		2006/07		
Variable	mean	median	mean	median
real net crop income (in MK)	13,361	5,939	27,466	9,194
real non-farm income (in MK)	3,754	475	20,155	3,565
real value of livestock & durable assets (in MK)	16,240	5,443	88,075	25,550
land holding	0.97	0.81	1.33	1.01
land holding /AE	0.27	0.19	0.37	0.26
		2008/09		
Variable	mean	median	mean	median
real net crop income (in MK)	18,778	11,849	30,952	17,789
real non-farm income (in MK)	13,978	4,000	47,762	15,000
real value of livestock & durable assets (in MK)	24,651	7,680	115,196	33,900
land holding	1.01	0.81	1.31	1.01
land holding /AE	0.27	0.20	0.33	0.24

Table 2.2 *Ganyu* Supply and Demand Summary Statistics by Year

	Year		
	2003/04	2006/07	2008/09
Number of households	2,968	2,968	1,375
% demanding ganyu	23	22	30
mean days demanded	13.7	5.4	5.3
median days demanded	0	0	0
mean days demanded if >0	60.2	25	17.3
median days demanded if >0	15	12	8
% supplying ganyu	52	40	46
mean days supplied	39.8	10.8	24.2
median days supplied	3	0	0
mean days supplied if >0	76.3	26.7	52.6
median days supplied if >0	45	12	28
% supply & demand ganyu	7.3	5.1	8.1
% doing neither	32.4	43.0	31.6

Table 2.3 Subsidized fertilizer acquired by Ganyu Supplying and Demanding Households at Different Points of the Distribution (in Kilograms)

			Ganyu Supplying Households			
Year	mean	10%	25%	50%	75%	90%
2003/04	10	0	0	0	10	15
2006/07	45	0	0	50	100	100
2008/09	49	0	0	50	100	100
			Ganyu Demanding Households			
Year	mean	10%	25%	50%	75%	90%
2003/04	21	0	0	0	10	50
2006/07	109	0	0	100	100	200
2008/09	72	0	50	50	100	100

Table 2.4 Factors Affecting the Quantity of Subsidized Fertilizer a Household Acquires

Variables	CRE Tobit Estimator Whole Population Coefficient	P-value
=1 if MP resides in community	-5.52	(0.411)
MP in community * year2002/03 dummy	17.69*	(0.067)
MP in community * year2003/04 dummy	-12.93**	(0.017)
MP in community * year2006/07 dummy	1.92	(0.845)
Distance from village to district main town, in km	0.13**	(0.025)
Distance from village to nearest paved road, in km	0.10*	(0.063)
=1; if farm credit organization in village	2.22	(0.294)
Real 2009 Kwacha, total net non-farm income * 1,000	-0.003	(0.811)
Age of household head	0.18	(0.159)
=1; if death in the family over the previous 2 years	-2.39	(0.484)
Ratio: landholding / adult equivalent in the household	8.87	(0.425)
Household landholding in hectares	4.19	(0.475)
Real 2009 kwacha value of livestock & durable assets * 1,000	0.02	(0.593)
=1 if household head attended school	5.36**	(0.048)
Real 2009 kwacha/kg, harvested hybrid maize price	1.40***	(0.009)
Real 2009 kwacha/kg, harvested tobacco maize price	0.54***	(0.000)
Real 2009 kwacha/kg commercial fertilizer price kwacha	0.07	(0.130)
# of children under 6 yrs old in HH	-0.85	(0.630)
# of children > 6 yrs & < 14 yrs in HH	3.80**	(0.034)
# of males > 14 yrs & < 65 yrs in HH	-1.34	(0.540)
# of females > 14 yrs & < 65 yrs in HH	-1.21	(0.517)
# of males > 65 yrs in HH	13.32**	(0.014)
# of females > 65 yrs in HH	-7.01	(0.118)
=1; if household headed by female	0.34	(0.944)
Average cum. rainfall over past 5 growing seasons in cm	-0.05***	(0.007)
Coefficient of variation on past 5 season avg. rainfall	-49.86*	(0.085)
Cumulative rainfall over current growing season in cm	0.00	(0.881)
Observations	7,311	
R^2	0.03	

Note: *, **, *** denotes that corresponding coefficients are significant at the 10%, 5% and 1% level respectively; model includes year dummies, district dummies, and household time averages of all time-varying covariates; model estimated with survey weights.

Table 2.5 Factors Affecting Community Level Agricultural Wage Rates; Three Waves

Variables	(1) POLS	(2) FE
Average qty of subsidized fertilizer per HH in community	0.002***	0.002***
	(0.000)	(0.000)
Std. dev. of qty of subsidized fertilizer per HH in community	-0.001***	-0.001***
	(0.000)	(0.000)
Distance from village to district capital, in km	-0.001***	NA
	(0.000)	NA
Distance from village to paved road, in km	-0.000	NA
	(0.113)	NA
=1 if farm credit in village	-0.023***	NA
	(0.000)	NA
Real value of HH livestock + durable assets	-0.000	0.000
	(0.837)	(0.984)
Landholding, in ha	-0.003	-0.005
	(0.309)	(0.358)
Real commercial fertilizer price, Mk/kg	0.001***	0.001***
	(0.000)	(0.001)
Real harvested hybrid price, district level, Mk/kg	0.017***	0.014***
	(0.000)	(0.000)
Real harvested tobacco price, regional level, Mk/kg	0.003***	0.002***
	(0.000)	(0.000)
Quantity maize harvested by household, in kg	-0.000	0.000
	(0.624)	(0.543)
Quantity of tobacco harvested by household, in kg	0.000	0.000
	(0.325)	(0.211)
Long run cum. avg rainfall over previous 5 growing seasons, in cm	-0.001***	-0.001***
	(0.000)	(0.000)
Coefficient of variation on lr avg rainfall=sd/mean	0.540***	0.579***
	(0.000)	(0.000)
Observations	7,311	7,311
R^2	0.59	0.52

Note: *, **, *** denotes that corresponding coefficients are significant a the 10%, 5% and 1% level respectively; model includes dummy variables for year, district, and month of interview, interaction effect of average subsidized fertilizer * std deviation of subsidized fertilizer produced coefficient of very small economic magnitude, so interaction was excluded from final estimation; model estimated with survey weights.

Table 2.6 Factors Affecting the Number of Days Households Supply Agricultural Labor; Community Level Predicted Wage; Three Waves

Tobit Estimator	(1) Pooled	(2) CRE	(3) CRE IV	(4) Pooled	(5) CRE	(6) CRE IV
Variables	Whole Population			Ganyu Supplying Population		
Reduced form residual	NA	NA	-0.15	NA	NA	-0.08
	NA	NA	(0.33)	NA	NA	(0.37)
Kgs of subsidized fertilizer acquired	-0.05***	-0.06**	-0.06*	-0.06***	-0.12***	-0.12***
	(0.00)	(0.05)	(0.05)	(0.00)	(0.01)	(0.01)
Log predicted community median wage rate	-24.61	-30.19**	-30.88*	-52.93**	-49.71**	-49.60
	(0.19)	(0.09)	(0.08)	(0.03)	(0.05)	(0.14)
Distance from village to district main town, in km	0.09***	0.09***	0.04	0.02	0.02	-0.01
	(0.00)	(0.00)	(0.47)	(0.52)	(0.56)	(0.85)
distance from village to nearest paved road, in km	0.04	0.04	0.01	-0.01	-0.02	-0.04
	(0.32)	(0.25)	(0.90)	(0.80)	(0.74)	(0.69)
=1; if farm credit org. in village	1.71	1.67	1.06	1.58	0.82	0.44
	(0.36)	(0.35)	(0.62)	(0.61)	(0.80)	(0.99)
Real 2009 Kwacha, total net non-farm income * 1,000	-0.00	-0.00	-0.00	-0.10	-0.00	-0.00
	(0.61)	(0.76)	(0.77)	(0.88)	(0.98)	(0.98)
Age of hh head	-0.22***	-0.22***	-0.29***	-0.17*	-0.17	-0.21
	(0.00)	(0.00)	(0.00)	(0.05)	(0.10)	(0.11)
'=1 if death in the family over the previous 2 years	0.59	-0.44	0.39	-2.23	-5.87	-5.42
	(0.74)	(0.87)	(0.89)	(0.44)	(0.21)	(0.37)
Ratio: land / adult equivalent in the household	-3.34	1.54	-1.90	0.54	6.32	4.49
	(0.35)	(0.81)	(0.83)	(0.92)	(0.41)	(0.36)
Household land in hectares	-2.06	-2.90	-4.37*	-3.69*	-5.15	-6.01
	(0.11)	(0.26)	(0.30)	(0.07)	(0.11)	(0.21)
Real 2009 kwacha value of livestock & durable assets * 1,000	-0.01***	-0.004***	-0.001***	-0.10***	-0.10***	-0.10***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
'=1 if household head attended school	-9.86***	-9.83***	-11.79***	-5.14**	-5.65**	-6.76**
	(0.00)	(0.00)	(0.00)	(0.03)	(0.02)	(0.03)
Real 2009 kw/kg, harvested hybrid maize price	0.44	0.37	-0.08	-0.92	-0.88	-1.15
	(0.35)	(0.40)	(0.90)	(0.26)	(0.30)	(0.10)

Table 2.6 Continued

Real 2009 kw/kg, harvested tobacco price	0.11 (0.11)	0.13** (0.04)	-0.07 (0.69)	0.16 (0.12)	0.19* (0.07)	0.07 (0.95)
Real 2009 kw/kg commercial fertilizer price	0.01 (0.67)	0.06** (0.04)	0.03 (0.42)	-0.02 (0.62)	0.02 (0.73)	0.00 (0.82)
# of children under 6 yrs old in HH	2.55*** (0.00)	2.41*** (0.01)	2.72** (0.02)	2.60** (0.02)	1.81 (0.26)	1.98 (0.20)
# of children > 6 yrs & < 14 yrs in HH	1.75*** (0.00)	3.36*** (0.00)	1.93 (0.20)	2.96*** (0.00)	4.52*** (0.00)	3.73** (0.01)
# of males > 14 yrs & < 65 yrs in HH	5.83*** (0.00)	4.70*** (0.00)	5.19*** (0.00)	5.04*** (0.00)	3.65* (0.08)	3.94 (0.11)
# of females > 14 yrs & < 65 yrs in HH	0.46 (0.60)	0.98 (0.40)	1.48 (0.29)	0.94 (0.52)	1.07 (0.61)	1.33 (0.38)
# of males > 65 yrs in HH	1.12 (0.67)	-2.18 (0.53)	-7.04 (0.17)	5.25 (0.23)	1.70 (0.77)	-1.03 (0.61)
# of females > 65 yrs in HH	-3.94** (0.06)	-4.21 (0.14)	-1.55 (0.70)	-2.30 (0.50)	-0.56 (0.91)	0.88 (0.53)
'=1 if hh headed by female	0.87 (0.61)	4.33 (0.20)	4.12 (0.28)	-1.77 (0.51)	-3.47 (0.54)	-3.52 (0.69)
Average cum. rainfall over past 5 growing seasons in cm	0.02 (0.17)	0.02 (0.13)	0.04** (0.05)	0.04** (0.04)	0.05** (0.03)	0.06** (0.02)
Coefficient of variation on past 5 season avg. rainfall	-40.9*** (0.01)	-40.91*** (0.01)	-20.47 (0.34)	-53.06** (0.03)	-54.20** (0.02)	-43.41* (0.05)
Cumulative rainfall over current growing season in cm	-0.01 (0.13)	0.00 (0.69)	0.00 (0.69)	-0.00 (0.55)	0.00 (0.97)	0.00 (0.79)
Observations	7,311	7,311	7,311	3,837	3,837	3,837
R^2	0.03	0.03	0.03	0.04	0.04	0.04

Note: *, **, *** denotes that corresponding coefficients are significant a the 10%, 5% and 1% level respectively; Bootstrapped p-values in parenthesis, completed at 500 repetitions; models include year dummies, district dummies, month of interview dummies; models using CRE include household time averages of all time-varying covariates. Interaction effect of average subsidized fertilizer * std deviation of subsidized fertilizer produced coefficient of very small economic magnitude, so interaction was excluded from final estimation; model estimated with survey weights.

Table 2.7 Effect of Fertilizer Subsidies on *Ganyu* Labor Supply, by Asset Quintile, For the Ganyu Supplying Population

Asset Quintile	(1) Coefficient	P-value	(2) Average % Change for Subsidy Recipients	(3) Mean Real Value of Assets in '000 MK	(4) Mean Kgs. of Subsidized Fertilizer Acquired	(5) Mean Number of Ganyu Days Supplied
Poorest 1	-0.11	(0.01)	-5.9%	1.17	21	39
2	-0.14	(0.01)	-6.5%	3.86	25	54
3	-0.13	(0.01)	-9.3%	8.88	33	46
4	-0.12	(0.01)	-11.7%	18.77	40	41
Richest 5	-0.10	(0.01)	-17.9%	132.09	59	33

Note: 150 Kwacha = US $1.00; p-values obtained via bootstrapping at 500 repetitions; numbers in column 2 calculated by row as: column 1 * (column 4/ column 5); Assets in (3) defined as real 2009 value of livestock + durable assets

Table 2.8 Factors Affecting the Number of Days Households Demand Hired-in Agricultural Labor; Community Level Predicted Wage; Three Waves

Tobit Estimator	(1) Pooled	(2) CRE	(3) CRE w/Residual	(4) Pooled	(5) CRE	(6) CRE w/Residual
Variables	**Whole Population**			**Ganyu Demanding Population**		
Kgs. of subsidized fertilizer acquired	0.02 (0.399)	-0.01 (0.818)	-0.01 (0.823)	0.03 (0.604)	-0.03 (0.877)	-0.03 (0.887)
Reduced form residual	NA NA	NA NA	0.06 (0.679)	NA NA	NA NA	0.63 (0.429)
Log predicted community median wage rate	15.95 (0.847)	-17.46 (0.727)	-17.29 (0.729)	74.57 (0.799)	-148.69 (0.550)	-147.83 (0.553)
Distance from village to district main town, in km	-0.06 (0.178)	-0.07 (0.172)	-0.05 (0.521)	0.03 (0.816)	-0.10 (0.602)	0.12 (0.606)
Distance from village to nearest paved road, in km	-0.08 (0.143)	-0.10 (0.120)	-0.08 (0.263)	0.14 (0.657)	-0.07 (0.611)	0.09 (0.842)
=1; if farm credit organization in village	6.76* (0.057)	6.97** (0.046)	7.25* (0.061)	10.31 (0.201)	14.45 (0.137)	17.09 (0.150)
Real 2009 Kwacha, total net non-farm income * 1,000	0.00 (0.149)	0.00 (0.403)	0.00 (0.718)	0.00 (0.864)	-0.00 (0.623)	-0.00 (0.699)
Age of household head	-0.02 (0.630)	-0.04 (0.455)	-0.01 (0.940)	0.32 (0.431)	0.33 (0.382)	0.61 (0.297)
=1; if death in the family over the previous 2 years	2.79 (0.233)	1.26 (0.498)	0.93 (0.683)	-3.65 (0.625)	-12.28 (0.353)	-15.50 (0.336)
Ratio: landholding / adult equivalent in the HH	5.86 (0.413)	9.39 (0.217)	10.73 (0.333)	-32.93 (0.343)	15.64 (0.496)	29.79 (0.460)
HH landholding in ha	8.55 (0.179)	3.74 (0.223)	4.34 (0.401)	32.42 (0.181)	7.99 (0.298)	14.27 (0.440)
Real 2009 kwacha value of live-stock & durable assets * 1,000	0.00 (0.467)	0.00 (0.693)	0.00 (0.768)	0.00 (0.750)	0.00 (0.867)	0.00 (0.771)
=1 if household head attended school	16.97* (0.050)	15.13** (0.042)	15.91* (0.060)	28.56 (0.119)	22.52 (0.131)	30.83 (0.145)
Real 2009 kwacha/kg, harvested hybrid mz price	1.42 (0.335)	2.00 (0.199)	2.19 (0.217)	1.00 (0.807)	4.41 (0.368)	6.20 (0.317)
Real 2009 kwacha/kg, harvested tobacco pr.	-0.06 (0.809)	0.07 (0.680)	0.15 (0.563)	-0.31 (0.715)	0.33 (0.636)	1.18 (0.409)
# of children under 6 yrs. old in in HH	2.24 (0.253)	2.51 (0.283)	2.38 (0.337)	9.87 (0.264)	12.68 (0.291)	11.41 (0.351)

Table 2.8 Continued

# of children > 6 yrs & < 14 yrs in HH	0.19 (0.850)	0.52 (0.570)	1.08 (0.512)	-2.53 (0.484)	-2.31 (0.486)	3.64 (0.617)
# of males > 14 yrs & < 65 yrs in HH	1.03 (0.454)	-1.33 (0.629)	-1.53 (0.600)	-0.52 (0.860)	-15.87 (0.366)	-17.96 (0.343)
# of females > 14 yrs & < 65 yrs in HH	1.86 (0.190)	1.00 (0.572)	0.81 (0.715)	1.09 (0.733)	3.28 (0.59)	0.94 (0.843)
# of males > 65 yrs in HH	-2.81 (0.622)	1.33 (0.722)	3.20 (0.560)	-13.72 (0.486)	-3.52 (0.899)	17.20 (0.456)
# of females > 65 yrs in HH	-0.38 (0.765)	1.38 (0.776)	0.39 (0.938)	2.76 (0.893)	13.81 (0.476)	4.20 (0.925)
=1; if household headed by female	-3.59 (0.189)	-5.34 (0.283)	-5.31 (0.310)	8.04 (0.329)	1.55 (0.994)	1.51 (0.979)
Avg. cum. rainfall over the past 5 growing	0.02 (0.620)	0.00 (0.980)	-0.00 (0.799)	0.03 (0.886)	-0.10 (0.542)	-0.18 (0.435)
Coefficient of variation on past 5 growing seasons	10.87 (0.762)	9.39 (0.726)	1.21 (0.977)	69.69 (0.674)	100.98 (0.516)	11.06 (0.875)
cum rainfall over current growing season in cm	0.01 (0.110)	0.01 (0.149)	0.01 (0.179)	0.01 (0.685)	-0.02 (0.307)	-0.02 (0.430)
Observations	7,311	7,311	7,311	1,693	1,693	1,693
R^2	0.02	0.03	0.03	0.02	0.02	0.02

Note: *, **, *** denotes that corresponding coefficients are significant at the 10%, 5% and 1% level respectively; Bootstrapped p-values in parenthesis, completed at 500 repetitions; models include year dummies, district dummies, month of interview dummies; models using CRE include household time averages of all time-varying covariates; model estimated with survey weights.

APPENDICES

APPENDIX A: FACTORS AFFECTING THE NUMBER OF DAYS HOUSEHOLDS SUPPLY AGRICULTURAL LABOR; HOUSEHOLD LEVEL PREDICTED WAGE USING HECKMAN PROCEDURE; THREE WAVES FOR *GANYU* SUPPLYING POPULATION

Table 2.A1 Factors Affecting the Number of Days Households Supply Agricultural Labor; Household Level Predicted Wage Using Heckman Procedure; Three Waves for *Ganyu* Supplying Population

	(1)	(2)	(3)
Variables	Pooled	CRE	CRE w/Residual
Reduced form residual			-0.23
			(0.248)
Kilograms of subsidized fertilizer acquired	-0.07***	-0.14***	-0.14***
	(0.002)	(0.002)	(0.002)
Log predicted community median wage rate	-626.48	-746.27	-739.02
	(0.521)	(0.521)	(0.524)
Distance from village to district main town, in km	-0.58	-0.60	-0.63
	(0.627)	(0.627)	(0.608)
distance from village to nearest paved road, in km	-0.16	-0.11	-0.11
	(0.743)	(0.743)	(0.731)
binary=1; if farm credit organization in village	-8.31	-10.67	-11.32
	(0.716)	(0.716)	(0.701)
Real 2009 Kwacha, total net non-farm income	0.2	0.2	0.2
* 1,000	(0.678)	(0.678)	(0.680)
'=1 if death in the family over the previous 2 years	-2.51	-6.08	-4.44
	(0.165)	(0.165)	(0.378)
Ratio: landholding / adult equivalent in the Household	0.62	6.51	15.83
	(0.392)	(0.392)	(0.310)
Household landholding in hectares	0.10	-6.19	-14.02
	(0.824)	(0.824)	(0.632)
Real 2009 kwacha value of livestock & durable assets	-0.05	-0.04	-0.04
* 1,000	(0.898)	(0.898)	(0.892)
Real 2009 kwacha/kg, harvested hybrid maize price	4.86	5.26	4.48
	(0.797)	(0.797)	(0.826)
Real 2009 kwacha/kg, harvested tobacco price	2.00	2.51	2.34
	(0.570)	(0.570)	(0.597)
Real 2009 kwacha/kg commercial fertilizer price	0.42	0.90	0.90
	(0.399)	(0.399)	(0.401)
Average cum. rainfall over past 5 growing seasons in Cm	-0.14	-0.26*	-0.23
	(0.647)	(0.647)	(0.685)
Coefficient of variation on past 5 season avg. rainfall	193.80	181.12	198.30
	(0.592)	(0.592)	(0.557)
Cumulative rainfall over current growing season in Cm	0.12	0.17	0.17
	(0.407)	(0.407)	(0.406)
Observations	3,837	3,837	3,837
R^2	0.04	0.04	0.04

Table 2.A1 continued

Note: *, **, *** denotes that corresponding coefficients are significant at the 10%, 5% and 1% level respectively; p-values in parentheses, obtained via bootstrap at 100 repetitions; model includes household demographic variables, dummy variables for year, district, and month of interview; model estimated with survey weights.

Appendix A presents the results for factors affecting the number of days a household supplies ganyu labor during the year using the predicted household wage, obtained using the *heckit* procedure following Heckman (1980). Using the *heckit* method we take the following steps to deal with the wage truncation issue; first, we consider a household equation for ω_{it} as follows:

11) $\omega_{it} = \mathbf{M_{it}}\boldsymbol{\delta} + v_{it}$

where **M** is a vector of factors that affect household wage rate. These factors include education of the household head, age of the household head, livestock and durable assets, and landholding size. The vector of corresponding parameters is represented by $\boldsymbol{\delta}$, and v represents the error term. Without using the Heckman method, we would only be modeling accepted wages and our estimates would not be consistent across the population. Therefore we need to estimate a reduced form model of the household's binary decision *G*, of whether or not to supply *ganyu* labor in season *t* as follows:

12) $G_{it} = \mathbf{N_{it}}\boldsymbol{\psi} + \varsigma_{it}$

where N represents the factors affecting the household's decision whether or not to supply ganyu labor. Included in N are two additional variables, not included in M that affect participation but do not affect wage rate. We use the variables for number of children under six in the household as one of the exclusion restrictions. The idea is that young children require attention from household members, so this may affect the probability that the household participates in the *ganyu* labor market, but having more young children does not affect the household's wage rate directly. Having more young children under six years old could also cause the parents to be more likely to work *ganyu* to feed the family. The quantity of subsidized fertilizer that a household receives is also included as an additional variable in 12) because the quantity of subsidized fertilizer that a household receives may affect whether or not they work *ganyu* but would not directly affect the ganyu wage rate that they receive. The number of children under six years old in the household and the quantity of subsidized fertilizer acquired by the household in equation 12) allows the ganyu participation equation to be identified.

We estimate the inverse mill's ratio (IMR), from equation 12) and include it as a covariate in the wage rate equation 11). Including the IMR in 11) allows us to estimate the wage offer $\omega_{oit.}$ In order to identify equation 11) we include an additional variable, years of experience of the household head, that is not in the structural labor supply model. Experience is calculated as the age of the household head, minus years of schooling, minus six (Abdouli and Delgado). We would expect experience to affect wages but not affect the quantity of labor supplied, all else equal. From equation 11) we obtain the predicted value wage rate $\widehat{\omega}_{it,}$ and include it as a covariate in the labor supply estimated in equation 8). Results are presented in the table in appendix A. Standard errors for equation 8) are obtained via bootstrapping to account for the reduced form previous stage estimation.

Results using the *heckit* method indicate that on average each additional kilogram of subsidized fertilizer causes a household to work 0.07 fewer days of ganyu labor in the pooled specification and 0.14 fewer days in the CRE specification. The average ganyu supplying household receives 35 kilograms of subsidized fertilizer and supplies 42 days of ganyu labor. Therefore once the endogeneity of subsidized fertilizer is considered in columns 2 and 3, participating in the program causes the average household to reduce the amount of ganyu labor that they supply by 13%. This result is similar to the 10% reduction in ganyu labor supply, estimated in table 6 using predicted median community wage, rather than predicted household wage.

APPENDIX B: FACTORS AFFECTING THE NUMBER OF DAYS HOUSEHOLDS SUPPLY AGRICULTURAL LABOR; COMMUNITY LEVEL PREDICTED WAGE; TWO WAVES FOR *GANYU* SUPPLYING POPULATION

Table 2.B1 Factors Affecting the Number of Days Households Supply Agricultural Labor; Community Level Predicted Wage; Two Waves for *Ganyu* Supplying Population

Variables	(1) Pooled	(2) CRE	(3) CRE w/Residual
Reduced form residual	NA	NA	0.48
	NA	NA	(0.341)
Kilograms of subsidized fertilizer acquired in current Yr.	-0.05	0.00	0.00
	(0.111)	(0.946)	(0.925)
Kilograms of subsidized fertilizer acquired in previous Year	-0.09***	-0.09**	-0.11**
	(0.005)	(0.027)	(0.041)
Log predicted community median wage rate	8.99	-17.83	-16.17
	(0.707)	(0.542)	(0.577)
Distance from village to district main town, in km	-0.06	-0.06	-0.11
	(0.196)	(0.240)	(0.165)
distance from village to nearest paved road, in km	0.00	-0.01	-0.04
	(0.982)	(0.875)	(0.645)
binary=1; if farm credit organization in village	-0.03	-0.72	2.43
	(0.995)	(0.863)	(0.674)
Real 2009 Kwacha, total net non-farm income * 1,000	-0.003	-0.001	-0.001
	(0.989)	(0.994)	(0.994)
'=1 if death in the family over the previous 2 years	-4.40	-19.86**	-18.39
	(0.285)	(0.081)	(0.147)
Ratio: landholding / adult equivalent in the household	0.32	-14.03	-15.47
	(0.967)	(0.166)	(0.328)
Household landholding in hectares	-3.34	3.65	12.07
	(0.246)	(0.296)	(0.234)
Real 2009 kwacha value of livestock & durable assets * 1,000	-0.1**	-0.04	-0.03
	(0.012)	(0.205)	(0.239)
Real 2009 kwacha/kg, harvested hybrid maize price	-3.09	-1.37	-2.09
	(0.102)	(0.467)	(0.364)
Real 2009 kwacha/kg, harvested tobacco price	0.09	-0.01	0.36
	(0.475)	(0.933)	(0.365)
Real 2009 kwacha/kg commercial fertilizer price	-0.04	0.01	-0.10
	(0.291)	(0.862)	(0.450)
Average cum. rainfall over past 5 growing seasons in cm	0.01	-0.02	-0.10
	(0.923)	(0.833)	(0.474)
Coefficient of variation on past 5 season avg. rainfall	11.98	31.77	125.12
	(0.917)	(0.781)	(0.427)
Cumulative rainfall over current growing season in cm	-0.02	-0.00	0.04
	(0.148)	(0.667)	(0.416)
Observations	1,486	1,486	1,486

Table 2.B1 continued

Note: *, **, *** denotes that corresponding coefficients are significant at the 10%, 5% and 1% level respectively; p-values in parentheses, obtained via bootstrap at 500 repetitions; model includes household demographic variables, dummy variables for year, district, and month of interview; model estimated with survey weights. R^2 = 0.02 for all estimations

In order to ensure that our results are robust to the possibility that some households may have made some of their labor supply decisions and then received subsidized fertilizer we estimate the labor supply model using current year and past year subsidized fertilizer quantities. To estimate this effect we use data from the 2006/07 survey and the 2008/09 survey, as data on prior year fertilizer use is not available in the 2003/04 survey. Results from this analysis are presented here in appendix 2, and indicate that each additional kilogram of subsidized fertilizer acquired in the previous year reduces household labor supply in the current year by 0.11 days. The average household in the *ganyu* supplying population acquires 31 kilograms of subsidized fertilizer in the previous year and works 42 days of *ganyu* in the current year. Therefore the average household that participates in the subsidy program one year earlier reduces the quantity of *ganyu l*abor supplied in the current year by 8%. This result is similar to the 10% reduction in *ganyu* labor supply estimated in table 6 using predicted median community wage. It is also similar to the 13% reduction in *ganyu* labor supply using the predicted household wage in appendix B.

REFERENCES

REFERENCES

Abdouli, A., and C. Delgado. 1999. "Determinants of Non-farm Earnings of Farm-based Husbands and Wives in Northern Ghana." *American Journal of Agricultural Economics* 81(1): 117-130

Alwang, J., and P.B. Siegel. 1999. "Labor Shortages on Small Landholdings in Malawi: Implications for Policy Reforms." *World Development* 27(8): 1461-1475.

Banful, A. 2010. "Old Problems in the New Solutions? Politically Motivated Allocation of Program Benefits and the "New" Fertilizer Subsidies." (in press) *World Development*

Bardhan, P. 1979. "Labor Supply Functions in a Poor Agrarian Economy." *American Economic Review* 69(1): 73-83.

Bryceson, D.F. 2006. "Ganyu Casual Labour, Famine and HIV/AIDS in Rural Malawi: Causality and Casualty." Jou*rnal of Modern African Studies* 44(2): 173-202.

Chamberlain, G. 1984. "Panel data". In Grilliches, Z., Intriligator, M.D., eds. *Handbook of Econometrics*, Vol. 2 North Holland, Amsterdam. 1247-1318.

Chibwana, C., M. Fisher, G. Shively. 2010. "Land Allocation Effects of Agricultural Input Subsidies in Malawi." Working Paper, Department of Agricultural Economics, Purdue University. West Lafayette, Indiana.

Chibwana, C., M. Fisher, W. Masters, G. Shively. 2010. "Measuring the Impacts of Malawi's Farm Input Subsidy Program." Working Paper, Department of Agricultural Economics, Purdue University. West Lafayette, Indiana.

de Janvry, A., and E. Sadoulet. 2006. "Progress in Modeling of Rural Household's Behavior Under Market Failures." In de Janvry, A., R. Kanbur, eds. *Poverty, Inequality and Development* Vol. 2 Springer, New York. 155-181.

Dorward, A. 2006. "Markets and Pro-Poor Agricultural Growth: Insights from Livelihood and Informal Rural Economy Models in Malawi." *Agricultural Economics* 35:157-169.

Dorward, A. 2007. "Impacts of the Agricultural Input Subsidy Programme in Malawi: Insights fromRural Livelihood Modeling." Working paper, Agricultural Input Subsidy Programme Evaluation. London, School of Oriental and African Studies.

Dorward, A., E. Chirwa, V. Kelly, T.S. Jayne, R. Slater, and D. Boughton. 2008. "Evaluation of the 2006/07 Agricultural Input Subsidy Programme, Malawi." Final Report. Lilongwe, Malawi.

Dorward A., E. Chirwa, and R. Slater. 2010. "Evaluation of the 2008/09 Agricultural Input Subsidy Porgramme, Malawi." Report on Implementation. Lilongwe, Malawi.

Dorward, A., and E. Chirwa. 2011. "The Malawi Agricultural Input Subsidy Programme: 2005/06 to 2008/09." *International Journal of Agricultural Sustainability.* (16): 232-247.

Duflo, E., M. Kremer, and J. Robinson. 2009. “Nudging Farmers to Use Fertilizer: Theory and Experimental Evidence from Kenya.” NBER Working Paper No. 15131, Cambridge MA.

Dugger, C. W. 2007. Ending Famine, Simply by Ignoring the Experts. *New York Times,* December 2, 2007, p. 1.

Goldberg, J. 2010. “Kwacha Gonna Do? Experimental Evidence about Labor Supply in Malawi.” Working Paper, Department of Economics. University of Michigan

Govereh, J., E. Malawo, T. Lungu, T. Jayne, K. Chinyama and P. Chilonda. 2009. “Trends and Spatial Distribution of Public Agricultural Spending in Zambia: Implications for Agricultural Productivity Growth.” FSRP Working Paper No. 36, Dept. of Agr. Food & Resource Econ., Michigan State University.

Harrigan, J. 2008. “Food Insecurity, Poverty and the Malawian Starter Pack: Fresh Start or False Start?” *Food Policy* 3: 237-49.

Heckman, J. 1980. "Sample Selection Bias as a Specification Error with an Application to the Estimation of Labor Supply Functions." In J. P. Smith, ed., *Female Labor Supply: Theory and Estimation* Princeton, N.J.: Princeton University Press.

Holden S., and R. Lunduka. 2010a. “Impacts of the Fertilizer Subsidy Program in Malawi: Targeting, Household Perceptions and Preferences.” Working Paper, Department of Economics and Resource Management. Norwegian University of Life Sciences.

Holden S., and R. Lunduka. 2010b. “Too Poor to be Efficient? Impacts of the targeted fertilizer subsidy program in Malawi on farm plot level input use, crop choice and land productivity.” Working Paper, Depart. of Econ. and Resource Management. Norwegian University of Life Sciences.

IMF, 2010. Fifth Review Under the Three-Year Arrangement Under the Extended Credit Facility, Requests for Waiver of Nonobservance of Performance Criterion and Modification of Performance Criteria, and Financing Assurances Review. International Monetary Fund, Washington, DC.

Jacoby, H. 1993. “Shadow Wages and Peasant Family Labour Supply: An Econometric Application to the Peruvian Sierra.” *Review of Economic Studies* 60(4): 903-920

Jayne, T.S., N. Mason, R. Myers, J. Ferris, D. Mather, M. Beaver, N. Lenski, A. Chapoto, and D. Boughton. 2010a. “Patterns and Trends in Food Staples Markets in Eastern and Southern Africa: Toward the Identification of Priority Investments and Strategies for Developing Markets and Promoting Smallholder Productivity Growth.” *Michigan State University International Development Working Paper*. East Lansing, MI.

Jayne, T.S., N. Sitko, J. Ricker-Gilbert, and J. Mangisoni. 2010b. “Malawi’s Maize Marketing System.” *Michigan State University International Development Working Paper* 104. East Lansing, MI.

Levy, S., C. Barahona, and B. Chinsinga. 2004. “Food Security, Social Protection, Growth and Poverty Reduction Synergies: The Starter Pack Programme in Malawi.” *Natural Resource Perspectives* 95

Mkadawire, R. and Ferguson, A. 1990. “Smallholder agricultural food security and estate expansion in Malawi: A case study of Salima ADD”

Mundlak, Y. 1978. “On the Pooling of Time Series and Cross Section Data.” *Econometrica* 46: 69-85.

Nkonde, C., N.M. Mason, N.J. Sitko, and T.S. Jayne. 2011. “Who Gained and Who Lost from Zambia’s 2010 Maize Marketing Policies?” FSRP Working Paper #49, Department of Agricultural, Food and Resource Economics, Michigan State University.

Papke, L.E., and J.M. Wooldridge. 2008. Panel Data Methods for Fractional Response Variables with an Application to Test Pass Rates. *Journal of Econometrics* 145: 121-133.

Peters, P. 1998. “Agricultural Commercialization, Rural Economy and Household Livelihoods 1990-1997.” Harvard Institute for International Development. Cambridge MA.

Ricker-Gilbert, J., T.S. Jayne and E. Chirwa. 2011. “Subsidies and Crowding Out: A Double-Hurdle Model of Fertilizer Demand in Malawi.” *American Journal of Agricultural Economics.* 93(1): 26-42.

Rivers, D., and Q.H. Vuong. 1988. “Limited Information Estimators and Exogeneity Tests for Simultaneous Probit Models.” *Journal of Econometrics* 39: 347-366.

Rosenzweig, M. 1978. “Rural Wages, Labor Supply, and Land Reform: A Theoretical and Empirical Analysis.” *American Economic Review* 68(5): 847-861.

Singh, I., L. Squire, and J. Strauss. 1986. *Agricultural Household Models*. Baltimore: Johns Hopkins University Press.

Skoufais, E. 1994. “Using Shadow Wages to Estimate Labor Supply of Agricultural Households.” *American Journal of Agricultural Economics* 76(2): 215-227.

Smith, R., and R. Blundell. 1986. "An Exogeneity Test for a Simultaneous Equation Tobit Model with an Application to Labor Supply," *Econometrica* 54: 679-685.

Whiteside, M. 1998. “When the Whole is More Than the Sum of the Parts – the Effect of Cross-border Interactions on Livelihood Security in Southern Malawi and Northern Mozambique.” A report for Oxfam GB. www.ids.ac.uk/eldis/malmoz.htm

Whiteside, M. 2000. “Ganyu Labour in Malawi and Its Implications for Livelihood Security Interventions – An Analysis of Recent Literature and Implications for Poverty Alleviation.” *Agricultural Research & Extension Network* 99

Wooldridge, J.M. 2011. *Econometric Analysis of Cross Section and Panel Data, 2nd Edition*. London: MIT Press.

Xu, Z., W.J. Burke, T.S. Jayne., and J. Govereh. 2009. "Do Input Subsidy Programs "Crowd In" or "Crowd Out" Commercial Market Development? Modeling Fertilizer Use Decisions in a Two-Channel Marketing System." *Agricultural Economics* 40(1): 79-94.

CHAPTER 3
WHAT ARE THE ENDURING EFFECTS OF FERTILIZER SUBSIDY PROGRAMS ON RECIPIENT FARM HOUSEHOLDS? EVIDENCE FROM MALAWI

Agriculture has come back into focus in recent years as a crucial driver of growth in Sub-Saharan Africa (SSA). After being largely out of favor during the 1990s and early 2000s, input subsidy programs have been reintroduced in much of Africa as a major component of national agricultural policies. A strand of the development literature has revived the case for fertilizer subsidy programs, asserting that they can help poor farmers break out of a low input/low output poverty trap and kick start growth processes that can sustainably raise their incomes and assets even after they stop participating in the program (Dorward et al., 2004; Morris et al. 2007).

A key research issue associated with this topic is whether the benefits of receiving subsidized fertilizer last only one season or whether they are of a more enduring nature. To our knowledge, this issue has never been addressed empirically based on farm survey evidence. Understanding the dynamic effects of input subsidy programs informs important policy questions related to whether (or under what conditions) receiving subsidized fertilizer can provide enduring positive effects on poor households' incomes, assets, and access to food.

If the benefits of fertilizer subsidies are found to be one-off, lasting only one season, such programs may still be useful and financially sustainable if the contemporaneous benefits outweigh the costs but the assertion of dynamic and sustained growth processes would not be supported. If the program produces no significant effects at any point in time then serious doubts should be raised about subsidy programs' relevance to boosting productivity and improving livelihoods. On the other hand, if receipt of the subsidy in prior years has enduring long-term impacts on households' production, incomes, and assets, then this would give credence to the argument that subsidies can kick-start sustained growth processes. These questions can now begin to be tested empirically using farm-level panel data.

Over the past several years numerous countries including Kenya, Tanzania, Uganda, Zambia, Senegal, Ghana and Malawi have introduced or revived programs that provide inorganic fertilizer and often hybrid maize seeds to farmers below commercial market prices. Despite their potential benefits, the costs of implementing large-scale fertilizer subsidy programs are high. For example, in 2008 Malawi spent roughly 70% of the Ministry of Agriculture's budget or just over 16% of the government's total budget subsidizing fertilizer and seed (Dorward and Chirwa 2011). In Zambia, 57% of total government spending on agriculture was devoted to fertilizer and maize subsidies in 2010, equivalent to 2% of the nation's gross domestic product (Nkonde et al., 2011; IMF, 2010). Therefore, obtaining precise estimates of the current and lagged impacts of fertilizer subsidy programs on recipients' well-being will help policy makers determine the role they should play in future agricultural development and rural wealth creation programs.

This study uses household panel survey data from Malawi to determine how fertilizer subsidies acquired by recipient households in the current year and up to three consecutive prior years affect current year indicators of their well-being. The four sets of indicators are: production of maize and tobacco, the specific crops which Malawi's input subsidy programs were targeted to promote; net value of rainy-season crop production; value of livestock and durable asset wealth, and total household income (including off-farm income). We use a framework adapted from the research and development (R&D) literature (Pakes and Griliches 1980) and estimate a distributed lag model where current year and past year quantities of subsidized fertilizer enter as covariates in the models of household well-being. The impact of current and lagged receipt of fertilizer subsidies on these indicators provides a broad understanding of how the policy may improve the lives of rural households.

Malawi makes for an interesting case study because since 2005/06 the country has implemented an innovative targeted input voucher program where the government distributes vouchers to selected farmers who meet certain criteria. Under this program, targeted farmers can then redeem the vouchers in exchange for fertilizer at a reduced price. The program received popular acclaim in a front-page New York Times article (Dugger 2007) and is widely being perceived as a test case for possible broader implementation elsewhere in Africa. However, more evaluation needs to be conducted in order to help policy makers understand the potential enduring effects of fertilizer subsidy programs on the lives of recipients.

Malawi's targeted fertilizer subsidy program was supposed to correct some of the inefficiencies that plagued universal fertilizer subsidy programs of the past by 1) targeting vouchers to farmers who would not otherwise purchase fertilizer at commercial prices and 2) involving the private sector in the procurement, distribution and retail selling of subsidized fertilizer. These two programmatic features of the subsidy were intended to reduce the negative impact on the private sector and minimize crowding out of commercial fertilizer purchases by farmers. A recent study in Malawi by Ricker-Gilbert, Jayne and Chirwa (2011) estimates that after controlling for other factors, one kilogram of subsidized fertilizer crowds out 0.22 kilograms of commercial fertilizer on average in the years between 2003 and 2007. The authors find that wealthier farmers who receive subsidized fertilizer displace a greater proportion of their commercial purchases with the subsidy than do poorer farmers. Another study based in Zambia by Xu et. al (2009) finds that subsidized fertilizer crowds out commercial fertilizer in areas where the private fertilizer sector is relatively established but crowds in commercial fertilizer in areas where the private sector is weak.

Several recent studies address the farm-level impacts of fertilizer subsidies. Holden and Lunduka (2010) use plot-level data from households in central and southern Malawi to look at the impact of fertilizer subsidies on cropping decisions and fertilizer use efficiency. The authors find that maize area has decreased during the years of the subsidy while maize yield has increased over the same period. Another study by Chibwana, Fisher and Shively (2010) uses plot-level data from two districts in the central region of Malawi and finds that the subsidy program causes the share of recipients' area planted to maize and tobacco (the crops targeted by the program) to rise, while causing the share of area planted to other crops to decline. Another study using experimental evidence from Kenya finds that offering small, time-limited fertilizer subsidies provided at harvest (while farmers have cash) can substantially increase fertilizer use the next season (Duflo, Kremer and Robinson 2009). The authors argue that small, timely discounts increase welfare more than large-scale fertilizer subsidies or *laissez-faire*.

The studies mentioned above are all confined to measuring contemporaneous impacts, but to our knowledge this article is the first household-level study to estimate the enduring or dynamic effects of receiving subsidized fertilizer. This article benefits from a rich data set with detailed recall data that allows us to measure how the program affects recipients' production, assets, and income over time. Moreover, while most previous studies measure impacts on farm input use and/or crop output, we consider the broader impacts of the subsidy program on household-level incomes and asset wealth.

Several policy papers have come down on either side of the debate with some raising the question of whether or not subsidizing fertilizer is a sustainable strategy for growth (Harrigan 2008, GRAIN 2010). Others point towards Malawi's large logistical achievement of making subsidized fertilizer available to a many farmers across the country, and the impact of the program on maize production (Dorward and Chirwa 2011). Dorward and Chirwa argue that the subsidy program should continue to be funded in order to help households break out of the low-maize productivity poverty trap. The intent of our paper is to inform this debate by evaluating the evidence that fertilizer subsidies may have enduring, as well as contemporaneous benefits for recipient households.

When evaluating the impacts of fertilizer subsidies, it is essential to understand that they are not distributed randomly, so dealing with this issue is a major part of the paper's modeling effort. It is likely that the quantity of subsidized fertilizer that a household receives is endogenous in a model of household production, assets or income, because the amount received is likely correlated with factors in the error term of these models. Another issue is that in these models subsidized fertilizer takes on the properties of a corner solution variable. The corner solution issue arises because many people in Malawi receive no subsidized fertilizer, but beyond that, the quantity of subsidized fertilizer that people obtain takes on a relatively continuous distribution for those who receive it. By addressing endogeneity and corner solution issues this paper should be a useful application for researchers dealing with non-random program selection in other contexts where the potentially endogenous variable of interest is non-linear. This study also intends to provide government policy makers and donor agencies with accurate estimates of the effects of fertilizer subsidies on key indicators of household well-being and how those benefits are either sustained or dissipated over time.

Results indicate that receiving subsidized fertilizer in a given year positively affects household-level maize and tobacco production, as well as the net value of rainy-season crop production in that year. Receipt of subsidized fertilizer over the prior three seasons also has a significant positive effect on current year maize production. However, receipt of subsidized fertilizer in the prior three consecutive years has no discernable effect on the net value of rainy-season crop production for households in the current year. Moreover, we find no evidence that prior or current receipt of subsidized fertilizer contributes to off-farm or total household income. We also find no significant evidence to indicate that receiving subsidized fertilizer causes households to increase their livestock and durable asset wealth.

The rest of the paper is organized as follows. The next section briefly describes the context and evolution of Malawi's fertilizer subsidy program. This is followed by the study's conceptual framework, then an explanation of the well-being measures used in this study, and the modeling methodology and identification strategy. Subsequent sections present data, results, and conclusions.

Fertilizer Distribution and Subsidies in Malawi

Fertilizer subsidy programs have existed almost every year for decades in Malawi. However, after experiencing a drought-affected poor harvest in 2004/05, the Government of Malawi decided to greatly expand the scale of its targeted fertilizer subsidy program to promote maize and tobacco production. During the 2005/06 season coupons for around 131,000 metric tons of fertilizer (2.63 million 50kg bags) were distributed to farmers. The subsidy program cost US $48 million during the 2005/06 growing season (Dorward and Chirwa 2011).

The rains were good in 2005/06 and yields were high, making the subsidy program very popular. Consequently it was extended and further scaled up for the 2006/07 growing season. During that year the government procured and distributed 175,000 metric tons of fertilizer to farmers for maize and tobacco production. Coupons for subsidized maize seed were available as well. Coupon recipients paid the equivalent of US $6.75 for a 50 kg bag of fertilizer. The same 50 kg bag of fertilizer cost the government US $24.50 delivered at market, amounting to a subsidy rate of about 72% (Dorward and Chirwa 2011). Officially each household was eligible to receive two coupons good for two 50-kilogram bags of fertilizer at a discounted price. In reality, the actual amount of subsidized fertilizer acquired by households varied greatly. The program cost nearly US $85 million (Dorward and Chirwa 2011) with most of the bill being paid by the Malawian government and a minority by the UK's Department for International Development (DFID).

Fertilizer was also available for purchase from private suppliers at commercial prices during both the 2005/06 and 2006/07 growing season. Six private firms won the right to procure and distribute subsidized fertilizer through their retail networks. Farmers who received coupons could redeem them at participating retail stores along with US $6.75 to obtain their fertilizer. Retailers would then submit the coupon and receipt to the government for payment.

The subsidy program was scaled-up even further in 2007/08 when 216,500 metric tons of fertilizer was procured by the Malawian government at an estimated cost of nearly US $117 million. The government made 202,000 metric tons of subsidized fertilizer available in the 2008/09 season and spent an estimated US $265 million on the program. The higher cost was due to an increase in fertilizer prices and an expansion of the subsidy to smallholder tea and coffee crops (Dorward and Chirwa 2011). The private sector was excluded from distributing subsidized fertilizer in 2008/09, however a seed subsidy in that year did involve private retailers. The proportion of the fertilizer cost that was paid by the government increased to greater than 90% in 2008/09. Farmers were officially required to pay the equivalent of US $5.33 for a 50 kg bag of fertilizer that cost between US $40 to $70 at commercial prices.

Throughout the years of the subsidy's implementation, the process of determining who received coupons for fertilizer subsidies was subject to a great deal of local idiosyncrasies. At the regional level, coupons were supposed to have been allocated based on the number of hectares under cultivation. At the village level, subsidy program committees and the village heads were supposed to determine who was eligible for the program. In more recent years open community forums were held in some villages where community members could decide for themselves who should receive the subsidy. The general program eligibility criteria was that beneficiaries should be "full time smallholder farmers who cannot afford to purchase one or two bags of fertilizer at prevailing commercial prices as determined by local leaders in their areas" (Dorward et al. 2008). However, numerous unofficial criteria may have been used in voucher allocation, such as households' relationship to village leaders, length of residence, and social and/or financial standing of the household in the village. It is also possible that factors which are unobservable to us as researchers, such as health shocks and social connections, affect household production and income as well as influence how much subsidized fertilizer a household receives. Therefore, we consider the fact that subsidized fertilizer is likely to be endogenous in our models of household well-being.

Conceptual Framework

Consider a farm household in the context of a Singh, Squire, Strauss (1986) model whose level of well-being in a current period is denoted by Y. Well-being is affected by observable factors and an unobservable factor K, which can be thought of as representing unobservable productive measures that are built up by the household over time. The concept of K is borrowed from the R&D literature, where it is described by Pakes and Griliches as "the level of economically valuable technological knowledge" at the firm level.

Adapting the work of Pakes and Griliches to our context, assume that the household's level of K at time t is affected by the following:

1) K_t=f(S_{t-L}, ε_t)

where the amount of subsidized fertilizer that a household acquires in current and previous years is represented by S_{t-L}, where L= 0, 1, ….., L. When L=0, S_t represents the current year effect of receiving some quantity of subsidized fertilizer on the level of K in that year. When L>0, S_{t-L} represents the effect of receiving some quantity of subsidized fertilizer in previous years on the household's level of K in year t. In this context, K represents unobservable productive factors that are built up over time, such as nutrients in the soil, and improved fertilizer management practices that a farmer obtains from using and experimenting with fertilizer in multiple time periods. The unobservable factors affecting K_t are represented by ε_t.

It is unrealistic to assume that production and consumption decisions can be separated in a country like Malawi, with its imperfect credit and labor markets along with risk factors caused by high weather variability and other shocks (Alwang and Siegel 1999; Bryceson 2006). Therefore consider a non-separable farm household's level of well-being Y at time t as a function of the following:

2) Y_t= f(K_t, X_t, P_t, ω_t, T_t, C_t, v_t)

Household-level observable factors that affect well-being are represented by X_t. These factors include the value of household livestock and durable assets, landholding, and demographic composition. The price of fertilizer and other inputs are represented by ω_t, while P_t represents the output price per unit of the agricultural good. Transfer costs of using fertilizer, such as distance to a paved road are represented by T_t. Credit availability is denoted by C_t. Unobservable factors affecting well-being are represented by v_t.

Measures of Household Well-being

The following indicators are used to measure the impact of fertilizer subsidies on household well-being denoted by Y. The specific well-being indicators are 1) household wealth, measured as the value of household livestock and durable assets; 2) production of maize and tobacco, the main crops targeted by the subsidy program; 3) net value of all crops harvested by the household during the rainy season; 4) household income, including both off-farm income of the household and total household income.

These four indicators were chosen for several reasons. First, some of them are considered of major importance by African policy makers. For example, the Malawian government's official rationale for its fertilizer subsidy program includes maize self-sufficiency, hence our interest in dynamic effects on maize production. Asset wealth and income are widely considered important indicators of household welfare and are therefore considered appropriate for inclusion here. We would also have wished to examine the subsidy's effects on household consumption and nutritional status but such information was not available in this or any other nationally representative recent surveys in Malawi. Each of the five indicators are now discussed in more depth.

i) Value of livestock and durable assets

Theoretically, through reducing fertilizer prices, and boosting agricultural production, fertilizer subsidies could provide farm households with the incentives and opportunities to accumulate assets and wealth over time. Value of assets is an important measure of well-being because it is relatively stable over time and can be compared with income, which is generally more volatile. Assets are defined in this study as the self-reported value of livestock and durable goods. This includes productive durable assets such as farm equipment and consumption assets such as furniture and cooking equipment. We put value of assets in real 2009 terms, by dividing the nominal value of assets by the CPI in Malawi.

ii) Output supply: Household maize and tobacco production

In Malawi, vouchers are distributed at the start of the rainy season in October with the specific aim to boost the production of maize and tobacco, the country's main food and cash crop. Hence we hypothesize that the receipt of the subsidy will directly contribute to maize and tobacco production in that season. Since the majority of farm households are autarkic or net consumers of maize, increases in its production may indicate an improvement in the household's food security situation so long as an increase in maize production is not offset by a decrease in production of other staple crops. It may also be possible that receiving some quantity of subsidized fertilizer over a period of time in the past could boost current year maize production due to nutrient buildup in the soil, through learning about fertilizer application and management, or through an accumulation of productive assets from higher crop income in prior years.

iii) Net value of rain-fed crop production

As long as recipient households are not diverting resources from other crops to the main crops being targeted by the subsidy program, one would expect the subsidy program to raise the net value of rainy-season crop production. Net value of rainy-season crop production is calculated in this study by taking the total value of all crops produced and subtracting from it the cost of renting land, purchasing seed, purchasing fertilizer, and hiring labor. Family labor input is not measured in the surveys so its cost (or opportunity cost) is not considered in this calculation. We also do not have data on payment for land that has been purchased by households.

iv) Off-farm income of households

Estimating how the subsidy affects household off-farm income gives a measure of whether or not the subsidy has any positive spill-over effects that may encourage households to invest and engage in other off-farm activities over time. It could be possible that receiving subsidized fertilizer in some past year causes an increase in production and income in that past year and encourages investment in other enterprises for the future. Conversely, receiving subsidized fertilizer in a certain year may encourage on-farm work which could potentially crowd out off-farm activities. With lagged quantities of subsidized fertilizer we can measure its dynamic effect on off-farm activities. We measure off-farm income for household *i* at time *t* by considering income earned from sources such as, earnings from off-farm agricultural labor, non-farm enterprises, rental income, and pensions.

v) Total household income

The effect of receiving subsidized fertilizer on total household income provides an overall measure of the program's impact on household well-being. Total household income includes net value of all crop production, livestock and animal product income, income from off-farm agricultural labor, other safety-net programs, and non-farm income.

Methodology

Combining equations 1) and 2) into an estimating equation generates the following model where the well-being of household (i) in district (j) time (t) as a function of the following factors:

$$3)\ \mathrm{Y}_{ijt} = \alpha + \sum_{\mathrm{j=0}}^{\mathrm{J}} \beta_{\mathrm{k}} \mathbf{S_{i,jt-L}} + \sigma\, \mathbf{P_{ijt}} + \delta\, \boldsymbol{\omega}_{\mathbf{ijt}} + \boldsymbol{\varsigma} \mathbf{X_{ijt}} + c_i + \mu_{ijt}$$

where Y again represents one of the well-being measures discussed in the previous section. The effect of *K* on well-being is captured through $S_{ij,t-L,}$ which represents the quantity of subsidized fertilizer that a household receives at time (t-L), where L= 0, 1, ….., L. When L=0, the parameter, β, provides an estimate of the contemporaneous effect of subsidized fertilizer on well-being in year t. When L>0, β gives us the magnitude of subsidized fertilizer's dynamic effect on well-being. The summation of β_k for all time periods represents the long-run dynamic effect of subsidized fertilizer on household well-being. In order to test whether or not the effect of receiving subsidized fertilizer in a previous year is independent of receiving subsidized fertilizer in the year before it, we also interact the lagged $S_{ij,t-L}$ variables and test the significance of the coefficients.

Output prices in equation 3) are represented by **P** and input prices are represented by $\boldsymbol{\omega}$. Other factors that affect well-being such as household demographics, assets, landholding, and rainfall are denoted by the vector **X**. Shocks that are observable to us as researchers such as deaths in the household and chronic illnesses of household members are also included in **X**. The error term in equation (3) has two components. First, c_i represents the time constant unobserved factors that affect well-being. These unobservable factors may include farming ability and risk aversion of the household. Second, μ_{ijt} represents the time-varying shocks that affect well-being. These factors include intra-household dynamics and health shocks.

Identification Strategy

The goal of this study is to determine how offering households some quantity of subsidized fertilizer affects key indicators of their well-being over time. This section discusses the strategy used in this article to identify causal impacts of how acquiring subsidized fertilizer affects household well-being over time. The first part of this section describes the ideal dataset and how to use it as a guide to compare with the dataset used in this study to evaluate the Malawi fertilizer subsidy program.

From an evaluation standpoint it would be ideal if 1) the coupons that granted households the right to purchase fertilizer at a subsidized price had been distributed randomly to eligible households; 2) everyone who participated in the program acquired equal amounts of subsidized fertilizer, so that the "treatment" would be even across participants; 3) the treatment was constant over time for individual recipients, so that recipients obtained a uniform quantity of subsidized fertilizer in every year. Had these three conditions occurred, we could cleanly establish independence between participating in the subsidy program and the unobservable factors in the error term of the well-being models. We would also have a treatment group where everyone received the same degree of treatment, and we would have a treatment and control group that did not vary over time. In such a scenario, we could just compare the differences in mean outcomes between participants in the subsidy program and non-participants as the average treatment effect of the subsidy program.

Clearly the government of Malawi did not randomly distribute vouchers for fertilizer because it sought to target those in greatest need or those for whom they believed the subsidy program would have the greatest impact. Some of the factors affecting who receives subsidized fertilizer are observable to us as researchers and can be controlled by including them as covariates in the model, while others are inevitably unobservable and end up in the error term in equation 4. Fortunately our data set is longitudinal and follows the same households in Malawi over a period of time. Therefore we are able to deal with the potential correlation between the amount of subsidized fertilizer a household receives and the error term using panel data methods that will be discussed later on in this section. In addition, because we know how much subsidized fertilizer households receive in different years, we can deal with the fact that treatment is not constant and people receive various quantities of subsidized fertilizer over time.

Furthermore, if we were interested in evaluating the effect of the voucher program itself, it may make sense to treat participation as a binary decision. However, in this study we are interested in addressing how the quantity of subsidized fertilizer acquired affects household outcomes of interest over time. As can be expected with human nature, not everyone who participates in the subsidy program participates in the same degree, as participants in the subsidy program report acquiring various quantities of subsidized fertilizer across the sample. Therefore, to treat this evaluation in a simple, treatment or no treatment framework, where the household either receives a voucher or does not, would be throwing away information that is highly likely to affect the outcome variables of interest.

Controlling for Unobserved Heterogeneity, c_i

Estimating equation (3) via Pooled OLS will yield inconsistent estimates if c_i is correlated with the observed covariates in the model. For linear models, such as those estimating maize production, net value of rainy-season crop production, value of assets, off-farm income, and total household income, potential correlation between c_i and the other covariates can be controlled by estimating equation (4) in first difference (FD) form as:

$$4)\ \Delta Y_{ijt} = \alpha + \sum_{\mathrm{j=0}}^{\mathrm{J}} \beta_{\mathrm{k}} \mathbf{\Delta S_{i,jt-k}} + б\ \Delta \mathbf{P_{ijt}} + \delta\ \Delta\, \boldsymbol{\omega}_{\mathbf{ijt}} + \boldsymbol{\varsigma}\mathbf{\Delta X_{ijt}} + \Delta\mu_{ijt}$$

where Δ represents the change in the given variable, computed by subtracting its value in year t from its value in year t-1. The first-difference (FD) estimator removes c_i from the model. Estimating equation (5) via FD requires the assumption of strict exogeneity where the covariates must be uncorrelated with $\Delta\mu_{itj}$ in all time periods.

In this study, the model of tobacco production takes on properties of a corner solution, as many people do not grow tobacco, and is thus non-linear. To obtain consistent estimates in non-linear panel models, the covariates must be independent of c_i. This is often a strong assumption, but it can be relaxed by modeling c_i using a framework called either correlated random effects (CRE) or the Mundlak–Chamberlain device, following the works of Mundlak (1978) and Chamberlain (1984). To implement the CRE framework in equation (3), we include a vector of variables containing the means of all time-varying covariates for household *i*, denoted by $\bar{X}i$. These variables have the same value for each household in every year but vary across households (for more on the CRE framework, see Wooldridge 2011).

Controlling for Unobserved Shocks, μ_{ijt}

We also need to consider the fact that estimates of subsidized fertilizer's impact on production and income will still be inconsistent if ΔS_{ijt} is correlated with unobservable time-varying shocks $\Delta\mu_{itj}$ in equation (4) and with $\Delta\mu_{itj}$ in the nonlinear tobacco production model. Many panel studies simply assume zero correlation between covariates and the time varying error, a potentially unrealistic assumption that can lead to biased coefficient estimates, particularly when the covariate of interest is not determined randomly. In this study, the amount of subsidized fertilizer acquired is likely to be correlated with unobserved time-varying factors affecting crop production due to its non-random distribution process.

Subsidized fertilizer, the potentially endogenous explanatory variable of interest in this study is a non-linear corner solution variable, because many households do not receive subsidized fertilizer, but for recipients, the quantities received are relatively continuous. Therefore, we use the control function (CF) method to deal with correlation between ΔS_{ijt} and $\Delta\mu_{itj}$. The CF method entails taking the residuals from a reduced form model where kilograms of subsidized fertilizer acquired by the household is the dependent variable, and then including the residuals from that model as a covariate in the structural models in equations (3) and (4). The significance of the coefficient on the residual both tests and controls for correlation between ΔS_{ijt} and $\Delta \mu_{itj}$. Should the reduced form residual be found to be statistically significant when using the CF approach, bootstrapping should be used to obtain accurate standard errors that take estimation of the reduced form model into account (for more information on the CF approach see Rivers and Vuong 1988, Smith and Blundel 1986, Papke and Wooldridge 2008). This study maintains the assumption that previous quantities of subsidized fertilizer $\Delta S_{it\text{-}k}$ received by the household in past years are predetermined and not correlated with $\Delta \mu_{ijt}$ *in* the current period.

In order to implement the CF approach one needs an instrumental variable (IV) that is correlated with the potentially endogenous variable ΔS_{ijt} but not correlated with the error term in the structural models of production, assets, and income. A good IV for this study is a variable for whether or not a Member of Parliament (MP) resides in the community. This seems like a strong instrument *ex ante* because it is a measure of socio-political capital that could influence the quantity of subsidized fertilizer allocated to a community. Also, there is little reason to believe that this IV is endogenous at the household-level for the following reasons; 1) the IV is a community-level variable that does not affect the household directly; 2) we condition on other covariates $\mathbf{X}_{ijt}$, which control for village-level factors such as distance to the main district town and road access that may affect where a Member of Parliament lives and also household well-being; 3) we use an FD estimator in the linear models and a CRE estimators in the non-linear tobacco production model. These estimators remove time-constant unobservable factors at the village and household-level from the model, which could be correlated with our instrument. Therefore the IV, having a member of parliament in the village, need only be uncorrelated with $\Delta \mu_{ijt}$ the change in unobservable time-varying factors in the error term of the structural models; 5) in order to make a stronger case that our IV is exogenous we use an indirect test, where we regress a variable defined as whether or not a household head attended school on the IV and other variables in our structural model. The idea is that perhaps Members of Parliament live in villages where the population is more educated and likely to vote. Since attending school is a predetermined factor, if the IV shows up as not having a statistically significant affect on education, then it strengthens our argument that it is exogenous. Results from this model indicate that the p-value for the MP variable is 0.22 when estimated as a linear probability model, so having an MP in the village does not affect whether household heads attend school. Ultimately the exogeneity of our instrument, whether or not a member of parliament lives in the village, is a maintained hypothesis, but for the reasons stated above we feel confident that the assumption is reasonable.

Functional form

Maize production, net value of rainy-season crop production, off-farm income and total household income are all estimated in level form, because the distributions of these variables are relatively continuous and because it is not possible to use logs for some households that reported negative net incomes. The value of household livestock and durable assets is measured in log form, because the level form of this variable is highly skewed, but all values are positive.

We use a FD estimator rather that a household fixed-effects estimator to estimate these models for the following three reasons; 1) this study uses inverse probability weights (IPW) to deal with potential attrition bias. The sequential nature of FD makes it preferable to FE when including IPWs. (Attrition will be discussed in the following section). 2) FD provides an efficiency gain over FE in the presence of serial correlation, because with FD the error term is estimated as $\Delta\mu_{ijt}$. 3) We ultimately end up estimating the model using two time periods, so results using FD and FE estimators are virtually the same.

Tobacco production is modeled in a log-normal hurdle framework because a significant number of farmers do not produce tobacco. The log normal hurdle is estimated in two steps. The first step uses a probit estimator where the dependent variable is whether or not the household produces any tobacco. Second, for those who produce tobacco, we estimate the quantity produced in log form. The partial effects of interest incorporate both steps in the log-normal hurdle model (for more information on the log-normal hurdle model see Wooldridge 2011). Since the dependent variables in the models of tobacco production and value of assets are estimated in log form, the coefficients are interpreted as semi-elasticities. Therefore for the variables of kilograms of subsidized fertilizer used, each additional kilogram of subsidized fertilizer affects production by a certain percent.

Data

Data used in this study come from three surveys of rural farm households in Malawi. The first wave of data comes from the Second Integrated Household Survey (IHHS2), a nationally representative survey conducted during the 2002/03 and 2003/04 growing seasons that covers 26 districts. The second wave of data comes from the 2007 Agricultural Inputs Support Survey (AISS1) conducted after the 2006/07 growing season. The budget for AISS1 was much smaller than the budget for IHHS2 and of the 11,280 households interviewed in IHHS2, only 3,485 of them lived in enumeration areas that were re-sampled in 2007. Of these 3,485 households, 2,968 were re-interviewed in 2007, which gives us an attrition rate of 14.8%.

The third wave of data comes from the 2009 Agricultural Inputs Support Survey II (AISS2) conducted after the 2008/09 growing season. The AISS2 survey had a subsequently smaller budget than the AISS1 survey in 2007, so of the 2,968 households first sampled in 2003 and again in 2007, 1,642 of them lived in enumeration areas that were revisited in 2009. Of the 1,642 households in revisited areas, 1,375 were found for re-interview in 2009, which gives us an attrition rate of 16.3% between 2007 and 2009.

Both AISS1 and AISS2 asked respondents how much subsidized fertilizer they received in the past two years as well as in the current year. The IHHS2 survey did not ask recall questions on fertilizer use in prior seasons, so the IHHS2 wave of data cannot be used for measuring the dynamic effect of prior receipt of subsidized fertilizer on contemporaneous production, assets, and income. In total we ultimately end up with 1,375 households in our two-wave balanced panel made up mainly of information from the AISS1 and AISS2 surveys. We use the IHHS2 dataset only to get the quantity of fertilizer acquired by households in the year of that survey in order to set up the variables for lagged quantities of subsidized fertilizer acquired by households.[1]

Lag structure

The AISS1 and AISS2 surveys both ask questions about the quantities of subsidized fertilizer that households receive in current and previous years. Ultimately we are able to obtain current year and three-year-lagged quantities of subsidized fertilizer at the household level. With more years of recall data it would have been useful to give the lags a more flexible structure such as Almon (polynomial distributed) or partial adjustment. Given that we have only three years of lagged values of fertilizer to go along with two panel years of production, assets, and income data, we end up running an unrestricted distributed lag model with subsidized fertilizer quantities in their level form. The dynamic impact of fertilizer subsidies on production, assets and income can be measured using a joint F-test. For robustness, we also run the model as a cross-section using household-level data only from the AISS2 survey in 2008/09, which makes it possible to include current year and five-years of lagged subsidized fertilizer quantities. Testing this alternative specification allows us to see if three years of lagged data are sufficiently long to capture the dynamic effect. This alternative specification comes at a cost, as we are not able to use FD to control for correlation between covariates and c_i. The results from this alternative specification are presented in appendix (B).

Attrition Bias

Potential attrition bias caused by households leaving the panel in different waves for systematic reasons is a major issue that must be addressed. We recognize that the attrition rate is fairly high in this data set at nearly 16% between each survey. To ensure that the results using our balanced panel are robust to attrition bias, we compare our base results with those using inverse probability weights (IPW). The IPW technique involves three steps: (i) use probit to measure whether observable factors in one wave affect whether a household is re-interviewed in the next wave; (ii) obtain the predicted probabilities (Pr_{it}) of being re-interviewed in the following wave; (iii) compute the IPW = ($1/Pr_{it}$) and apply it to all models estimated. For households originally sampled in 2004, the IPW for household i in 2007=$1/Pr_{i2007}$ and the IPW in 2009= $1/(Pr_{i2007}*Pr_{i2009})$. (For more information on IPW see Wooldridge 2011). We multiply the IPW by the survey sampling weights in the first wave to control for the probability of the household being selected for interview from the population.

Fertilizer Prices

Fertilizer prices used in the study are calculated as Malawian Kwacha per kilogram of commercial fertilizer. The price is an aggregation of Urea and Nitrogen/Phosphorus/Potassium (NPK) prices. These prices are based on what respondents in the survey say they paid for commercial fertilizer during the planting season from October to December. For those buying commercially we use the observed price that they paid, while for those who did not buy commercially we use the district median price to proxy for the price that the farmer faces for the input. Fertilizer prices are in real 2009 terms, which is calculated by dividing the nominal price by the CPI in Malawi.

Maize Seed Prices

Seed prices in this study are calculated as Malawian Kwacha per kilogram of commercial seed. These prices are an aggregation of prices for local, composite and hybrid maize varieties, and are based on what respondents in the survey say they paid for commercial purchases during the planting season in Malawi. For those buying seed commercially we use the observed price that they paid, while for those who did not buy commercially we use the district median price to proxy for the price that the farmer faces for the input. Seed prices are in real 2009 terms.

Labor Wage Rates

Wage rates for labor hired by households on their plot are calculated as Malawian Kwacha per day of labor. In the survey we only have wage rates for hired in labor and have no way to value family labor other than to include a variable for adult equivalence as a proxy in our model. For those who hire in labor, we use the price that they pay, while for those who do not hire in labor, we use the district median price to proxy for the price that the farmer faces for the input. Labor wage rates are in real 2009 terms.

Maize and Tobacco Prices

Maize prices used in this study are calculated as the median district price received per kilogram by households in the survey. Tobacco prices are calculated as the median regional price received by households in the survey because there are fewer households who sell tobacco. These are observed prices received by households that directly affect net value of crop production and income but may not be known to farmers at the time of planting. We make the assumption that farmers at planting time know the price they are going to receive at harvest time in order to use these prices in our production, asset and income models. Prices for maize and tobacco are in Malawian Kwacha per kilogram and are in real 2009 terms.

Rainfall

The rainfall variables come from district-level experiment station records. We include the average cumulative annual rainfall over the previous five growing seasons to model farmer expectation. The standard deviation of rainfall over the past five years is also included to give an estimate of rainfall variability. This variable is expected to be negatively related to maize production. We also include cumulative rainfall over the growing season to account for rainfall's impact on production.

All other explanatory variables are constructed from the household surveys.

Results

Table 3.1 presents the data means and medians for variables used in this analysis. The means and medians are displayed for the 2004, 2007 and 2009 survey years, and are based on the 1,375 households for whom we have information from all three survey waves. Note that because the 2004 survey does not contain lagged quantities of subsidized fertilizer received by households, the econometric analysis in this study uses data only from the 2007 and 2009 surveys. Nevertheless, we include descriptive information from 2004 in table 3.1 for comparison. Table 3.1 indicates that mean maize production at the household level increased over time from 523 kilograms/hh in 2004 to 582 kg/hh in 2007 to 616 kg/hh in 2009. Tobacco production at the household level also increased over time from 11.1 kilograms/hh in 2004 to 28.5 kg/hh in 2007 to 71.5 kg/hh in 2009. Real net value of rainy-season crop production increased across waves, due to both an increase in mean production per household and an increase in crop price, as real maize price remained relatively constant between 2004 and 2007 at around 12 kwacha per kg but increased to more than 28 kwacha per kg in 2009. Real tobacco prices increased between 2004 and 2007, from 103 kwacha/kg to 190 kwacha/kg, but then dropped to 130 kwacha/kg in 2009. It is interesting to note that the wage rate for labor increased, as did maize price over time. The correlation between maize price and labor wage rate is 0.29, which makes sense as many workers in Malawi are paid in kind with maize. Mean off-farm household income in 2004 stood at 31,300 kwacha/hh but declined sharply to 10,300 kwacha/hh in 2007. Off-farm income rebounded to an average of 38,800 kwacha/hh in 2009. Total household income made up of all types of farm income plus non-farm income followed the same trend as off-farm income going from 47,400 kwacha/hh in 2004 to 27,200 kwacha/hh in 2007, then back up to 69,000 kwacha/hh in 2009.

Input costs for fertilizer, seed, and land rental generally increased across waves, particularly between 2007 and 2009. Commercial fertilizer prices rose from 83 Kwacha/kg in 2007 to 139 kwacha/kg in 2009, which was likely influenced by a rise in world nitrogen prices. Household size and demographic composition measured in adult equivalence stayed roughly the same at about, four across waves. Household livestock and durable assets increased across survey waves, going from an average of around 32,600 kwacha per household in 2004 to 53,100 kwacha per household in 2007, to 55,700 kwacha per household in 2009. Households' median landholding size remained constant at 0.81 hectares over the three waves while mean landholding varied slightly.

Table 3.2 displays the mean and distribution of the subsidized fertilizer variable over the six years for which data is available going back from 2008/09. Table 3.2 shows that subsidized fertilizer use increased substantially when the program was scaled up starting in the 2005/06 growing season. The average kilograms of subsidized fertilizer received by households declined from 61 kgs/hh in 2006/07 to 55 kgs/hh in 2008/09. This decrease was due to the increase in world fertilizer prices during this time, which forced the government of Malawi to procure and distribute a smaller amount of subsidized fertilizer.

Table 3.3 presents the reduced form results for factors affecting how much subsidized fertilizer a household receives in year t. Recall that this model is estimated via tobit and the coefficients estimated are Average Partial Effects (APE). The instrumental variable (IV), if a member of parliament (MP) resides in the community, is statistically significant at the 2% level. This indicates that it is a strong instrument because it is partially correlated with the quantity of subsidized fertilizer a household receives. The coefficient indicates that on average households in villages with a Member of Parliament get close to seven and a half more kilograms of subsidized fertilizer than households in other villages. This finding highlights the possibility that political connections affect subsidized fertilizer receipt in Malawi.

The quantity of subsidized fertilizer that a household received two years ago has a significant effect on how much subsidized fertilizer the household receives in the current period. The coefficient indicates that each additional kilogram received two years earlier leads to the household receiving a 0.70 fewer kilograms of subsidized fertilizer on average in the current year. This finding indicates that there was some small degree of rotation among beneficiaries, holding the total quantity of program fertilizer distributed in that year constant. In addition, despite guidelines to the contrary, households that own more land receive significantly more subsidized fertilizer. Furthermore, households with fewer assets and female headed households do not receive significantly more subsidized fertilizer. It may seem possible that we are "over-controlling" for female headed households and that the variable may show up insignificant due to multicollinearity. We adjusted the model specifications to exclude other variables such as death in the household and assets which are correlated with female headed households. The female headed household variable did not end up being statistically significant in any of these specifications. There is also marginally significant evidence that households whose heads attended school received about three kilograms more subsidized fertilizer than other households on average.

Table 3.4 presents the results for the factors affecting the value of household livestock and durable assets. Column 1 in table 3.4 presents the results using an OLS estimator, which assumes that the covariates are uncorrelated with both c_i and u_{it} in equation (3). Column 2 presents the value of asset results using the first-difference (FD) estimator which controls for correlation between c_i and the observable covariates but assumes zero correlation between the covariates and Δu_{it} in equation (4). We find that the reduced form residual from the subsidized fertilizer model (results presented in table 3) is not statistically significant when included in the livestock and durable assets model presented in column 2 of table 4[2]. Therefore after first-differencing we find no significant correlation between s_{it} and Δu_{it} so the results in column 2 are assumed to sufficiently control for subsidized fertilizer's potential endogeneity.

Results from table 3.4 indicate that controlling for unobserved heterogeneity (c_i) has a significant impact on whether or not subsidized fertilizer has an effect on value of livestock assets. When c_i is not controlled in column 1) subsidized fertilizer has a significant and positive contemporaneous and dynamic effect on the value of household assets. Conversely, when c_i is controlled in column 2) using the FD estimator, subsidized fertilizer does not have a significant contemporaneous or dynamic effect on the value of household assets. Therefore it may not be realistic to assume that receiving subsidized fertilizer over a period of three or four years will lead to a significant increase in assets for smallholders.

The coefficients in Table 3.4 should be interpreted as semi-elasticities in this log-linear model. We find that female headed households have 77% fewer assets than male headed households. An interesting finding is that having a death in the household leads to the household having 29% higher assets. This may at first seem surprising but the descriptive results from the survey indicate that in 2009 only 11% of households who experienced a death say that they recovered from the shock by selling livestock or other assets, while 31% of households recovered from the shock through support from neighbors or relatives. Therefore, due to social support networks, assets may in fact be higher for those households who have recently experienced a death. The deaths could also be older members of the household who have little impact on wealth creation.

Table 3.5 displays the supply response estimates for factors affecting household level maize production. The reduced form residual is not significant, so the FD estimator used in column 2 of table 3.5 is assumed to sufficiently control for the potential endogeneity of subsidized fertilizer. Results from the FD estimator in column 2 indicate that the quantity of subsidized fertilizer a household receives has a positive and significant contemporaneous effect on maize supply response. According to the FD estimator, each additional kilogram of subsidized fertilizer acquired by the household in year t, leads to an increase in maize production of 1.65 kilograms in that year *ceteris paribus*. The effect of receiving subsidized fertilizer in the previous year has an individually significant effect on maize production in the current year. Each additional kilogram of subsidized fertilizer received in the previous year boosts maize production by 1.82 kilograms in the current year on average.

Subsidized fertilizer acquired either two years ago or three years ago does not individually produce a significant effect on current year maize production. However when the coefficients from receiving a kilogram of subsidized fertilizer in the three previous years are added together and tested, the result is statistically significant (p-value = 0.026). The sum of the coefficients indicates that an additional kilogram of subsidized fertilizer acquired in each of the previous three years boosts maize production in the current year by 3.16 kilograms on average. The increase in maize production from receiving subsidized fertilizer in the past could be due to nutrient build up in the soil, or a learning and experimentation process from receiving subsidized fertilizer over a period of time.

Not surprisingly, having higher assets and more land also leads to significantly greater maize production. Higher maize prices lead to greater maize production as an additional kwacha increase in the price of maize boosts the average household's maize production by 27 kilograms on average. This result is consistent with what we would expect *ex ante*.

Table 3.6 presents the results for factors affecting household-level tobacco production. Recall that this model is set up as a log-normal hurdle model as many people do not grow tobacco, but for those who do, the distribution of production is relatively continuous. Column (1) of table 3.6 presents the results using a pooled estimator that assumes the covariates and the error term are uncorrelated. Column (2) presents the results using the CRE estimator, along with the residuals from the reduced form model to control for endogeneity of subsidized fertilizer. The reduced form residual generated by the model presented in table 3.3 is not statistically significant in the overall log-normal hurdle, but we find evidence that it is significant in hurdle 1 of the model so it is included in the overall model estimation. Therefore the model presented in column (2) should sufficiently control for the potential endogeneity of subsidized fertilizer.

The coefficients in Table 3.6 should be interpreted as semi-elasticities. Results from column (2) in table 3.6 indicate that each additional kilogram of subsidized fertilizer received in the current year increases tobacco production by 0.7%. Recall from table 1 that average tobacco production is 71.5 kilograms per household in 2009, up from 28.5 kilograms per household in 2007. Subsidized fertilizer received in the previous three years does not appear to have a significant effect on tobacco production in the current year, indicating that there is no dynamic effect of receiving subsidized fertilizer in the past on household level tobacco production. Households that are further from the road and from the district capital grow more tobacco. This result may seem surprising but it could be because these households have less access to other non-farm sources of income and need to grow tobacco to earn cash. Households with older heads grow less tobacco, which makes sense as tobacco cultivation is labor intensive. Households where the head attended school grow less tobacco, possibly because these households have other non-farm income opportunities.

Table 3.7 presents the results for factors affecting the net value of rainy-season crop production at the household level. The reduced form residual is not significant, so the FD estimator used in column

2 of table 3.7 is assumed to sufficiently control for the potential endogeneity of subsidized fertilizer. Results from the FD estimator in column 2 shows that each additional kilogram of subsidized fertilizer received in the current year leads to a 174 kwacha increase in crop income in that year, roughly equal to US $1.16. There does not appear to be a significant dynamic effect from subsidized fertilizer on the current year value of rainy-season crop income. Table 3.7 also indicates that value of assets and hectares of land are the major drivers of net value of rainy-season crop production. Results from the model show that a 1 percent increase in value of livestock and durable assets increases the net-value of rainy season crop production by nearly 2,400 kwacha or US $16.00. One extra hectare boosts the net value of rainy-season crop production by about US $63.00 on average. It is also interesting to note that the price of commercial fertilizer has a negative effect on net value of rainy-season crop production. This makes sense as fertilizer is a major cost of production.

Table 3.8 shows the factors influencing off-farm income and table 3.9 shows the factors influencing total household income. Note that the reduced form residual is not significant in either model, so the FD estimator used in column (2) is assumed to sufficiently control for the potential endogeneity of subsidized fertilizer in both table 3.8 and table 3.9. Results from these two tables tell the same story, although the subsidy has positively affected net value of rainy-season crop production in table 3.7, we do not find evidence of spill-over effects from the subsidy to off-farm income in table 3.8 or total household income in table 3.9. We are particularly interested to see if there is any dynamic effect from the subsidy on either of these income measures, as it may take a few years for the benefits of improved crop income to generate increases in off-farm and total household income. We do not find evidence that this occurs over the 3 year lag period covered in this survey data. The lack of statistically significant positive effects of even current year subsidized fertilizer acquisition on current year total income could indicate some crowding out of off-farm activities by the fertilizer subsidy, as households who receive subsidized fertilizer may shift resources away from off-farm work to crop production. This is consistent with the negative coefficient on current year subsidized fertilizer acquisition in the off-farm income model in table 3.8, although this relationship is not statistically significant.

Table 3.10 displays the results for receiving subsidized fertilizer over time on the different indicators of well-being used in this study. Row one presents the contemporaneous effect of receiving subsidized fertilizer in the current year. Row two presents the sum of the effects of receiving a kilogram of subsidized fertilizer in the two previous years, while row three presents the sum of the effects of receiving subsidized fertilizer in the previous three years. In the case of assets and tobacco production, the results are presented as semi-elasticities. The results are presented as elasticities for the other indicators. It is evident from row 1 in table 3.10 that receiving a kilogram of subsidized fertilizer has a significant positive contemporaneous effect on maize production, tobacco production and net value of rainy-season crop production. None of the other contemporaneous effects are statistically significant. The magnitude of the significant coefficients in row one indicate that a one percent increase in subsidized fertilizer receipt during the current year boosts maize production by 0.16% in that year. A one kilogram increase in subsidized fertilizer receipt in the current year boosts tobacco production by 0.70% in that year. A one percent increase in subsidized fertilizer receipt in the current year boosts the net value of rainy-season crop production by 0.50% in that year.

The only significant dynamic effect from receiving subsidized fertilizer is through its impact on maize production, as a one percent increase in the amount of subsidized fertilizer acquired in the previous two years boosts maize production by 0.16% in the current year. There is significant evidence to suggest that a one percent increase in the amount of subsidized fertilizer acquired in the previous three years boosts maize production by 0.17% in the current year. The significance of receiving subsidized fertilizer in the previous periods on maize production in the current period could be due to a buildup of soil organic matter or phosphorus in the soil, or perhaps farmers learn to use fertilizer more effectively when they receive it over a period of time. Receiving subsidized fertilizer over time does not have a significant enduring effect on any of the other well-being indicators in this study.

As mentioned previously, we run two alternative model specifications in order to test the robustness of our results. First, it is possible that there are cumulative effects of successive years of participation in the subsidy program on the dependent variables, and that the effect of receiving subsidized fertilizer in a previous year depends on how much was received in prior years. To test for this possibility, we interact the variable for kilograms of subsidized fertilizer acquired in year t-2 with kilograms of subsidized fertilizer acquired in year t-3, and kilograms of subsidized fertilizer acquired in year t-1 with kilograms of subsidized fertilizer acquired in year t-2. These interactions are included as covariates in the well-being models. Results from this alternative specification are generally similar to the main specification presented in this paper. The interacted lagged effects show virtually no statistical or economic significance when the FD estimator is used, which indicates that the lagged effects of receiving subsidized fertilizer in a prior year can be treated as an independent event.

The second alternative specification estimates the well-being models using household data from 2008/09 only, which then allows us to include current year and five years of lagged subsidized fertilizer quantities as covariates. This approach has the disadvantage of treating the sample as a cross section and thus losing the ability to control for some aspects of unobserved heterogeneity but it does allow us to examine the lagged effects of the subsidy program over a longer period. The results from this alternative specification are virtually the same as the results using the OLS estimator in the main model specifications presented in this paper. Lagged quantities of subsidized fertilizer from four years ago and five years ago seem to have no significant impact on any of the well-being indicators in 2008/09.

Appendix C presents the results for the model specification where lagged quantities of subsidized fertilizer acquired are interacted with one another. Appendix D presents results for the model specification using the 2008/09 household data as a cross-section and including current year and five years of lagged subsidized fertilizer quantities.

Conclusions

Fertilizer subsidies are regaining support as a popular policy tool to increase fertilizer use among small farmers in Africa. Proponents of fertilizer subsidies cite its potential to boost smallholder production and kick-start growth processes that can lift millions of smallholder farmers out of poverty. However, the costs of large-scale fertilizer subsidy programs can be high, as the Malawian government spent 16% of its total budget subsidizing fertilizer and seed during the 2008/09 growing season. Evidence that such programs confer sustained benefits to farm household recipients would bolster the case that fertilizer subsidies may play an important role in reducing chronic rural poverty.

This study uses panel data from Malawi with recall information on how much subsidized fertilizer households have used for the six years going back from the 2008/09 season, to assess the impact of subsidized fertilizer on household assets, crop production, and income over time. Results from this study begin to quantify the household-level benefits of the subsidy program and provide evidence of the dynamic or enduring effects of the program. Our main findings are as follows: first, fertilizer subsidies have a positive and significant contemporaneous impact on maize production at the household-level as each additional kilogram of subsidized fertilizer acquired by the household in year t leads to an increase in maize production of 1.65 kilograms during that year. We also find evidence that subsidized fertilizer has a statistically significant dynamic effect on maize production. One additional kilogram acquired by households in each of the three previous years boosts maize production by 3.16 kilograms in the current year. Second, fertilizer subsidies have a significant current year effect on the quantity of tobacco produced. Each additional kilogram of subsidized fertilizer in the current year boosts tobacco production by 0.7% in that year. We do not find evidence of longer run impacts from the subsidy on tobacco production.

Our third major finding is that subsidized fertilizer has a significant positive contemporaneous effect on the net value of rainy-season crop production at the household level. Each kilogram of subsidized fertilizer received in the current year leads to a US $1.16 increase in net value of rainy-season crop production during that year. These contemporaneous benefits can be contrasted to the full retail price of fertilizer in Malawi, which ranged from roughly US $0.55 to $0.90 per kg during the panel period, although recipient farmers paid only US $0.10 to $0.15 per kg. Fourth, although subsidized fertilizer is found to positively affect the contemporaneous net value of rainy-season crop production, it has no significant impact on off-farm income or total household income either in the current period or over time. This result may indicate that some households that receive subsidized fertilizer re-allocate labor from off-farm activities to on-farm activities. The coefficient on the variable measuring the quantity of subsidized fertilizer acquired in the current year is negative in the off-farm income model, and although it is not statistically significant, it provides some evidence that there may be some crowding out of off-farm work towards on-farm due to the subsidy.

Fifth, we find no significant evidence that receiving subsidized fertilizer in the current year or in past years has any significant impact on increasing the value of household assets, which include small animals, cattle, draft equipment, and durable assets. This result indicates that it may not be realistic to assume that subsidizing fertilizer over a three or four year period will lead to a significant increase in smallholder asset accumulation, at least in the case of Malawi.

This study also finds evidence that households in villages where a member of parliament resides are likely to receive 7.5 more kilograms of subsidized fertilizer on average than households in other villages. This indicates that political connections affect subsidized fertilizer receipt in Malawi. Furthermore, despite guidelines to the contrary, we find that subsidized fertilizer tends to be allocated to households with larger landholdings and that households headed by females and poorer households do not receive significantly more subsidized fertilizer than other households. It is possible that targeting poorer households might reduce the degree of crowding out of commercial fertilizer found in other studies (e.g., Ricker-Gilbert, Jayne, and Chirwa, 2011), and contribute to greater total fertilizer use by recipient farmers.

It is worth noting that this study measures the direct benefits of the subsidy program to recipient farmers, measured in terms of production, assets and income growth. The subsidy program may have had other general equilibrium effects, such as lowering maize prices and boosting agricultural wage rates, which this study does not directly estimate. Finally, it is essential to weigh the benefits and costs of subsidizing fertilizer next to other alternative public investments and policies designed to promote smallholder food security and poverty reduction.

Endnotes

[1] For 692 observations the quantity of subsidized and commercial fertilizer they acquired in year t-3 comes from the 2002/03 growing season since the IHHS2 data took two growing seasons to collect. Therefore for these observations their t-3 fertilizer quantities are actually t-4 quantities. We control for this issue by interacting the t-3 subsidized fertilizer quantity with a dummy for being interviewed in 2002/03 as opposed to those interviewed in 2003/04.

[2] The reduced form model for value of livestock and durable assets does not include value of assets as a covariate

Table 3.1 Means and Medians of Variables Used in the Analysis, by Region and Survey Year

Variables	2004 Mean	2004 Median	2007 Mean	2007 Median	2009 Mean	2009 Median
Dep Var: Kgs of maize produced by hh	523	280	582	350	616	386
Kgs of tobacco produced by hh	11.1	0	28.5	0	71.5	0
Real HH assets in 2009 kwacha * 1,000 [2]	32.6	10.9	52.7	10.7	56.4	13.8
Net value of rain-fed crop production, real 2009 kwacha * 1,000	14.3	9.4	14.9	6.4	24.4	14.7
Real off-farm income, real 2009 kwacha * 1,000	31.3	9.7	10.3	2.6	38.8	13
Net total hh income, real 2009 kwacha * 1,000	47.4	25.4	27.2	13.5	69	39.9
Covariates: Kg Subsidized fertilizer yr t	14.3	0	61	50	55	50
Kg Subsidized fertilizer yr t-1	NA	NA	26	0	68	50
Kg Subsidized fertilizer yr t-2	NA	NA	3.5	0	60	50
Kg Subsidized fertilizer yr t-3	NA	NA	14	0	25	0
Distance to district capital, in km	39	35	39	32	39.5	35
Distance to paved road, in km	17.7	9	17.7	9	17.1	8
=1 if farm credit organization in village	0.3	0	0.3	0	0.3	0
Landholding of hh, in ha	1.05	0.81	0.98	0.81	1.07	0.81
Household head age	45	42	44	41	44	40
=1 if household headed by female	0.3	0	0.3	0	0.3	0
=1 if HH head attended school	0.7	1	0.7	1	0.7	1
Adult Equivalence	3.7	3.5	4.1	3.9	4.3	4
=1 if death in family over past 2 yrs	0.14	0	0.1	0	0.09	0
=1 if chronic illness in family over past 2 yrs	NA	NA	0.1	0	0.17	0
Commercial fert price kw/kg, real 2009 Kwacha	62.4	62.2	83.2	80.6	139	133
Wage rate for ag labor kwacha/day, real 2009 Kwacha	176	173	212.4	151.3	414	405
Land rental price kwacha/hectare, real 2009 Kwacha	3,337	3,361	3,927	3,521	5,999	5,997
Seed price kwacha/kg, real 2009 Kwacha	NA	NA	104	95	178	167
Observed hybrid maize pr., district level, real 2009 Kwacha	11.5	10.9	12	10.7	28.2	30
Tobacco price, regional level, real 2009 Kwacha	103	103	190	203	130	127
Rainfall over growing season, in 1,000 cm	842	809	1,031	993	1,061	1,041
. rainfall over previous five growing seasons	984	878	904	877	913	850
Std. deviation of average cumulative rainfall	226	225	242	227	236	251
=1 if MP in village (Instrumental Variable)	0.3	0	0.3	0	0.1	0

Note: [2] Value of Assets is included as a covariate in all models where it is not the dependent variable; descriptive statistics are weighted by survey weights multiplied by inverse probability weights; 1,375 households followed over all three waves. US $1.00 equal roughly 150 Malawian Kwacha

Table 3.2 Distribution of Variable Measuring Kilograms of Subsidized Fertilizer Acquired by Households in Malawi, by Year

Growing season	Mean kgs. acquired	% of sample within 10 kgs. of mean	Kilograms of Subsidized Fertilizer Acquired at Different Points in the Distribution, by Year				
			10th Percentile	25th percentile	50th percentile	70th percentile	90th percentile
2008/09	56	32	0	0	50	100	100
2007/08	70	0.5	0	0	50	100	100
2006/07	62	0.2	0	0	50	100	100
2005/06	26	5	0	0	0	50	100
2004/05	4	92	0	0	0	0	0
2003/04	15	23	0	0	0	10	20

N=1,375

Table 3.3 Factors Influencing the Quantity of Subsidized Fertilizer Received by Households
(Dependent Variable = Kilograms of Subsidized Fertilizer Received by the Household in Year t)

Covariates	Tobit Estimator with CRE Coefficient	P-value
=1 if MP in community (IV)	7.53**	(0.015)
Kg Subsidized fertilizer yr t-1	0.03	(0.218)
Kg Subsidized fertilizer yr t-2	-0.70***	(0.000)
Kg Subsidized fertilizer yr t-3	-0.07	(0.141)
=1 if farm credit organization in village	1.17	(0.561)
Distance to paved road, in km	-0.05	(0.236)
Distance to district capital, in km	-0.01	(0.687)
log of real hh assets in 2009 kwacha	0.69	(0.401)
total land owned by household in ha	4.28**	(0.016)
log age of hh head	1.36	(0.541)
=1 if household head attended school	2.90	(0.113)
=1 if household headed by female	0.01	(0.999)
Log of adult equivalence in hh	-1.96	(0.628)
=1 if death in family over past 2 yrs	-1.24	(0.791)
=1 if chronic illness in family over past 2 yrs	0.86	(0.759)
Observed harvested hybrid mz price, dist level, real 2009 kwacha	-1.67***	(0.009)
Observed harvested tobacco price, region level, real 2009 kwacha	0.40***	(0.000)
Commercial fertilizer price kwacha/kg, real 2009 kwacha	-0.02	(0.626)
Ag. Labor wage rate Kwacha/day on hh plot, real 2009 kwacha	-0.00	(0.498)
Commercial seed price, Kwacha/kg, real 2009 Kwacha	0.01	(0.583)
cumulative rainfall over current growing season in cm	0.00	(0.885)
Average annual rainfall over previous 5 growing seasons, in cm	-0.08	(0.112)
Std deviation of average long run rainfall	0.01	(0.862)
Subsidyfert_t-3 * year dummy	0.08	(0.117)
2007 year dummy	-88.40***	(0.000)
observations	2,750	
R^2	0.12	

Note: ***, **, * denotes that coefficients are significant at 1%, 5% and 10% level respectively; coefficients are Average Partial Effects (APE) obtained via the *Margins* command in Stata; regression includes district dummies and household averages of all time-varying covariates which are not shown.

Table 3.4 Factors Influencing the Value of Household Assets
(Dependent Variable: Log of Household Livestock and Durable Assets)

Covariates	(1) OLS Estimator Coefficient	P-value	(2) FD Estimator Coefficient	P-value
Kg Subsidized fertilizer yr t	0.004***	(0.000)	0.0004	(0.615)
Kg Subsidized fertilizer yr t-1	0.002***	(0.000)	0.0005	(0.297)
Kg Subsidized fertilizer yr t-2	0.002***	(0.000)	-0.0008	(0.388)
Kg Subsidized fertilizer yr t-3	0.001	(0.270)	0.0005	(0.572)
=1 if farm credit organization in village	0.18*	(0.050)	-	-
Distance to paved road, in km	-0.002	(0.290)	-	-
Distance to district capital, in km	-0.003**	(0.042)	-	-
total land owned by household in ha	0.25***	(0.000)	0.20***	(0.000)
log age of hh head	0.09	(0.360)	-	-
=1 if household head attended school	0.43***	(0.000)	-	-
=1 if household headed by female	-0.73***	(0.000)	-0.77***	(0.000)
Log of adult equivalence in hh	0.52***	(0.000)	0.27*	(0.064)
=1 if death in family over past 2 yrs	0.20*	(0.052)	0.29**	(0.010)
=1 if chronic illness in family over past 2 yrs	-0.07	(0.413)	0.08	(0.448)
Harvest hybrid mz pr., dist level, real 2009 Kw.	0.02	(0.455)	-0.04*	(0.059)
Harvest tobacco pr., region level, real 2009 Kw	-0.01***	(0.000)	-0.01**	(0.013)
Commercial fertilizer price Kw/kg, real 2009 Kw	0.00	(0.830)	-0.002**	(0.032)
Ag. Labor wage rate Kw/day on hh plot, real 2009 kwacha	0.001***	(0.000)	0.0001	(0.174)
Commercial seed price, Kw/kg, real 2009 Kw.	0.002***	(0.000)	0.0006	(0.237)
Cum. rainfall over current growing season in cm	-0.00	(0.689)	-0.0003*	(0.072)
Avg. annual rainfall over prev. 5 growing seasons, in cm	-0.001	(0.387)	-0.003	(0.131)
Std deviation of average long run rainfall	0.001	(0.585)	0.001	(0.257)
Subsidyfert_t-3 * year dummy	0.00	(0.679)	-0.0004	(0.701)
2007 year dummy	0.77**	(0.038)	-	-
Observations	2,750		1,375	
R^2	0.32		0.07	

Note: ***, **, * denotes that coefficients are significant at 1%, 5% and 10% level respectively; OLS estimation includes district dummies. Residual from reduced form model not significant in asset value models so not included in final estimation; constant not shown.

Table 3.5 Factors Influencing Household Maize Production
(Dependent Variable= Kilograms of Maize Produced by the Household in Year t)

	(1) OLS Estimator		(2) FD Estimator	
Covariates	Coefficient	P-value	Coefficient	P-value
Kg Subsidized fertilizer yr t	2.89***	(0.000)	1.65***	(0.004)
Kg Subsidized fertilizer yr t-1	1.80***	(0.008)	1.82***	(0.003)
Kg Subsidized fertilizer yr t-2	2.10**	(0.020)	0.52	(0.507)
Kg Subsidized fertilizer yr t-3	0.54	(0.397)	0.82	(0.441)
=1 if farm credit organization in village	38.88	(0.233)	-	-
Distance to paved road, in km	-0.60	(0.417)	-	-
Distance to district capital, in km	-0.93	(0.109)	-	-
log of real hh assets in 2009 kwacha	83.40***	(0.000)	42.68***	(0.001)
total land owned by household in ha	188.10***	(0.000)	186.73***	(0.000)
log age of hh head	-17.71	(0.600)	-	-
=1 if household head attended school	27.38	(0.303)	-	-
=1 if household headed by female	85.70**	(0.012)	55.74	(0.308)
Log of adult equivalence in hh	69.95*	(0.052)	74.14	(0.121)
=1 if death in family over past 2 yrs	19.97	(0.732)	80.99	(0.378)
=1 if chronic illness in family over past 2 yrs	58.40	(0.111)	123.59***	(0.002)
Observed hybrid mz price, dist level, real 2009 kwacha	36.40***	(0.004)	26.86**	(0.040)
Observed tobacco price, region level, real 2009 kwacha	-0.16	(0.879)	0.79	(0.410)
Commercial fertilizer price kwacha/kg, real 2009 kwacha	0.57	(0.277)	0.85	(0.127)
Ag. Labor wage rate Kwacha/day on hh plot, real 2009 kwacha	0.16	(0.152)	0.11	(0.370)
Commercial seed price, Kwacha/kg, real 2009 Kwacha	0.61***	(0.000)	0.40	(0.175)
cumulative rainfall over current growing season in cm	0.27***	(0.002)	0.22**	(0.017)
Average annual rainfall over previous 5 growing seasons, in cm	0.034	(0.968)	-0.58	(0.510)
Std deviation of average long run rainfall	-1.14	(0.147)	-0.69	(0.376)
Subsidyfert_t-3 * year dummy	0.14	(0.868)	0.31	(0.826)
2007 year dummy	837***	(0.000)	-	-
Observations	2,678		1,348	
R^2	0.43		0.17	

Table 3.5 Continued

Note: ***, **, * denotes that coefficients are significant at 1%, 5% and 10% level respectively; OLS estimation includes district dummies. Residual from reduced form model not significant in maize production models so not included in final estimation; constant not shown.

Table 3.6 Factors Influencing Household Tobacco Production

(Dependent Variable= Log of Kilograms of Tobacco Produced by the Household in Year t)

Covariates	(1) Log-normal Hurdle Pooled Estimation APE	P-value	(2) Log-normal Hurdle CRE Estimation APE	P-value
Residual	-	-	-0.101	(0.674)
Kg Subsidized fertilizer yr t	0.010***	(0.000)	0.007*	(0.095)
Kg Subsidized fertilizer yr t-1	0.002	(0.298)	-0.008	(0.251)
Kg Subsidized fertilizer yr t-2	0.004**	(0.016)	0.107	(0.117)
Kg Subsidized fertilizer yr t-3	-0.002	(0.437)	0.002	(0.838)
=1 if farm credit organization in village	-0.291	(0.409)	-0.717	(0.165)
Distance to paved road, in km	0.017***	(0.002)	0.018**	(0.045)
Distance to district capital, in km	0.019***	(0.000)	0.022***	(0.001)
log of real hh assets in 2009 kwacha	0.385***	(0.000)	0.144	(0.446)
total land owned by household in ha	0.558***	(0.000)	-0.042	(0.933)
log age of hh head	-0.877**	(0.026)	-1.101*	(0.056)
=1 if household head attended school	-0.502*	(0.098)	-0.881*	(0.058)
=1 if household headed by female	-0.966	(0.011)	-2.507*	(0.060)
Log of adult equivalence in hh	0.423	(0.196)	1.070	(0.174)
=1 if death in family over past 2 yrs	0.240	(0.515)	0.019	(0.979)
=1 if chronic illness in family over past 2 yrs	-0.326	(0.392)	-0.345	(0.674)
Hybrid maize price, dist level, real 2009 kwacha	0.101	(0.813)	0.409	(0.341)
Tobacco price, regional level, real 2009 kwacha	0.008	(0.446)	-0.055	(0.185)
Commercial fertilizer pr Kw/kg, real 2009 kwacha	0.010***	(0.004)	0.006	(0.481)
Ag. labor wage rate Kwacha/day on hh plot, real 2009 kwacha	-0.0004	(0.420)	0.0001	(0.889)
Commercial seed price, Kw/kg, real 2009 Kwacha	0.0002	(0.918)	0.002	(0.392)
Cum. rainfall over current growing season in cm	-0.002	(0.262)	-0.001	(0.347)
Average annual rainfall over previous 5 growing seasons, in cm	0.018	(0.161)	0.042**	(0.047)
Std deviation of average long run rainfall	-0.022	(0.213)	-0.034*	(0.071)
Subsidyfert_t-3 * year dummy	15.623***	(0.000)	16.075***	(0.000)
2007 year dummy	0.252	(0.967)	15.110	(0.515)
Observations	2,687		2,687	
Number of bootstrap reps	474		763	

Table 3.6 Continued

Note: ***, **, * denotes that coefficients are significant at 1%, 5% and 10% level respectively; estimation includes district dummies, which are not shown; estimation in column 2 includes household averages for all time varying covariates, which are not shown; coefficients are Average Partial effects (APE); p-values obtained via bootstrapping.

Table 3.7 Factors Influencing the Net Value of Rainy-Season Crop Production
(Dependent Variable = Net Value of Rainy-Season Crop Production by Household in Year t, in 2009 Kwacha)

Covariates	(1) Log-normal Hurdle Pooled Estimation APE	P-value	(2) Log-normal Hurdle Pooled Estimation APE	P-value
Kg Subsidized fertilizer yr t	164**	(0.027)	174***	(0.000)
Kg Subsidized fertilizer yr t-1	-20	(0.349)	-32	(0.388)
Kg Subsidized fertilizer yr t-2	37	(0.217)	56	(0.560)
Kg Subsidized fertilizer yr t-3	23	(0.275)	13	(0.811)
=1 if farm credit organization in village	-6,087***	(0.001)	-	-
Distance to paved road, in km	-13	(0.756)	-	-
Distance to district capital, in km	56**	(0.042)	-	-
log of real hh assets in 2009 kwacha	2,690***	(0.000)	2,427***	(0.003)
total land owned by household in ha	8,930***	(0.000)	9,377***	(0.000)
log age of hh head	-1,162	(0.574)	-	-
=1 if household head attended school	55	(0.973)	-	-
=1 if household headed by female	-974	(0.523)	-6,829	(0.189)
Log of adult equivalence in hh	-600	(0.716)	365	(0.909)
=1 if death in family over past 2 yrs	1,394	(0.639)	1,996	(0.697)
=1 if chronic illness in family over past 2 yrs	-1,003	(0.601)	-1,185	(0.707)
Observed harvested hybrid mz price, dist level, real 2009 kwacha	215	(0.683)	200	(0.750)
Observed harvested tobacco price, region level, real 2009 kwacha	11	(0.875)	-5	(0.951)
Commercial fertilizer price kwacha/kg, real 2009 kwacha	-63**	(0.046)	-65*	(0.058)
Ag. Labor wage rate Kwacha/day on hh plot, real 2009 kwacha	1	(0.911)	1	(0.860)
Commercial seed price, Kwacha/kg, real 2009 Kwacha	-3	(0.760)	-0.00	(1.000)
cumulative rainfall over current growing season in cm	13*	(0.065)	13	(0.105)
Average annual rainfall over previous 5 growing seasons, in cm	83	(0.141)	82	(0.139)
Std deviation of average long run rainfall	-117**	(0.018)	-109**	(0.033)
Subsidyfert_t-3 * year dummy	39	(0.569)	89	(0.421)
2007 year dummy	-6,705	(0.491)	-	-
Constant	-89,912	(0.161)	5,684	(0.669)
Observations	2,750		1,375	
R^2	0.22		0.11	

Table 3.7 Continued

Note: ***, **, * denotes that coefficients are significant at 1%, 5% and 10% level respectively; OLS estimation includes district dummies; reduced form residual not significant, so not included in final estimation.

Table 3.8 Factors Influencing Off-farm Income

(Dependent Variable = Off-farm Income by Household in Year t, in 2009 Kwacha)

Covariates	(1) OLS Estimator Coefficient	(1) OLS Estimator P-value	(2) FD Estimator Coefficient	(2) FD Estimator P-value
Kg Subsidized fertilizer yr t	-44	(0.162)	-114	(0.298)
Kg Subsidized fertilizer yr t-1	7	(0.707)	14	(0.615)
Kg Subsidized fertilizer yr t-2	40	(0.573)	-70	(0.521)
Kg Subsidized fertilizer yr t-3	-4	(0.938)	24	(0.634)
=1 if farm credit organization in village	15,716*	(0.053)	-	-
Distance to paved road, in km	-265***	(0.000)	-	-
Distance to district capital, in km	11	(0.843)	-	-
log of real hh assets in 2009 kwacha	7,825***	(0.000)	2,490	(0.255)
total land owned by household in ha	-13,268***	(0.003)	-9,844	(0.150)
log age of hh head	-5,829	(0.258)	-	-
=1 if household head attended school	2,982	(0.473)	-	-
=1 if household headed by female	-8,813	(0.424)	-1,990	(0.821)
Log of adult equivalence in hh	8,398*	(0.055)	12,064	(0.248)
=1 if death in family over past 2 yrs	3,305	(0.652)	20,280	(0.418)
=1 if chronic illness in family over past 2 yrs	5,108	(0.393)	5,693	(0.261)
Observed harvested hybrid mz price, dist level, real 2009 kwacha	-170	(0.954)	-908	(0.794)
Observed harvested tobacco price, region level, real 2009 kwacha	374**	(0.022)	328**	(0.045)
Commercial fertilizer price kwacha/kg, real 2009 kwacha	129	(0.311)	71	(0.265)
Ag. Labor wage rate Kwacha/day on hh plot, real 2009 kwacha	-2	(0.954)	-10	(0.753)
Commercial seed price, Kwacha/kg, real 2009 Kwacha	51	(0.218)	134	(0.193)
cumulative rainfall over current growing season in cm	32***	(0.006)	25*	(0.069)
Average annual rainfall over previous 5 growing seasons, in cm	-233*	(0.096)	-290*	(0.070)
Std deviation of average long run rainfall	155	(0.279)	204	(0.189)
Subsidyfert_t-3 * year dummy	-31	(0.680)	1	(0.993)
2007 year dummy	-34,291	(0.418)	-	-
Constant	105,067	(0.583)	48,725	(0.360)
Observations	2,750		1,375	
R^2	0.05		0.02	

Table 3.8 Continued

Note: ***, **, * denotes that coefficients are significant at 1%, 5% and 10% level respectively; OLS estimation includes district dummies. Residual from reduced form not significant in off-farm income models so not included in final estimation.

Table 3.9 Factors Influencing Total Household Income
(Dependent Variable = Total Income by Household in Year t, in 2009 Kwacha)

Covariates	(1) OLS Estimator Coefficient	P-value	(2) FD Estimator Coefficient	P-value
Kg Subsidized fertilizer yr t	132	(0.116)	85	(0.459)
Kg Subsidized fertilizer yr t-1	-10	(0.721)	-17	(0.699)
Kg Subsidized fertilizer yr t-2	91	(0.229)	22	(0.882)
Kg Subsidized fertilizer yr t-3	18	(0.737)	39	(0.616)
=1 if farm credit organization in village	7,571	(0.341)	-	-
Distance to paved road, in km	-295***	(0.001)	-	-
Distance to district capital, in km	60	(0.333)	-	-
log of real hh assets in 2009 kwacha	12,470***	(0.000)	6,348**	(0.024)
total land owned by household in ha	-4,565	(0.298)	314.86	(0.965)
log age of hh head	-8,267	(0.146)	-	-
=1 if household head attended school	4,150	(0.336)	-	-
=1 if household headed by female	-7,132	(0.520)	-3,806	(0.727)
Log of adult equivalence in hh	10,220**	(0.024)	16,178	(0.183)
=1 if death in family over past 2 yrs	4,005	(0.595)	21,766	(0.361)
=1 if chronic illness in family over past 2 yrs	3,834	(0.528)	3,942	(0.526)
Observed harvested hybrid mz price, dist level, real 2009 kwacha	501	(0.863)	-159	(0.962)
Observed harvested tobacco price, region level, real 2009 kwacha	406**	(0.022)	327*	(0.070)
Commercial fertilizer price kwacha/kg, real 2009 kwacha	71	(0.569)	3	(0.970)
Ag. Labor wage rate Kwacha/day on hh plot, real 2009 kwacha	-1	(0.966)	-7	(0.816)
Commercial seed price, Kwacha/kg, real 2009 Kwacha	68	(0.237)	148	(0.162)
cumulative rainfall over current growing season in cm	45***	(0.001)	39**	(0.012)
Average annual rainfall over previous 5 growing seasons, in cm	-144	(0.366)	-212	(0.235)
Std deviation of average long run rainfall	13	(0.931)	78	(0.644)
Subsidyfert_t-3 * year dummy	28	(0.779)	118	(0.418)
2007 year dummy	-35,893	(0.406)	-	-
Constant	-26,585	(0.901)	46,703	(0.377)
Observations	2,750		1,375	
R^2	0.09		0.03	

Table 3.9 Continued

Note: ***, **, * denotes that coefficients are significant at 1%, 5% and 10% level respectively; OLS estimation includes district dummies; total household income = net value of rainy season production + net value of dry season production + animal income + ag labor income + off-farm income. Residual from reduced form model not significant in total household income models so not included in final estimation.

Table 3.10 Impact of Subsidized Fertilizer Received Over Time on Measures of Household Well-being

		Value of Assets[1]	Maize Production[2]	Tobacco Production[1]	Value of Rainy Season Crop Production[2]	Non-Farm Income[2]	Total HH Income[2]
1	($\hat{\beta}$ kg. sub. fert. yr t)	0.04 (0.61)	0.16*** (0.00)	0.7* (0.10)	0.50*** (0.00)	-0.26 (0.30)	0.10 (0.45)
2	($\hat{\beta}$ kg. sub. fert. yr t-1 + $\widehat{\beta}$ kg. sub. fert. yr t-2)	-0.03 (0.76)	0.16*** (0.00)	9.90 (0.29)	0.05 (0.80)	-0.09 (0.57)	0.01 (0.96)
3	($\hat{\beta}$ kg Sub. fert. yr t-1 + $\hat{\beta}$ kg Sub. fert. yr t-2 + $\hat{\beta}$ kg Sub. fert. yr t-3)	-0.02 (0.87)	0.17** (0.02)	10.1 (0.35)	0.06 (0.67)	-0.04 (0.77)	0.03 (0.79)
	Mean	Mean Asset Value = 54,711 Kwacha	Mean Maize Production = 614 Kilograms	Mean Tobacco Production = 58 Kilograms	Mean Value of Rainy Season Crop Production = 20,131 Kwacha	Mean Non-farm Income= 25,850 Kwacha	Mean Total HH Income = 50,016 Kwacha

[1] coefficients are semi-elasticities; [2] coefficients are elasticities estimated at data mean; ***, **, * denotes that elasticities are significant at 1%, 5% and 10% level respectively; p-value in parentheses

APPENDICES

APPENDIX C: RESULTS WITH INTERACTION OF LAGGED SUBSIDIZED FERTILIZER QUANTITIES

Table 3.C1 Factors Influencing the Value of Household Assets
(Dependent Variable: Log of Household Livestock and Durable Assets)

	(1) OLS Estimator		(2) FD Estimator	
Covariates	Coefficient	P-value	Coefficient	P-value
Kg Subsidized fertilizer yr t	0.0038***	(0.000)	0.0006	(0.450)
Kg Subsidized fertilizer yr t-1	0.0030***	(0.000)	0.0001	(0.872)
Kg Subsidized fertilizer yr t-2	0.0032***	(0.000)	-0.0010	(0.264)
Kg Subsidized fertilizer yr t-3	0.0006	(0.573)	0.0009	(0.348)
Subsidized fert. t-2 * Subsidized fert. t-3	0.0000	(0.905)	-0.0000	(0.563)
Subsidized fert. t-1 * Subsidized fert. t-2	0.0000***	(0.000)	0.0000	(0.129)
=1 if farm credit organization in village	0.1780*	(0.051)	-	-
Distance to paved road, in km	-0.0018	(0.342)	-	-
Distance to district capital, in km	-0.0027**	(0.042)	-	-
total land owned by household in ha	0.2608***	(0.000)	0.1841***	(0.000)
log age of hh head	0.0861	(0.398)	-	-
=1 if household head attended school	0.4209***	(0.000)	-	-
=1 if household headed by female	-0.7233***	(0.000)	-0.7761***	(0.000)
Log of adult equivalence in hh	0.5079***	(0.000)	0.2720*	(0.063)
=1 if death in family over past 2 yrs	0.1727*	(0.088)	0.2954***	(0.008)
=1 if chronic illness in family over past 2 yrs	-0.0669	(0.456)	0.0766	(0.460)
Observed harv. hybrid mz pr., dist level, real 2009 kw.	0.0183	(0.371)	-0.0392*	(0.055)
Observed harv. tobacco pr., region level, real 2009 kw.	-0.0076***	(0.000)	-0.0050**	(0.014)
Commercial fertilizer price Kw/kg, real 2009 kwacha	0.0003	(0.804)	-0.0024**	(0.035)
Ag. labor wage rate Kw/day on hh plot, real 2009 kw.	0.0006***	(0.000)	0.0001	(0.208)
Commercial seed price, Kw/kg, real 2009 Kwacha	0.0019***	(0.000)	0.0006	(0.236)
cumulative rainfall over current growing season in cm	-0.0000	(0.813)	-0.0003*	(0.066)
Avg. annual rainfall over prev. 5 growing seasons, in cm	-0.0018	(0.350)	-0.0027	(0.137)
Std deviation of average long run rainfall	0.0011	(0.504)	0.0017	(0.269)
Subsidyfert_t-3 * year dummy	0.0006	(0.584)	-0.0006	(0.557)
2007 year dummy	0.8772**	(0.019)	-	-
Constant	8.8250***	(0.000)	0.6759*	(0.080)
Observations	2,750		1,375	
R^2	0.32		0.07	

Table 3.C1 Continued

Note: ***, **, * denotes that coefficients are significant at 1%, 5% and 10% level respectively; OLS estimation includes district dummies. Residual from reduced form model not significant in asset value models so not included in final estimation.

Table 3.C2 Factors Influencing Household Level Maize Production
(Dependent Variable= Kilograms of Maize Produced by the Household in Year t)

Covariates	(1) OLS Estimator Coefficient	P-value	(2) FD Estimator Coefficient	P-value
Kg Subsidized fertilizer yr t	2.88***	(0.000)	1.83***	(0.007)
Kg Subsidized fertilizer yr t-1	1.68	(0.102)	1.52	(0.134)
Kg Subsidized fertilizer yr t-2	2.13***	(0.006)	0.43	(0.582)
Kg Subsidized fertilizer yr t-3	1.39*	(0.066)	1.69	(0.108)
Subsidized fert. t-2 * Subsidized fert. t-3	-0.01	(0.135)	-0.01	(0.325)
Subsidized fert. t-1 * Subsidized fert. t-2	0.00	(0.796)	0.00	(0.521)
=1 if farm credit organization in village	42.16	(0.199)	-	-
Distance to paved road, in km	-0.61	(0.389)	-	-
Distance to district capital, in km	-0.92	(0.114)	-	-
log of real hh assets in 2009 kwacha	84.10***	(0.000)	40.39***	(0.001)
total land owned by household in ha	186.99***	(0.000)	175.83***	(0.000)
log age of hh head	-16.76	(0.632)	-	-
=1 if household head attended school	26.92	(0.314)	-	-
=1 if household headed by female	83.76**	(0.013)	44.94	(0.406)
Log of adult equivalence in hh	68.45*	(0.058)	76.21	(0.120)
=1 if death in family over past 2 yrs	26.03	(0.638)	91.02	(0.320)
=1 if chronic illness in family over past 2 yrs	55.56	(0.121)	122.96***	(0.002)
Observed harvested hybrid mz price, dist level, real 2009 kwacha	36.93***	(0.004)	26.94**	(0.040)
Observed harvested tobacco price, region level, real 2009 kwacha	-0.08	(0.936)	0.77	(0.415)
Commercial fertilizer price Kw/kg, real 2009 kwacha	0.58	(0.259)	0.85	(0.127)
Ag. Labor wage rate Kw/day on hh plot, real 2009 kwacha	0.16	(0.163)	0.10	(0.408)
Commercial seed price, Kw/kg, real 2009 Kwacha	0.60***	(0.000)	0.40	(0.180)
cumulative rainfall over current growing season in cm	0.27***	(0.003)	0.21**	(0.021)
Average annual rainfall over previous 5 growing seasons, in cm	0.01	(0.994)	-0.54	(0.549)
Std deviation of average long run rainfall	-1.12	(0.165)	-0.70	(0.378)
Subsidyfert_t-3 * year dummy	-0.51	(0.528)	0.03	(0.980)
2007 year dummy	835.05***	(0.000)	-	-
Constant	-2,292.24***	(0.000)	-543.36**	(0.016)
Observations	2,687		1,348	
R^2	0.43		0.18	

Table 3.C2 Continued

Note: ***, **, * denotes that coefficients are significant at 1%, 5% and 10% level respectively; OLS estimation includes district dummies. Residual from reduced form model not significant in maize production models so not included in final estimation.

Table 3.C3 Factors Influencing Household Level Tobacco Production

(Dependent Variable= Log of Kilograms of Tobacco Produced by the Household in Year t)

Covariates	(1) Log-normal Hurdle Pooled Estimation APE	P-value	(2) Log-normal Hurdle CRE Estimation APE	P-value
Kg Subsidized fertilizer yr t	0.010***	(0.000)	0.008*	(0.077)
Kg Subsidized fertilizer yr t-1	0.003	(0.317)	-0.010	(0.192)
Kg Subsidized fertilizer yr t-2	0.006***	(0.009)	0.108	(0.270)
Kg Subsidized fertilizer yr t-3	0.001	(0.793)	0.004	(0.828)
Subsidized fert. t-2 * Subsidized fert. t-3	0.000***	(0.000)	0.000***	(0.000)
Subsidized fert. t-1 * Subsidized fert. t-2	0.000	(0.842)	0.000	(0.495)
=1 if farm credit organization in village	-0.275	(0.432)	-0.694	(0.356)
Distance to paved road, in km	0.017***	(0.002)	0.018*	(0.097)
Distance to district capital, in km	0.019***	(0.000)	0.022***	(0.002)
log of real hh assets in 2009 kwacha	0.376***	(0.000)	0.128	(0.571)
total land owned by household in ha	0.599***	(0.000)	-0.034	(0.956)
log age of hh head	-0.901**	(0.021)	-1.122*	(0.053)
=1 if household head attended school	-0.528	(0.086)	-0.923	(0.109)
=1 if household headed by female	-0.968***	(0.009)	-2.704*	(0.085)
Log of adult equivalence in hh	0.417	(0.210)	1.051	(0.239)
=1 if death in family over past 2 yrs	0.195	(0.607)	0.047	(0.960)
=1 if chronic illness in family over past 2 yrs	-0.341	(0.362)	-0.331	(0.679)
Observed harvested hybrid mz price, dist level, real 2009 kwacha	0.104	(0.807)	0.396	(0.447)
Observed harvested tobacco price, region level, real 2009 kwacha	0.008	(0.449)	-0.056	(0.335)
Commercial fertilizer price Kw/kg, real 2009 kwacha	0.010***	(0.004)	0.005	(0.650)
Ag. Labor wage rate Kw/day on hh plot, real 2009 kwacha	0.000	(0.476)	0.000	(0.844)
Commercial seed price, Kw/kg, real 2009 Kwacha	0.000	(0.978)	0.002	(0.482)
cumulative rainfall over current growing season in cm	-0.002	(0.223)	-0.001	(0.434)
Average annual rainfall over previous 5 growing seasons, in cm	0.018	(0.151)	0.043*	(0.098)
Std deviation of average long run rainfall	-0.022	(0.196)	-0.035*	(0.099)
Subsidyfert_t-3 * year dummy	15.505***	(0.000)	15.980***	(0.000)
2007 year dummy	0.381	(0.946)	14.879	(0.562)
Observations	2,687		2,687	
Number of bootstrap reps	1,518		1,518	

Table 3.C3 Continued

Note: ***, **, * denotes that coefficients are significant at 1%, 5% and 10% level respectively; estimation includes district dummies, which are not shown; estimation in column 2 includes household averages for all time varying covariates, which are not shown; coefficients are Average Partial effects (APE); p-values obtained via bootstrapping.

Table 3.C4 Factors Influencing Net Value of Rainy-Season Crop Production

(Dependent Variable = Net Value of Rainy-Season Crop Production by Household in Year t, in 2009 Kwacha)

	(1) OLS Estimator		(2) FD Estimator	
Covariates	Coefficient	P-value	Coefficient	P-value
Kg Subsidized fertilizer yr t	167**	(0.025)	166***	(0.000)
Kg Subsidized fertilizer yr t-1	-37	(0.106)	-17	(0.802)
Kg Subsidized fertilizer yr t-2	11	(0.780)	65	(0.328)
Kg Subsidized fertilizer yr t-3	49	(0.195)	-6	(0.938)
Subsidized fert. t-2 * Subsidized fert. t-3	-0	(0.522)	0	(0.825)
Subsidized fert. t-1 * Subsidized fert. t-2	0	(0.278)	-0	(0.774)
=1 if farm credit organization in village	-6,021***	(0.001)	-	-
Distance to paved road, in km	-18	(0.671)	-	-
Distance to district capital, in km	56**	(0.041)	-	-
log of real hh assets in 2009 kwacha	2,770***	(0.000)	2,504***	(0.002)
total land owned by household in ha	8,580***	(0.000)	9,787***	(0.000)
log age of hh head	-984	(0.632)	-	-
=1 if household head attended school	137	(0.932)	-	-
=1 if household headed by female	-1,124	(0.463)	-6,456	(0.204)
Log of adult equivalence in hh	-453	(0.784)	262	(0.934)
=1 if death in family over past 2 yrs	2,011	(0.490)	1,658	(0.747)
=1 if chronic illness in family over past 2 yrs	-1,202	(0.536)	-1,124	(0.712)
Observed harvested hybrid mz price, dist level, real 2009 kwacha	163	(0.760)	223	(0.703)
Observed harvested tobacco price, region level, real 2009 kwacha	14	(0.839)	-5	(0.943)
Commercial fertilizer price Kw/kg, real 2009 kwacha	-64**	(0.043)	-66*	(0.061)
Ag. Labor wage rate Kw/day on hh plot, real 2009 kwacha	0	(0.969)	2	(0.819)
Commercial seed price, Kw/kg, real 2009 Kwacha	-3	(0.741)	-0	(0.997)
cumulative rainfall over current growing season in cm	12*	(0.073)	13*	(0.092)
Avg. annual rainfall over prev. 5 growing seasons, in cm	86	(0.126)	80	(0.156)
Std deviation of average long run rainfall	-121**	(0.015)	-108**	(0.035)
Subsidyfert_t-3 * year dummy	21	(0.720)	96	(0.342)
2007 year dummy	-8,963	(0.352)	-	-
Observations	2,750		1,375	
R^2	0.23		0.11	

Note: ***, **, * denotes that coefficients are significant at 1%, 5% and 10% level respectively; OLS estimation includes district dummies; reduced form residual not significant, so not included in final estimation; constant not shown.

Table 3.C5 Factors Influencing Off-farm Income
(Dependent Variable = Off-farm Income by Household in Year t, in 2009 Kwacha)

Covariates	(1) OLS Estimator Coefficient	P-value	(2) FD Estimator Coefficient	P-value
Kg Subsidized fertilizer yr t	-42	(0.175)	-132	(0.229)
Kg Subsidized fertilizer yr t-1	19	(0.405)	55	(0.117)
Kg Subsidized fertilizer yr t-2	20	(0.800)	-26	(0.823)
Kg Subsidized fertilizer yr t-3	-136**	(0.029)	41	(0.588)
Subsidized fert. t-2 * Subsidized fert. t-3	1**	(0.014)	-0	(0.606)
Subsidized fert. t-1 * Subsidized fert. t-2	-0	(0.507)	-0*	(0.066)
=1 if farm credit organization in village	15,215*	(0.063)	-	-
Distance to paved road, in km	-266***	(0.000)	-	-
Distance to district capital, in km	9	(0.869)	-	-
log of real hh assets in 2009 kwacha	7,754***	(0.000)	2,633	(0.231)
total land owned by household in ha	-13,282***	(0.003)	-8,949	(0.201)
log age of hh head	-5,898	(0.250)	-	-
=1 if household head attended school	3,104	(0.453)	-	-
=1 if household headed by female	-8,578	(0.435)	-1,329	(0.880)
Log of adult equivalence in hh	8,714**	(0.045)	11,737	(0.267)
=1 if death in family over past 2 yrs	2,620	(0.714)	19,676	(0.432)
=1 if chronic illness in family over past 2 yrs	5,470	(0.364)	5,974	(0.243)
Observed harvested hybrid mz price, dist level, real 2009 kwacha	-294	(0.922)	-768	(0.823)
Observed harvested tobacco price, region level, real 2009 kwacha	364**	(0.026)	322*	(0.050)
Commercial fertilizer price Kw/kg, real 2009 kwacha	126	(0.319)	65	(0.301)
Ag. Labor wage rate Kw/day on hh plot, real 2009 kwacha	-1	(0.970)	-9	(0.777)
Commercial seed price, Kw/kg, real 2009 Kwacha	54	(0.198)	133	(0.194)
cumulative rainfall over current growing season in cm	31***	(0.006)	27**	(0.048)
Average annual rainfall over previous 5 growing seasons, in cm	-227	(0.103)	-294*	(0.066)
Std deviation of average long run rainfall	150	(0.293)	210	(0.182)
Subsidyfert_t-3 * year dummy	70	(0.330)	5	(0.956)
2007 year dummy	-35,358	(0.413)	-	-
Constant	8,873	(0.942)	43,842	(0.399)
Observations	2,750		1,375	
R^2	0.05		0.02	

Table 3.C5 Continued

Note: ***, **, * denotes that coefficients are significant at 1%, 5% and 10% level respectively; OLS estimation includes district dummies; reduced form residual not significant, so not included in final estimation.

Table 3.C6 Factors Influencing Total Household Income

(Dependent Variable = Total Income by Household in Year t, in 2009 Kwacha)

	(1) OLS Estimator		**(2) FD Estimator**	
Covariates	Coefficient	P-value	Coefficient	P-value
Kg Subsidized fertilizer yr t	136	(0.104)	57	(0.619)
Kg Subsidized fertilizer yr t-1	-13	(0.703)	47	(0.584)
Kg Subsidized fertilizer yr t-2	54	(0.524)	91	(0.510)
Kg Subsidized fertilizer yr t-3	-74	(0.301)	68	(0.523)
Subsidized fert. t-2 * Subsidized fert. t-3	1	(0.149)	-0	(0.517)
Subsidized fert. t-1 * Subsidized fert. t-2	0	(0.798)	-1	(0.252)
=1 if farm credit organization in village	7,199	(0.368)	-	-
Distance to paved road, in km	-299***	(0.000)	-	-
Distance to district capital, in km	59	(0.343)	-	-
log of real hh assets in 2009 kwacha	12,471***	(0.000)	6,563**	(0.019)
total land owned by household in ha	-4,840	(0.283)	1,666	(0.819)
log age of hh head	-8,192	(0.148)	-	-
=1 if household head attended school	4,313	(0.315)	-	-
=1 if household headed by female	-7,049	(0.524)	-2,814	(0.795)
Log of adult equivalence in hh	10,597**	(0.019)	15,678	(0.201)
=1 if death in family over past 2 yrs	3,895	(0.599)	20,859	(0.381)
=1 if chronic illness in family over past 2 yrs	3,988	(0.515)	4,374	(0.478)
Observed harvested hybrid mz price, dist level, real 2009 kwacha	357	(0.903)	56	(0.986)
Observed harvested tobacco price, region level, real 2009 kwacha	399**	(0.024)	318*	(0.079)
Commercial fertilizer price Kw/kg, real 2009 kwacha	68	(0.584)	-6	(0.932)
Ag. Labor wage rate Kw/day on hh plot, real 2009 kwacha	-1	(0.972)	-6	(0.857)
Commercial seed price, Kw/kg, real 2009 Kwacha	70	(0.226)	147	(0.165)
cumulative rainfall over current growing season in cm	44***	(0.001)	41***	(0.007)
Average annual rainfall over previous 5 growing seasons, in cm	-137	(0.390)	-218	(0.224)
Std deviation of average long run rainfall	6	(0.967)	87	(0.611)
Subsidyfert_t-3 * year dummy	100	(0.288)	124	(0.359)
2007 year dummy	-38,492	(0.382)	-	-
Constant	-85,414	(0.521)	39,202	(0.444)
Observations	2,750		1,375	
R^2	0.09		0.03	

Table 3.C6 Continued

Note: ***, **, * denotes that coefficients are significant at 1%, 5% and 10% level respectively; OLS estimation includes district dummies; reduced form residual not significant, so not included in final estimation.

APPENDIX D: RESULTS WITH 2008/09 HOUSEHOLD DATA AND FIVE YEARS OF LAGGED SUBSIDIZED FERTILIZER DATA

Table 3.D1 Factors Influencing the Value of Household Assets

(Dependent Variable: Log of Household Livestock and Durable Assets)

Covariates	(1) OLS Estimator Coefficient	P-value
Kg Subsidized fertilizer yr t	0.0032***	(0.000)
Kg Subsidized fertilizer yr t-1	0.0027***	(0.000)
Kg Subsidized fertilizer yr t-2	0.0023***	(0.000)
Kg Subsidized fertilizer yr t-3	0.0018**	(0.024)
Kg Subsidized fertilizer yr t-4	-0.0015	(0.517)
Kg Subsidized fertilizer yr t-5	0.0010	(0.158)
=1 if farm credit organization in village	0.1745*	(0.095)
Distance to paved road, in km	-0.0022	(0.319)
Distance to district capital, in km	-0.0022	(0.149)
total land owned by household in ha	0.2018***	(0.001)
log age of hh head	0.0735	(0.540)
=1 if household head attended school	0.3938***	(0.000)
=1 if household headed by female	-0.7391***	(0.000)
Log of adult equivalence in hh	0.4838***	(0.000)
=1 if death in family over past 2 yrs	-0.0444	(0.755)
=1 if chronic illness in family over past 2 yrs	-0.0436	(0.702)
Observed harvested hybrid mz price, dist level, real 2009 kw	0.0502	(0.146)
Observed harvested tobacco price, region level, real 2009 kwacha	0.0255***	(0.007)
Commercial fertilizer price Kw/kg, real 2009 kwacha	0.0027**	(0.036)
Ag. Labor wage rate Kw/day on hh plot, real 2009 kwacha	0.0005***	(0.000)
Commercial seed price, Kw/kg, real 2009 Kwacha	0.0017**	(0.036)
cumulative rainfall over current growing season in cm	-0.0002	(0.506)
Average annual rainfall over previous 5 growing seasons, in cm	0.0000	(0.952)
Std deviation of average long run rainfall	-0.0012	(0.368)
Constant	2.6131*	(0.061)
Observations	1,375	
R^2	0.36	

Note: ***, **, * denotes that coefficients are significant at 1%, 5% and 10% level respectively; OLS estimation includes district dummies.

Table 3.D2 Factors Influencing Household Level Maize Production
(Dependent Variable= Kilograms of Maize Produced by the Household in Year t)

Covariates	(1) OLS Estimator Coefficient	P-value
Kg Subsidized fertilizer yr t	1.43***	(0.006)
Kg Subsidized fertilizer yr t-1	2.06***	(0.008)
Kg Subsidized fertilizer yr t-2	2.52***	(0.009)
Kg Subsidized fertilizer yr t-3	-0.04	(0.945)
Kg Subsidized fertilizer yr t-4	-0.80	(0.435)
Kg Subsidized fertilizer yr t-5	0.13	(0.788)
=1 if farm credit organization in village	36.29	(0.424)
Distance to paved road, in km	-1.04	(0.313)
Distance to district capital, in km	-0.77	(0.225)
log of real hh assets in 2009 kwacha	88.03***	(0.000)
total land owned by household in ha	177.24***	(0.000)
log age of hh head	-22.62	(0.612)
=1 if household head attended school	24.68	(0.525)
=1 if household headed by female	143.59***	(0.007)
Log of adult equivalence in hh	61.58	(0.341)
=1 if death in family over past 2 yrs	3.04	(0.975)
=1 if chronic illness in family over past 2 yrs	33.01	(0.492)
Observed harvested hybrid mz price, dist level, real 2009 kwacha	-49.25**	(0.026)
Observed harvested tobacco price, region level, real 2009 kwacha	-0.29	(0.950)
Commercial fertilizer price Kw/kg, real 2009 kwacha	0.43	(0.539)
Ag. Labor wage rate Kw/day on hh plot, real 2009 kwacha	0.17	(0.212)
Commercial seed price, Kw/kg, real 2009 Kwacha	0.68***	(0.003)
cumulative rainfall over current growing season in cm	0.45**	(0.022)
Average annual rainfall over previous 5 growing seasons, in cm	-0.72**	(0.034)
Std deviation of average long run rainfall	-0.62	(0.459)
Constant	550.84	(0.431)
Observations	1,375	
R^2	0.45	

Note: ***, **, * denotes that coefficients are significant at 1%, 5% and 10% level respectively; OLS estimation includes district dummies.

Table 3.D3 Factors Influencing Net Value of Rainy-Season Crop Production
(Dependent Variable = Net Value of Rainy-Season Crop Production by Household in Year t, in 2009 Kwacha)

Covariates	**(1) OLS Estimator** Coefficient	P-value
Kg Subsidized fertilizer yr t	118***	(0.000)
Kg Subsidized fertilizer yr t-1	-17	(0.470)
Kg Subsidized fertilizer yr t-2	45	(0.155)
Kg Subsidized fertilizer yr t-3	17	(0.484)
Kg Subsidized fertilizer yr t-4	-58	(0.125)
Kg Subsidized fertilizer yr t-5	-28	(0.455)
=1 if farm credit organization in village	-9,209***	(0.002)
Distance to paved road, in km	-76	(0.173)
Distance to district capital, in km	87**	(0.031)
log of real hh assets in 2009 kwacha	4,088***	(0.000)
total land owned by household in ha	10,256***	(0.000)
log age of hh head	983	(0.721)
=1 if household head attended school	1,961	(0.422)
=1 if household headed by female	973	(0.700)
Log of adult equivalence in hh	-1,857	(0.535)
=1 if death in family over past 2 yrs	6,618	(0.191)
=1 if chronic illness in family over past 2 yrs	-2,284	(0.408)
Observed harvested hybrid mz price, dist level, real 2009 kwacha	3,000***	(0.001)
Observed harvested tobacco price, region level, real 2009 kwacha	-892***	(0.005)
Commercial fertilizer price Kw/kg, real 2009 kwacha	-76*	(0.052)
Ag. Labor wage rate Kw/day on hh plot, real 2009 kwacha	0	(0.935)
Commercial seed price, Kw/kg, real 2009 Kwacha	-18	(0.240)
cumulative rainfall over current growing season in cm	-1	(0.918)
Average annual rainfall over previous 5 growing seasons, in cm	43**	(0.015)
Std deviation of average long run rainfall	41	(0.363)
Constant	-30,171	(0.434)
Observations	1,375	
R^2	0.24	

Note: ***, **, * denotes that coefficients are significant at 1%, 5% and 10% level respectively; OLS estimation includes district dummies.

Table 3.D4 Factors Influencing Off-farm Income
(Dependent Variable = Off-farm Income by Household in Year t, in 2009 Kwacha)

Covariates	(1) OLS Estimator Coefficient	P-value
Kg Subsidized fertilizer yr t	-116	(0.214)
Kg Subsidized fertilizer yr t-1	25	(0.453)
Kg Subsidized fertilizer yr t-2	36	(0.725)
Kg Subsidized fertilizer yr t-3	-48	(0.679)
Kg Subsidized fertilizer yr t-4	93	(0.594)
Kg Subsidized fertilizer yr t-5	-80	(0.552)
=1 if farm credit organization in village	22,299	(0.115)
Distance to paved road, in km	-440***	(0.001)
Distance to district capital, in km	17	(0.864)
log of real hh assets in 2009 kwacha	11,758***	(0.004)
total land owned by household in ha	-23,747***	(0.006)
log age of hh head	-5,726	(0.491)
=1 if household head attended school	3,012	(0.642)
=1 if household headed by female	-16,151	(0.426)
Log of adult equivalence in hh	14,143**	(0.048)
=1 if death in family over past 2 yrs	11,736	(0.389)
=1 if chronic illness in family over past 2 yrs	9,263	(0.290)
Observed harvested hybrid mz price, dist level, real 2009 kwacha	-10,989***	(0.008)
Observed harvested tobacco price, region level, real 2009 kwacha	1,293*	(0.076)
Commercial fertilizer price Kw/kg, real 2009 kwacha	154	(0.471)
Ag. Labor wage rate Kw/day on hh plot, real 2009 kwacha	-9	(0.808)
Commercial seed price, Kw/kg, real 2009 Kwacha	95	(0.141)
cumulative rainfall over current growing season in cm	69**	(0.015)
Average annual rainfall over previous 5 growing seasons, in cm	-103**	(0.042)
Std deviation of average long run rainfall	-207**	(0.025)
Constant	120,995	(0.427)
Observations	1,375	
R^2	0.05	

Note: ***, **, * denotes that coefficients are significant at 1%, 5% and 10% level respectively; OLS estimation includes district dummies.

Table 3.D5 Factors Influencing Total Household Income

(Dependent Variable = Total Income by Household in Year t, in 2009 Kwacha)

Covariates	(1) OLS Estimator Coefficient	P-value
Kg Subsidized fertilizer yr t	51	(0.596)
Kg Subsidized fertilizer yr t-1	11	(0.790)
Kg Subsidized fertilizer yr t-2	85	(0.415)
Kg Subsidized fertilizer yr t-3	-40	(0.719)
Kg Subsidized fertilizer yr t-4	127	(0.588)
Kg Subsidized fertilizer yr t-5	-114	(0.397)
=1 if farm credit organization in village	10,421	(0.452)
Distance to paved road, in km	-532***	(0.000)
Distance to district capital, in km	104	(0.339)
log of real hh assets in 2009 kwacha	18,886***	(0.000)
total land owned by household in ha	-14,586*	(0.084)
log age of hh head	-7,147	(0.438)
=1 if household head attended school	6,304	(0.343)
=1 if household headed by female	-10,287	(0.609)
Log of adult equivalence in hh	16,023**	(0.036)
=1 if death in family over past 2 yrs	17,923	(0.198)
=1 if chronic illness in family over past 2 yrs	6,859	(0.439)
Observed harvested hybrid mz price, dist level, real 2009 kwacha	-9,441**	(0.028)
Observed harvested tobacco price, region level, real 2009 kwacha	702	(0.361)
Commercial fertilizer price Kw/kg, real 2009 kwacha	79	(0.700)
Ag. Labor wage rate Kw/day on hh plot, real 2009 kwacha	-10	(0.794)
Commercial seed price, Kw/kg, real 2009 Kwacha	108	(0.229)
cumulative rainfall over current growing season in cm	74**	(0.017)
Average annual rainfall over previous 5 growing seasons, in cm	-71	(0.191)
Std deviation of average long run rainfall	-244**	(0.020)
Constant	85,319	(0.581)
Observations	1,375	
R^2	0.08	

Note: ***, **, * denotes that coefficients are significant at 1%, 5% and 10% level respectively; OLS estimation includes district dummies.

REFERENCES

REFERENCES

Alwang, J., and P.B. Siegel. 1999. “Labor Shortages on Small Landholdings in Malawi: Implications for Policy Reforms.” *World Development* 27(8): 1461-1475.

Bryceson, D.F. 2006. “Ganyu Casual Labour, Famine and HIV/AIDS in Rural Malawi: Causality and Casualty.” Jou*rnal of Modern African Studies* 44(2): 173-202.

Chamberlain, G. 1984. “Panel data”. In Grilliches, Z., Intriligator, M.D., eds. *Handbook of Econometrics*, Vol. 2 North Holland, Amsterdam. 1247-1318.

Chibwana, C., M. Fisher, G. Shively. 2010. “Land Allocation Effects of Agricultural Input Subsidies in Malawi.” (in press) *World Development*.

Dorward, A., J. Kydd, J. Morrison, and I. Urey. 2004. “A Policy Agenda for Pro-Poor Agricultural Growth.” *World Development* 32(1):73-84.

Dorward, A., E. Chirwa, V. Kelly, T.S. Jayne, R. Slater, and D. Boughton. 2008. “Evaluation of the 2006/07 Agricultural Input Subsidy Programme, Malawi.” Final Report. Lilongwe, Malawi.

Dorward, A., and E. Chirwa. 2011. “The Malawi Agricultural Input Subsidy Programme: 2005/06 to 2008/09.” *International Journal of Agricultural Sustainability.* (16): 232-247.

Duflo, E., M. Kremer, and J. Robinson. 2009. “Nudging Farmers to Use Fertilizer: Theory and Experimental Evidence from Kenya.” NBER Working Paper No. 15131, Cambridge MA.

Dugger, C. W. 2007. Ending Famine, Simply by Ignoring the Experts. *New York Times,* December 2, 2007, p. 1.

GRAIN. 2010. *Unraveling the “Miracle” of Malawi’s Green Revolution.* Barcelona, Spain

Harrigan, J. 2008. “Food Insecurity, Poverty and the Malawian Starter Pack: Fresh Start or False Start?” *Food Policy* 3: 237-49.

Holden S., and R. Lunduka. 2010. “Too Poor to be Efficient? Impacts of the targeted fertilizer subsidy program in Malawi on farm plot level input use, crop choice and land productivity.” Unpublished Manuscript, Depart. of Econ. and Resource Management. Norwegian University of Life Sciences.

IMF, 2010. Fifth Review Under the Three-Year Arrangement Under the Extended Credit Facility, Requests for Waiver of Nonobservance of Performance Criterion and Modification of Performance Criteria, and Financing Assurances Review. International Monetary Fund, Washington, DC.

Morris, M., V.A. Kelly, R.J. Kopicki, and D. Byerlee. 2007. *Fertilizer Use in African Agriculture: Lessons Learned and Good Practice Guidelines.* Washington D.C.: The World Bank.

Mundlak, Y. 1978. “On the Pooling of Time Series and Cross Section Data.” *Econometrica* 46: 69-85.

Nkonde, C., N.M. Mason, N.J. Sitko, and T.S. Jayne. 2011. "Who Gained and Who Lost from Zambia's 2010 Maize Marketing Policies?" FSRP Working Paper #49, Department of Agricultural, Food and Resource Economics, Michigan State University.

Pakes and Griliches. 1980. "Patents and R&D at the Firm Level: A First Report." *Economic Letters* 5:377-381.

Papke, L.E., and J.M. Wooldridge. 2008. Panel Data Methods for Fractional Response Variables with an Application to Test Pass Rates. *Journal of Econometrics* 145: 121-133.

Ricker-Gilbert, J., T.S. Jayne and E. Chirwa. 2011. "Subsidies and Crowding Out: A Double-Hurdle Model of Fertilizer Demand in Malawi." *American Journal of Agricultural Economics.* 93(1): 26-42.

Rivers, D., and Q.H. Vuong. 1988. "Limited Information Estimators and Exogeneity Tests for Simultaneous Probit Models." *Journal of Econometrics* 39: 347-366.

Singh, I., L. Squire, and J. Strauss. 1986. *Agricultural Household Models*. Baltimore: Johns Hopkins University Press.

Smith, R., and R. Blundell. 1986. "An Exogeneity Test for a Simultaneous Equation Tobit Model with an Application to Labor Supply," *Econometrica* 54: 679-685.

Wooldridge, J.M. 2011. *Econometric Analysis of Cross Section and Panel Data, 2nd Edition*. London: MIT Press.

Xu, Z., W.J. Burke, T.S. Jayne., and J. Govereh. 2009. "Do Input Subsidy Programs "Crowd In" or "Crowd Out" Commercial Market Development? Modeling Fertilizer Use Decisions in a Two-Channel Marketing System." *Agricultural Economics* 40(1): 79-94.