Staff Paper

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

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Staff Paper 2011-09 **July 2011**

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The authors gratefully acknowledge funding support for this study from the United States Agency for International Development (USAID) Environment, Growth, and Technology Division to the Food Security III Cooperative Agreement at Michigan State University.

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Abstract

This article 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.

Introduction

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) $K_t = f(S_{t-L}, \varepsilon_t)$

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) $Y_t = f(K_t, X_t, P_t, \omega_t, T_t, C_t, v_t)$

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) $$\mathrm{Y}_{ijt} = \alpha + \sum_{\mathrm{j}=0}^{\mathrm{J}} \beta_{\mathrm{k}} \mathbf{S}_{\mathbf{i,jt-L}} + 6\mathbf{P}_{\mathbf{ijt}} + \delta\boldsymbol{\omega}_{\mathbf{ijt}} + \boldsymbol{ç}\mathbf{X}_{\mathbf{ijt}} + c_i + \mu_{ijt}$$

where Y_{ijt} 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 **ω**. 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 (c_i and μ_{ijt}) 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:

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

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 $\Delta\mu_{ijt}$ 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 $\Delta\mu_{ijt}$ in equation (4) and with μ_{ijt} 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 $\Delta\mu_{ijt}$. 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 μ_{ijt}. 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 ΔS_{it-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.[i]

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.

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 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 1 for comparison. Table 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 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 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 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 4 presents the results for the factors affecting the value of household livestock and durable assets. Column 1 in table 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.[ii] 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 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 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 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 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 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 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 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 6 should be interpreted as semi-elasticities. Results from column (2) in table 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 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 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 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 8 shows the factors influencing off-farm income and table 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 8 and table 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 7, we do not find evidence of spill-over effects from the subsidy to off-farm income in table 8 or total household income in table 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 8, although this relationship is not statistically significant.

Table 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 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.

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.

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Table 1: Means and Medians of Variables Used in the Analysis, by Region and Survey Year

	2004		2007		2009	
Variables	Mean	Median	Mean	Median	Mean	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[1]	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 price, 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
Avg. cumulative 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: [1] 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 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: Factors Influencing the Quantity of Subsidized Fertilizer Received by Households
(Dependent Variable = Kilograms of Subsidized Fertilizer Received by the Household in Year t)

	Tobit Estimator with CRE	
Covariates	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)
Number of 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 4: Factors Influencing the Value of Household Assets
(Dependent Variable: Log of Household Livestock and Durable Assets)

Covariates	(1) POLS 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)
Observed harvested hybrid mz price, dist level, real 2009 kwacha	0.02	(0.455)	-0.04*	(0.059)
Observed harvested tobacco price, region level, real 2009 kwacha	-0.01***	(0.000)	-0.01**	(0.013)
Commercial fertilizer price Kw/kg, real 2009 kwacha	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 Kwacha	0.002***	(0.000)	0.0006	(0.237)
cumulative rainfall over current growing season in cm	-0.00	(0.689)	-0.0003*	(0.072)
Average annual rainfall over previous 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)	-	-
Constant	9.28***	(0.000)	0.65*	(0.093)
Number of 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.

Table 5: Factors Influencing Household Maize Production
(Dependent Variable= Kilograms of Maize Produced by the Household in Year t)

Covariates	(1) POLS Estimator Coefficient	P-value	(2) FD Estimator 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)	-	-
Constant	-2,736**	(0.013)	-553**	(0.013)
Number of Observations	2,678		1,348	
R^2	0.43		0.17	

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 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)
Number of Observations	2,687		2,687	
Number of bootstrap reps	474		763	

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 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) POLS Estimator APE	(1) POLS Estimator P-value	(2) FD Estimator APE	(2) FD Estimator 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	

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 8: Factors Influencing Off-farm Income

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

	(1)		**(2)**	
	POLS Estimator		**FD Estimator**	
Covariates	Coefficient	P-value	Coefficient	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)
Number of Observations	2,750		1,375	
R^2	0.05		0.02	

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 9: Factors Influencing Total Household Income

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

Covariates	(1) POLS 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	

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 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 Subsidized fertilizer 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 Subsidized fertilizer yr t-1 + $\widehat{\beta}$ kg Subsidized fertilizer 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 Subsidized fertilizer yr t-1 + $\hat{\beta}$ kg Subsidized fertilizer yr t-2 + $\hat{\beta}$ kg Subsidized fertilizer 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

[i] 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.

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