Do Fertilizer Subsidies Affect the Demand for Commercial Fertilizer? An Example from Malawi.

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Food production is the major income component for the vast majority of rural African households, so increasing yields is essential for reducing poverty and improving livelihoods. There is widespread agreement that increased use of fertilizer and other productivity-enhancing inputs is a precondition for rural productivity growth and poverty reduction. While the benefits of using fertilizer are widely known, in 2002 fertilizer use in sub-Saharan Africa (SSA) stood at just 8 kg/ha compared to 78 kg/ha in Latin America and 101 kg/ha in South Asia (Morris et al. 2007). In an attempt to boost yields and food supplies, several African countries have re-introduced fertilizer subsidies after phasing them out in the 1990's. While the rationale of fertilizer subsidy programs is to raise fertilizer use and food production, these programs are often implemented without any empirical evidence of their impacts. The economics of subsidies not only depends on crop/fertilizer response rates, crop prices, and fertilizer prices, but also on the extent to which they increase total fertilizer use.

The objective of this study is to determine whether or not providing subsidized fertilizer to farmers significantly increases the quantity of inputs they use. It is possible that making fertilizer less expensive increases the quantity that farmers purchase. It could be that subsidizing fertilizer allows farmers to spend less money acquiring the same amount of fertilizer that they would have purchased at commercial prices. Knowing the extent to which the subsidy program displaces commercial fertilizer sales is important for measuring the costs and benefits of the program.

This study also provides evidence about whether farmers make input market decisions simultaneously or sequentially. There has been recent evidence that farmers in SSA make decisions about livestock output supply sequentially, first deciding to participate and then making quantity decisions (Bellemare and Barrett 2006). This has not been examined for input markets in SSA. Simultaneous decisions would indicate that farmers make participation and quantity purchase decisions at the same time. This would mean that their demand for fertilizer is inelastic, thus leaving them unable to adapt to changing market conditions and susceptible to market power exerted by fertilizer sellers. Sequential decision making indicates that farmers pay attention to market conditions, decide to participate and then decide how much fertilizer to buy.

This study uses panel data from Malawi, which recently implemented a large fertilizer subsidy program, to determine how receiving subsidized fertilizer affects (1) a farmer's decision to participate in the commercial fertilizer market, and (2) the amount of commercial fertilizer that a farmer purchases and whether or not this decision is made sequentially or simultaneously. Malawi makes for an interesting case study because since 2005/06 the country has implemented an innovative "input voucher program" where the government distributes vouchers to farmers that can be redeemed at private fertilizer dealerships. The program received popular acclaim in a front-page New York Times article (Dugger 2007). However, relatively little is known about the extent to which the program has affected total fertilizer use and whether or not it has been cost-effective.

Our study provides information that is highly relevant to current agricultural policy debates in Africa. In addition it makes several contributions to the academic literature. First, this study uses panel data methods to more consistently evaluate input demand. Many past studies that model fertilizer demand only do so in a cross- sectional context and thus are unable to account for unobserved heterogeneity. This study contributes to the scarce literature on input demand using panel data and uses correlated random effects to control for time-constant unobservable factors in a non-linear panel data context. The study also introduces some innovations for addressing time-varying unobservables.

Second this study provides (1) average partial effect (APE) estimates for factors influencing input market participation (2) APE's for factors affecting commercial demand and (3) an overall unconditional APE of subsidized fertilizer on commercial fertilizer purchases. Past studies only give partial effects at the average (PAE) and do not give an overall unconditional average partial effect of displacement (Xu et al. 2009). The APEs are more useful than the PAE for measuring displacement when many observations have zero values for fertilizer use. With unconditional APE we can better understand how subsidized fertilizer affects commercial sales with is essential for measuring the costs and benefits of the subsidy program.

The third contribution of this study is that it accounts for the fact that decisions to participate in the commercial fertilizer market and decisions about the quantity of fertilizer purchased may be made simultaneously or sequentially. The receipt of subsidized fertilizer may influence both of these decisions. Previous studies have looked at market participation and amount consumed as separate decisions in a variety of other contexts (Jones 1992; Garcia and Labeaga 1996, Croppenstedt et al. 2003, Bellemare et al. 2006). Testing for simultaneous or sequential decision making will offer insight into how farmers make input purchase decisions.

Perhaps most importantly, prior input demand studies have generally ignored likely endogeneity of subsidized fertilizer in a commercial fertilizer demand equation (Xu, et al. 2009). In reality it seems probable that time-varying shocks affecting participation and commercial purchases, such as intra-household issues or political turmoil, could also affect the amount of subsidized fertilizer that a household obtains. Therefore, the third contribution of this study is that it provides a way to deal with the fact that subsidized fertilizer is likely endogenous in a model of commercial fertilizer demand.

This paper can be useful for other applied research because it provides a way to obtain consistent parameter estimates when both the dependent variable (commercial fertilizer) and an endogenous explanatory variable (subsidized fertilizer) are corner solutions.[i] Corner solution models can often be used to examine the impacts of policy interventions on indicators such as technology adoption, market participation or demand for a good. Furthermore, when used as independent variables, amount of food aid received, hours of extension training, or hours of AIDS prevention received are often endogenous. These independent variables often also display properties of corner solutions because a nontrivial proportion of the population does not participate in these programs, just as a nontrivial proportion of the people in Malawi receive zero kilograms of subsidized fertilizer.

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. Next is the conceptual framework and Methodology. Subsequent sections present data, results and conclusions.

Fertilizer Distribution and Subsidies in Malawi

From independence in 1964 until the early 1980's Malawi like many other countries in SSA controlled input distribution and output markets through a government run parasatal agency, called ADMARC. Through this system small land holders received fertilizer and maize seeds below market prices. ADMARC also offered guaranteed pan-territorial maize prices to farmers at harvest and sold maize at a domestic price to consumers at a reduced price. The losses ADMARC incurred in the maize industry were offset by profits it made purchasing tobacco and sugar from small holders far below world price and exporting them at profit (Harrigan, 2008).

Malawi began phasing out the parasatal system in the 1980's due to the wave of market liberalization and structural adjustment pressures advanced by the World Bank, IMF and donor nations. Fertilizer subsidies and pan-territorial pricing schemes were viewed as market distorting, thus Malawi and many other SSA nations were pressured to remove them. As ADMARC's role in distributing fertilizer to farmer declined during the 1980's and early 1990's, a private fertilizer distribution industry developed to fill the void. Fertilizer sales grew on average by 6% per year between 1985 and 2005 (Dorward et al. 2008). ADMARC still intervened in input markets sporadically during the 1990's particularly in years of bad weather and high prices in order to stabilize the market.

By the late 1990's it became clear that in the years since market liberalization food insecurity had increased in Malawi because maize prices had become more volatile, the Malawian Kwacha had devalued making it expensive to import maize in lean years and, there had been years of recurring drought. As a result the Malawian government implemented two small scale input subsidy programs, Starter Pack and the Targeted Input Program (TIP) which helped between 1 million and 2.8 million households per year between 1998 and 2004. These programs distributed small amounts of hybrid maize (2kgs), fertilizer (15kgs) and legumes(1kg) to eligible households (Harrigan 2008).

Malawi experienced an extremely poor harvest in 2004/05 and as a result the government decided to embark on a large scale fertilizer subsidy program to promote maize and tobacco production. During the 2005/06 season coupons for 147,000 tonnes of fertilizer (2.9 million 50kg bags) were distributed to farmers. Each coupon entitled the holder to one 50kg bag of urea or 23:20 at a cost of US $6.75 and one 50 kg bag of Compound D or CAN at a cost of US $10.28 (Dorward et al. 2008). Coupons for hybrid maize seeds were distributed as well. The subsidy program cost US $51 million during the 2005/06 growing season.

The rains were good in 2005/06 and yields where high making the subsidy program very popular. As a result it was extended and scaled up for the 2006/07 growing season. During that year the government procured and distributed 185,000 metric tons of fertilizer to farmers. Coupon recipients again paid 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 (Dorward et al. 2008). The program cost more than US $73 million with a majority of the bill being paid by the Malawian government.

The subsidized fertilizer was distributed through both private and government channels. Six private firms won the right to procure and distribute subsidized fertilizer through their networks. Farmers who received coupons could hand them in at participating retailers along with US $6.75 to redeem their fertilizer. Retailers would then submit the coupon and receipt to the government for payment.

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 input 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).” With these guidelines it seems reasonable to assume that the criteria for coupon eligibility varied among villages. The village leaders could have determined eligibility based on numerous factors such as household’s relation to village leaders, years the household has lived in the village, if the household had a civil servant or various other non-economic factors. These factors would be observable to people in the village but not to the government administrators or to researchers evaluating the subsidy program. Along the same lines it could also be possible the unobservable factors that affect demand for commercial fertilizer such as political turmoil and inter and intra household issues could also influence how much subsidized fertilizer a household receives. Therefore the subsidized fertilizer could potentially be endogenous in a commercial fertilizer demand equation.

Malawi is a society where the vast majority of the population is very poor, with 90% of the population engaged in agriculture and a PPP per capita GDP of US $800 in 2008 (CIA World Fact book 2009). The top third of the rural population has a much higher standard of living than the bottom two thirds. For example the bottom tenth of Malawi's population consumed the equivalent of US $62 per year, people in the 50 percentile consumed the equivalent of US $152 per year, while the top tenth of the population consumed the equivalent of US $760 per year. (Ellis 2008). This disparity is common throughout SSA and indicates that if fertilizer subsidies are distributed to people in the low end of the wealth distribution, it could have a major impact on improving their well being. However if the subsidies are distributed to people on the upper end of the wealth distribution for non-economic reasons, it could further increase the inequality.

Conceptual Framework

This paper considers a farmer's demand for inputs and recognizes that this decision may be made in a sequential two step process or it may be a simultaneous decision. In the sequential process, the farmer decides whether or not to participate in the fertilizer market and if he chooses market participation the next step in the decision is the quantity to purchase. Simultaneous decision making means that the farmer makes market participation and quantity choices at the same time. Simultaneous market participation decisions in the output supply market have been modeled by Key Sadoulet and De Janvry (2000). Sequential market participation decisions have been modeled for output supply response by Holloway, Barrett and Ehui (2005) and by Bellmare and Barrett (2006). The latter study explicitly tests whether or not farmers make sequential or simultaneous market participation decisions and finds evidence to support sequential decision making.

Many studies modeling input demand assume the decision is made simultaneously (Adugna 1997, Nkonya et al. 1997, Kaliba et al. 2000, Minot et al. 2000, Isham 2002, Abdoulaye and Sanders 2005, Chirwa 2005). However Croppestedt, Demke and Meschi (2003) and Xu, Burke, Jayne and Govereh (2009) model the decision sequentially. Neither study explicitly tests whether the decision could be made sequentially or simultaneously, which we will do in this study.

A farmer's decision to participate in input markets can be understood based on an adapted framework from McFadden's (1974) random utility model. Farmer *i* at time *t* will participate in the commercial fertilizer market if

$$(1) \qquad U_{Pit} - U_{Nit} \geq 0$$

$$U_{Pit} = X_{it}\gamma + \varepsilon_{it} \geq 0$$

$$(2) \qquad P_{it} = \begin{cases} 1 \text{ if } U_{Pit} - \varepsilon_{it} \geq X_{it}\gamma \\ 0 \text{ if } U_{Pit} - \varepsilon_{it} \leq X_{it}\gamma \end{cases}$$

where U_{Pit} is the utility farmer (i) gains from participating in the commercial market at time (t) and U_{Nit} is the utility from not participating in the commercial fertilizer market. We can think of a small farmer in SSA utility as being a function of production, income, consumption smoothing and risk reduction he gets from using or not using fertilizer. X_{it} is the vector of explanatory variables that determine market participation and **γ** the vector of corresponding parameters. X_{it} includes factors such as maize prices, fertilizer prices, rainfall during the past growing season and household characteristics. Please see table 1 for a full list of explanatory variables.

X_{it} also includes factors which represent the transport costs and transactions costs associated with participation in the market. Various studies have shown that these "fixed costs" such as distance to the market, number of commercial dealers in the village and availability of credit affect farmers market participation decisions (de Janvry et al. 1990, Key et al. 2000, Croppestedt et al. 2003, Holloway et al. 2005, Bellmare and Barrett 2006). These factors must be considered in order to accurately understand a farmer's market participation decision.

We do not observe utility directly but we do observe P_{it} which takes on a value of zero if the farmer does not participate in the commercial market and a one if he does. ε_{it} represents the composite error ($c_i + \mu_{it}$), were c_i represents the time constant unobservable factors that affect commercial fertilizer participation, such as soil quality, the farmer's management ability, and his level of risk aversion, while μ_{it} represents the time varying shocks that affect decisions to participate in the fertilizer market.

When P_{it}=1 the farmer must decide how much fertilizer to purchase. Adapting the general format of Blaylock and Blisard (1992), we can think of demand for commercial fertilizer as follows.

(3) $Y_{it} = P_{it}(Y_{it}^*)$

(4) $Y^*_{it} = Z_{it}\beta + v_{it}$

Y_{it} represents the quantity of fertilizer the farmer actually purchases. Y^*_{it} represents a latent variable for the amount of fertilizer the farmer would like to purchase regardless of market participation. We only observe Y_{it} if P_{it}=1. Z_{it} represents a vector of variables that affect the amount of fertilizer purchased and β represents the vector of corresponding parameters. The variables in Z_{it} are the same as in X_{it} from equation (2), except those variables affecting the fixed cost of market participation, which are excluded from Z_{it}. The corresponding parameters are represented by β. v_{it} represents the composite error in the amount of fertilizer purchased, and is different from ε_{it} in the participation model.

Traditional models of input demand tend not to account for the fact that in many cases inputs may be available from both subsidized and unsubsidized channels, and that the interplay between these channels influences farmer behavior. The only study to address this issue is Xu, Burke, Jayne and Govereh. The authors of that study find that subsidized fertilizer in Zambia harms the private sector in regions where commercial dealers are well established but may actually help the private sector in areas where commercial dealers are not as prevalent. Our study extends their work by (1) providing an overall unconditional APE estimate of how much commercial fertilizer is displaced by subsidies, (2) testing whether farmers make input purchase decisions sequentially or simultaneously (3) testing and controlling for the likely endogeneity of subsidized fertilizer in a commercial fertilizer demand equation.

When thinking about the effect of subsidized fertilizer on the quantity of commercial fertilizer purchased, three scenarios may occur, following Xu, Burke, Jayne and Govereh.

Scenario 1
(ΔQComm / ΔQsub) > 0: The Subsidy program stimulates commercial fertilizer purchases.

Scenario 2
(ΔQComm / ΔQsub) = 0: The Subsidy program has no effect on commercial demand.

Scenario 3
(ΔQComm / ΔQsub) < 0: Subsidized fertilizer displaces farmers' purchases of commercial fertilizer.

Where *ΔQComm* is change in quantity of commercial fertilizer used ($QC_t – QC_{t-1}$) and *ΔQsub* is the change in quantity of fertilizer acquired from the subsidy over time ($Qs_t – Qs_{t-1}$) . Scenario 1 would indicate that the subsidy program promotes the development of the commercial fertilizer market and raises overall fertilizer use more than the quantities distributed through the subsidy program. Observing Scenario 2 would indicate that subsidized fertilizer does not adversely affect commercial demand. If scenario 3 occurs, it could negatively affect the commercial fertilizer sector and reduce the benefits of the program relative to its costs because some farmers are using subsidized fertilizer to replace fertilizers that they would have otherwise purchased at commercial prices.

Empirical Model

Fertilizer market participation and demand for commercial fertilizer can be analyzed using a corner solution model where a non-trivial portion of the data is located at zero. It may seem plausible that a Heckman selection approach could deal with our problem however this approach is relevant for incidental truncation where the zeros that one encounters in the data are actually missing values. For example, in the tradition woman's wage equation certain people do not work because their wage offer is below their reservation utility. A corner solution model is more appropriate than a selection model for our 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 fertilizer. However due to market and agronomic conditions many of them choose not to use it. Therefore the zeros that we encounter in the data truly reflect the farmer's optimization decision.

When we think of market participation and demand for fertilizer as being made simultaneously, the tobit estimator proposed by Tobin (1958) fits conceptually. Using a tobit indicates that fixed costs associated with market participation do not significantly affect a farmers decision to participate in commercial markets. It also means that factors affecting market participation and quantity decisions are one and the same, affecting the dependent variable in the same direction.

When thinking of market participation and demand for fertilizer as a sequential decision, the double hurdle (DH) model proposed by Cragg (1971) to address corner solutions is appropriate for analyzing the problem. The double hurdle model accounts for the possibility that factors influencing fertilizer market participation and factors influencing quantity of fertilizer purchased may be different. In the case of fertilizer, fixed costs may affect a farmer's decision to participate in the market but they may not affect the quantity purchased. The DH model also allows us to consider that the same factor can potentially affect participation and amount consumed in different ways.

The estimator for the DH model maximizes the following log-likelihood function derived from Wooldridge (2002).

(5) $$\ell i(\gamma,\beta) = 1[yit = 0]\log[1-\Phi(Xit\gamma)] + 1[yit > 0]\log[\Phi(Xit\gamma)] +$$

$$1[yit > 0]\left\{-\log\left[\Phi\left(\frac{Zit\beta}{\sigma}\right)\right] + \log\left\{\phi\left[yit - \left(\frac{Zit\beta}{\sigma}\right)\right]\right\} - \log(\sigma)\right\}$$

Where y_{it} represents commercial fertilizer purchases, Φ represents the standard normal c.d.f., ϕ represents the standard normal p.d.f. and σ represents the standard deviation. Cragg's original model assumes that the errors between hurdle 1 and hurdle 2 are independent, normally distributed and the cov (ε_{it}, v_{it}) = 0. When this assumption is maintained, first the maximum likelihood estimator (MLE) of γ in the first hurdle measuring participation can be obtained using a probit estimator. Second, the MLE of β which represents the parameter for the second hurdle measuring demand, can be estimated from a truncated normal regression model. When $\gamma=\beta/\sigma$ equation (5) collapses to the tobit log-likelihood function. The model specification of the DH estimator can be tested against the tobit using a likelihood ratio (LR) test. This test can be used to determine whether or not the data supports sequential or simultaneous input purchase decisions.

Several studies have relaxed the independent error term assumption using the rationale that an individual's decision about whether to purchase and his decision about how much to purchase may be linked and thus generate non-independent errors (Garcia and Labeaga, 1996). The studies that have compared results from a model where independence in the errors is assumed with results from the same model where the assumption is relaxed have found virtually identical coefficients and standard errors (Jones, 1992, Garcia and Labeaga, 1996). This indicates that when the model is correctly specified, the independence assumption can be maintained. We maintain the independence assumption in our study because we believe that the model is correctly specified and because the independence assumption facilitates estimation using panel data methods.

Controlling for unobserved heterogeneity

In order to obtain consistent estimates in our model, the independent variables must be independent of unobserved heterogeneity c_i in non-linear models. Previous cross-sectional studies do not control for c_i and using fixed effects is not appropriate in non-linear panel data models.[ii] In non linear models independence between independent variables and the unobserved heterogeneity must be maintained. This is often a strong assumption, but it can be relaxed by modeling c_i in the following way.

(6) $c_i = \psi + \overline{X}_i + a_i, \quad a_i \mid x_i \sim Normal\,(0, \sigma^2_a)$

Where $\overline{X}_i$ represents household means of the independent variables. Modeling the heterogeneity in this way known as the correlated random effects (CRE) or the

Mundlak-Chamberlain device following Mundlak (1978) and Chamberlain (1984). The CRE estimator requires 1) the model to have a standard normal distribution and 2) strict exogeneity conditional on c_i. The benefit of the CRE estimator is that by including time averages we can model the variation in the independent variable relative to their overall effect. It also allows us to measure the effects of time-constant independent variables just as in a traditional random-effects environment.

This paper uses a pooled CRE probit estimator for the model of market participation in hurdle 1 and pooled MLE on the truncated regression model using CRE to estimate commercial demand for fertilizer in hurdle 2. Pooled estimation allows one to obtain consistent estimates that are robust to serial correlation in the errors μ_{it}. The traditional Random Effects estimator is not robust to likely serial correlation, so by using a pooled estimator we elect to sacrifice some potential efficiency for robustness.

The commercial market participation decision (hurdle 1) made by farmer (i) at time (t) can be expressed in the following estimating equation using CRE

(7) $$P_{it} = \alpha + F_{it}\xi + X_{it}\beta + D_{it}\delta + \overline{X}_i \sigma + a_i + \mu_{it}$$

where P_{it} represents market participation as in equation (2). F_{it} represents the fixed costs of participating in the commercial fertilizer market. X_{it} represents the vector of explanatory variable that affect market participation. These include the amount of subsidized fertilizer received, education of household head and a binary variable for if there was a recent death in the family. D_{it} represents the vector of community characteristics such as fertilizer and maize prices. The model for commercial demand (hurdle two) represented by Y_{it} has the same explanatory variables as equation (7) except the fixed factors F_{it} are excluded.

Controlling for unobserved shocks

Even after controlling for correlation between independent variables and c_i, parameter estimates will still be inconsistent if the independent variables are correlated with unobservable time-varying shocks μ_{it}. Many panel studies simply assume independence between covariates and μ_{it} however this paper explicitly deals with the fact that acquiring subsidized fertilizer is likely to be endogenous. Endogeneity will occur if unobserved factors affecting commercial market participation also affect subsidized fertilizer acquisition.

We address the potential endogeneity problem by using an adaption of the Control Function (CF) approach used by Rivers and Vuong (1988) to control for a continuous endogenous explanatory variable and by Vella (1993) to control for an endogenous variable that is a corner solution. The CF provides a straightforward two-step procedure to test and control for endogeneity of subsidized fertilizer in a commercial market participation and demand. The CF has been applied recently to control for the endogeneity of school spending on students' test pass rate in a non-linear panel data context (Papke and Wooldridge 2008). The first step in the CF approach is to estimate the following reduced form equation using a pooled tobit estimator with CRE.

(8) $S_{it} = M_{it}\beta + \overline{M}_i\delta + \omega_{it}$

Where S_{it} represents the endogenous variable, subsidized fertilizer acquired by farmer (i) at time (t). M_{it} represents the vector of explanatory variables that affect S_{it} and $\overline{M}_i$ represents the household means of these variables and ω_{it} represents the composite error. M_{it} includes a variable (years the head of the family has lived in the village) that is not included in X_{it} in the structural model. This variable acts an instrumental variable (IV) and allows the structural equation to be identified. Years lived in the village is a good instrument because first it is a measure of socio-political capital that could influence how much subsidized fertilizer a household receives. Recall from section two that coupons for subsidized fertilizer were distributed at the local level by the village head man and an appointed committee. Second, there is little reason to believe that years lived in a village would directly affect the dependent variable in the structural model (market participation and demand for commercial fertilizer). This makes it safe to assume that the instrument itself is exogenous (ie., uncorrelated with the error term in the structural model).

The second step of the CF approach uses the reduced form residuals $\hat{\omega}_{it}$, obtained from equation (8) as an explanatory variable in the probit regression of P_{it} on S_{it}, X_{it}, $\overline{X}_i$, $\hat{\omega}_{it}$ to model hurdle (1) and then in the truncated regression of Y_{it} on S_{it}, Z_{it}, $\overline{Z}_1$, $\hat{\omega}_{it}$ to model hurdle (2). Vella's method computes the generalized residuals from the reduced form tobit model in the first step and in the second step uses the residuals as a regressor in a linear structural model with a continuous dependent variable. The situation in this paper is slightly different since the potentially endogenous variable (subsidized fertilizer) and the dependent variable in the structural model (commercial fertilizer) are both corner solutions. This paper conditions on receiving subsidized fertilizer and only uses observations from farmers who received positive quantities of subsidized fertilizer when estimating hurdles 1 and 2 of the commercial fertilizer demand equation (Wooldridge 2009). If the coefficient on $\hat{\omega}_{it}$ is significantly different from zero in the structural model then subsidized fertilizer is endogenous in a farmer's decision to purchase commercial fertilizer. Using the reduced form residual $\hat{\omega}_{it}$ and conditioning on subsidized fertilizer controls for endogeneity of subsidized fertilizer and produces consistent estimates in the commercial fertilizer demand equation.

Obtaining average partial effects

After obtaining coefficient estimates for parameters of interest such as subsidized fertilizer, we obtain the average partial effects (APE) of the subsidized fertilizer coefficient averaged across (i) and (t). The APE is the partial effect averaged across the population. The first step in obtaining the APE is to derive the partial effect for the explanatory variable of interest (j) for every observation (i) at time (t) in the dataset.

(9) Partial Effect$_j$ = $\partial E(y \mid \mathrm{X}, v) / \partial x_j$

Where the other elements of the independent variables and the unobservable factors are held constant (Wooldridge 2002). The APE for our DH model is then obtained from the following equation:

(10) APE $= \hat{\beta}\left[1/(NT)\sum_{i=1}^{N}\sum_{t=1}^{T} f(\mathrm{X}_{it}\hat{\beta}, \overline{\mathrm{X}}_{it}\hat{\delta}, \mathrm{Z}_{it}\hat{\beta}, \overline{\mathrm{Z}}_{i}\hat{\delta})\right]$

Where X_{it} and Z_{it} are the vectors of explanatory variable in hurdle (1) and hurdle (2) respectively. $\overline{X}_i$ and $\overline{Z}_i$ are the corresponding household means that are added to the original equations. The parameters to be estimated are β and δ. The APE is generally of greater interest than the partial effect at the average of the explanatory variable particularly in nonlinear models and in the case of discrete variables (Wooldridge 2002, Papke and Wooldridge 2008). The APE for the DH model can be obtained in the "Craggit" command in Stata, described in Burke (2008). This command allows us to jointly obtain the unconditional APE from the first and second stage of the double hurdle model. The Standard errors of the APE can be obtained via the delta method or by bootstrapping.

Data

Data used in this analysis come from two nationally representative surveys conducted by the Government of Malawi's National Statistical Office. The first survey, the Integrated Household Survey-II, covers two cropping seasons; our panel includes 1,087 households that were interviewed during the 2002/03 growing season and 1,319 households that were interviewed during the 2003/04 growing season. Therefore, the first year of the panel, while drawn from the same survey, covers two different years. Each model includes year dummies for both years to control for different year effects. During the first round of data collection there was a relatively small fertilizer subsidy program in operation, but commercial purchases accounted for over 85% of the farmers' total fertilizer use. The second year of the panel comes from the 2007 Agricultural Inputs Support Survey (AISS) conducted after the 2006/07 growing season.

A major fertilizer subsidy program, featuring the distribution of redeemable vouchers to farmers was implemented in both the 2005/06 and 2006/07 seasons. From these two surveys we create a balanced panel of 2,406 households from each of the two surveys, for a total of 4,812 observations.

Fertilizer prices used in the study are the median district price mentioned by farmers in the survey during the current year's planting season from October to December. In an input demand function, maize prices are correctly 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 naïve expectation of maize prices by using district-level historical monthly maize prices collected by the Ministry of Agriculture. For each year of the data, we compute expected maize prices as the average price over the 6-month period the proceeds the planting season. The rainfall variables come from district-level experiment station records. In an input demand equation the appropriate rainfall variable is also a farmer's naive expectation based on rainfall from previous years. We include cumulative rainfall over the previous growing season, along with long run average rainfall from the previous five growing seasons and the standard deviation of rainfall over that time. These data are compiled at the district level.

Results

The means and distribution of the variables used in the analysis are presented in Table 1. Results show that the majority of respondents did not use subsidized or commercial fertilizer. This is consistent with low fertilizer use overall in Malawi and other SSA countries. It also helps justify using a corner solution model over a linear model in this analysis.   Most villages do not have commercial fertilizer dealers and only 33% of the villages have farm credit organizations. Twenty-one percent of the households were headed by females. The median farm size is 1.13 hectares.

Realizing that fertilizer coupons are fairly fungible and resale may have occurred we examined whether or not this 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 gave the coupon away. The small percentage of resale should not significantly influence the results of the study.

Table 2 displays the total amount of subsidized and commercial fertilizer that respondents used in the years before and after the subsidy was scaled up in Malawi. Perhaps not surprisingly people use significantly more subsidized fertilizer with the advent of the subsidy while at the same time they use significantly less commercial fertilizer. Table 2 shows that total fertilizer use increased after the subsidy but that increase was not equal to the amount of subsidized fertilizer that the respondents received. This simple table indicates that subsidized fertilizer took the place of some commercial fertilizer from previous years.

Table 3 provides details on how the subsidy affects fertilizer acquisition at the household level. According to the table 40% of the sample purchased commercial fertilizer in the first year of the survey, before the subsidy was scaled up while 60% did not. During the second year, only 17% of households who purchased commercially in the first year and received the subsidy in the second year purchased commercially again in that year. Table 3 shows that 50% of the households who did not receive the subsidy in the second year bought commercially that year. This finding is what we might expect a priori and it indicates that when people who have purchasing power to buy fertilizer receive the subsidy, some of them use it in place of commercial sales.

For the group of farmers who did not purchase commercially in the first survey, only 46% received the subsidy in the second year. Of this group, only 6% of the people who received the subsidy also purchased commercially while 12% of the people who did not purchase commercial fertilizer in the first year and did not receive subsidy in the second year bought commercially in that year. This result is also consistent with what we might expect a priori and it indicates that even for the group of people who did not purchase commercially before the subsidy intervention, receiving subsidized fertilizer makes them less likely to purchase the input on the commercial market.

We can test the hypothesis that farmers make input decisions simultaneously vs. sequentially by comparing how well the tobit fits our data vs. the DH model. By estimating each model separately with the variables presented in table 4 we find that the log-likelihood for the DH model is -10,108 compared with a log-likelihood of -10,449 for the tobit model. The LR statistic is 682 giving it a p-value of (0.00), indicating that the tobit can be rejected in favor of the DH model. This provides evidence that farmer in SSA make input market decisions sequentially first deciding to participate and then how much to purchase. This finding supports Bellemare and Barrett's conclusion of sequential decision making in Livestock output markets.

Table 4 presents the results of the DH model on demand for commercial fertilizer. In this equation subsidized fertilizer is treated as exogenous. The coefficients in table 4 are the conditional APEs obtained from STATA's *margeff* command for the binary model estimated by probit and the truncated regression estimated by maximum likelihood. The subsidized fertilizer variable has a significant negative effect on probability of participating in the commercial fertilizer market but that effect is very small. However, in hurdle 2 after the participation decision has been made receiving one additional kilogram of subsidized fertilizer causes the farmer to buy 1.34 fewer kilograms of commercial fertilizer. The effect is marginally significant. This result provides evidence that when treated as exogenous, receiving subsidized fertilizer has a negative effect on a farmer's demand for commercial fertilizer.

According to table 4, having farm credit organizations in the village makes people less likely to participate in commercial markets. This finding may seem surprising but past research from Malawi indicates that formal lending institutions such as farmer cooperative tend to lend money to households with diverse on farm and off farm assets (Diagne and Zeller 2001). Therefore farmers in areas with credit cooperatives may use credit for activities other than purchasing fertilizer. One might believe that credit availability in the village is endogenous in a market participation model because it is correlated with unobservable factors that affect participation. We remedy this potential problem first by making the credit variable a village-level variable rather than a household-level variable meaning that it is less likely to be correlated with household-level heterogeneity. Second, the CRE framework removes correlation between independent variables like village credit organizations and village-level heterogeneity. The significance of credit availability in the village also indicates that fixed costs affect a farmer's market participation decision.

Table 4 also shows that value of household assets is a marginally significant negative factor in market participation and the magnitude of the effect is small. Once the market participation decision has been made, households with more assets demand larger amounts of commercial fertilizer. Land holding is a significant factor affecting participation in commercial fertilizer markets and the amount of commercial fertilizer farmers acquire. Older household heads are less likely to participate as are households with more young children, probably because adults in these households are time-constrained. Higher long-run average annual rainfall makes a farmer more likely to participate, probably because he or she expects more rain to generate a better yield response from fertilizer, but the effect is small.   The maize price coefficient has a negative sign and the fertilizer price coefficient has a positive sign for hurdle 1, both of which are surprising. Both coefficients are very small and it could be that small changes in price do not have large effects on market participation. Hurdle 2 clearly indicates that once the participation decision has been made maize price has a large significant positive influence on how much fertilizer is purchased. Fertilizer price is negative in hurdle 2, which is what we would expect a priori. These final two findings indicate that farmers who decide to participate in the commercial fertilizer market pay attention to input and output prices.

Table 5 presents the model of factors influencing access to subsidized fertilizer. This model uses a tobit estimator and provides insight into how the government makes subsidized fertilizer allocation decisions. The model also represents the estimation of the reduced form equation (8) used to control for the endogeneity of subsidized fertilizer in the structural model from equation (7). The coefficients presented in table 5 are the APEs. The coefficient for the instrumental variable (IV), years that the household head has lived in the village, has the expected positive sign and is significant at the 5% level. Although the IV is time constant it is safe to assume that any leftover heterogeneity from using CRE will be uncorrelated with the other independent variables in the structural model. The IV indicates that each additional year lived in a village translates to .09 additional kilograms of subsidized fertilizer acquired.

Villages with farm-credit organizations receive less subsidized fertilizer. Households that are farther from the road receive significantly more subsidized fertilizer, indicating that the government may be distributing to farmers who have limited access to inputs through commercial channels. Land holding is positively related to the amount of subsidized fertilizer acquired as are assets. This finding provides evidence that larger, wealthy farmers receive more of the subsidy. Female households and families with more women over 65 years old receive less subsidized fertilizer. Households with more men over 65 years old receive more subsidized fertilizer perhaps because they have stronger networks and are better connected within the community and to government officials. Furthermore it appears from the table that the government distributes subsidized fertilizer to households in areas that are more productive with higher long run average rainfall and lower variation in long-run average rainfall.

Table 6 presents the DH model of factors influencing demand for commercial fertilizer when subsidized fertilizer is treated as endogenous. The residual from the reduced form model $\hat{\omega}_{it}$ is significant in the model for hurdle 1, indicating that subsidized fertilizer is endogenous in a market participation model. When using the control function the subsidized fertilizer coefficient is negative and smaller than the coefficient in table 4, meaning subsidized fertilizer has a significant negative effect on commercial market participation even after controlling for endogeneity. The effect is small, however, probably because many farmers do not participate in the market. In hurdle 2, the P-value for the reduced form residual is 0.88, indicating that subsidized fertilizer is not endogenous in hurdle 2 once the participation decision has been made. Therefore we drop the residual and estimate the same model for hurdle 2 that we estimate in table 4. The results for hurdle 2 in table 6 are the same as for hurdle 2 in table 4.

Once endogeneity has been controlled in hurdle 1, distance from the road reduces the likelihood of participating in commercial markets, while farmers with higher assets are more likely to participate in the market. Older household heads are less likely to participate and households with women over 65 years old are more likely to participate. Fertilizer price oddly has positive effect on participation in commercial markets, but the effect is negative in hurdle 2.

The unconditional APE of subsidized fertilizer on commercial fertilizer demand that incorporates the partial effects of both hurdles is -0.198 with a p-value of (0.003) when subsidized fertilizer is treated as exogenous. This means that each additional kilogram of subsidized fertilizer causes a farmer to purchase close to 0.20 fewer kilograms of commercial fertilizer. The unconditional APE of subsidized fertilizer is only slightly more substantial at -0.200 with a p-value of (0.004), when endogeneity is controlled and the entire sample is used. It is not possible to calculate an APE for subsidized fertilizer when part of the data is used in hurdle 1 conditional on subsidized fertilizer>0 and a different part of the data for hurdle 2. Never the less these results are very similar as are the partial effect comparisons between table 4 and table 6.

For robustness the unconditional APE of subsidized fertilizer from the DH model can be compared with the APE of subsidized fertilizer using a tobit estimator which was already rejected in favor of the DH model. The APE for the tobit is -0.33 with a p-value of (0.000). The DH model is also more appropriate for our analysis than the linear model because in our case where the dependent variable (commercial fertilizer) has 72% of the observations with a zero value, the linear model is likely to be inaccurate for a wide range of the data.

Table 7 divides the observations into five groups (quintiles) based on value of assets in 2007 dollars. This table demonstrates that the effects of displacement increase as assets increase from -0.16 in the lowest income group to -0.25 in the highest group. This indicates that wealthier people who would be expected to purchase inputs commercially are displacing more of their commercial purchases with subsidized fertilizer.

Conclusions

In many developing countries, farmer input demand is affected by the interplay of public and commercial input distribution systems. There are concerns that the demand for commercial inputs may be displaced by the operation of government programs, but little empirical investigation has been conducted in the past. This paper develops a modeling framework to empirically estimate factors influencing participation in commercial fertilizer markets and the amount of fertilizer purchased. Not surprisingly, we find that when a subsidy is introduced subsidized fertilizer use increases while commercial fertilizer use decreases. Total fertilizer use increases but subsidized fertilizer displaces some commercial sales.

Our main findings are as follows: first, subsidized fertilizer has a significant negative impact on participation in commercial fertilizer markets but the magnitude of the effect is small; however once a farmer decides to participate in the market, the negative effect of subsidized fertilizer on commercial purchases is much more substantial. Second, subsidized fertilizer is endogenous in models of participation in commercial fertilizer markets. This problem can be dealt with using the control function approach. Third, once the commercial market participation decision has been made, demand for commercial fertilizer is positively driven by farm size, house hold assets, maize price, and negatively affected by fertilizer price and the amount of subsidized fertilizer a farmer receives. This indicates that farmers who participate in fertilizer markets pay attention to market conditions. Fourth, this study finds evidence to support the notion that farmers make input purchase decisions sequentially.

Fifth, when subsidized fertilizer is treated as exogenous, its unconditional APE is -.198, indicating that on average receiving one additional kilogram of subsidized fertilizer means the farmer buys 0.198 kg less commercial fertilizer. Interestingly, when endogeneity of subsidized fertilizer is controlled the APE of subsidized fertilizer changes only slightly to -0.200. While endogeneity is present and needs to be controlled for, due to the number of farmers who do not participate in commercial markets, the APE of subsidized fertilizer when endogeneity is controlled is not substantially different from when it is ignored. We find that displacement is greater for people with more assets. This paper should provide a useful framework to other applied researchers looking for a way to deal with endogenous corner solution variables.

The model estimating access to subsidized fertilizer demonstrates that the subsidies are targeted to people who have lived in the village longer and households with older men who may be better politically connected. Large, wealthy farmers also get more of the subsidy but there is evidence that the government targets people further from paved roads who may have limited access to commercial input dealers. These findings along with the statistically significant evidence of displacement provide quantitative information about the impacts of fertilizer subsidies. It seems that the program may have distributed subsidies to people would have otherwise purchased fertilizer at commercial prices. The program also generated some inefficiency with .2 kg of commercial fertilizer displaced by every kg of subsidized fertilizer. Even though Malawi has incorporated the private sector in its distribution process, the government still bares the majority of the subsidy cost so subsidized fertilizer that goes to farmers who would otherwise have paid commercial price rather than to others who would not have represents an inefficiency. Targeting must be effective and displacement must be minimized to ensure that the subsidies achieve the program objective of increasing yields and food-security while minimizing wasteful spending.

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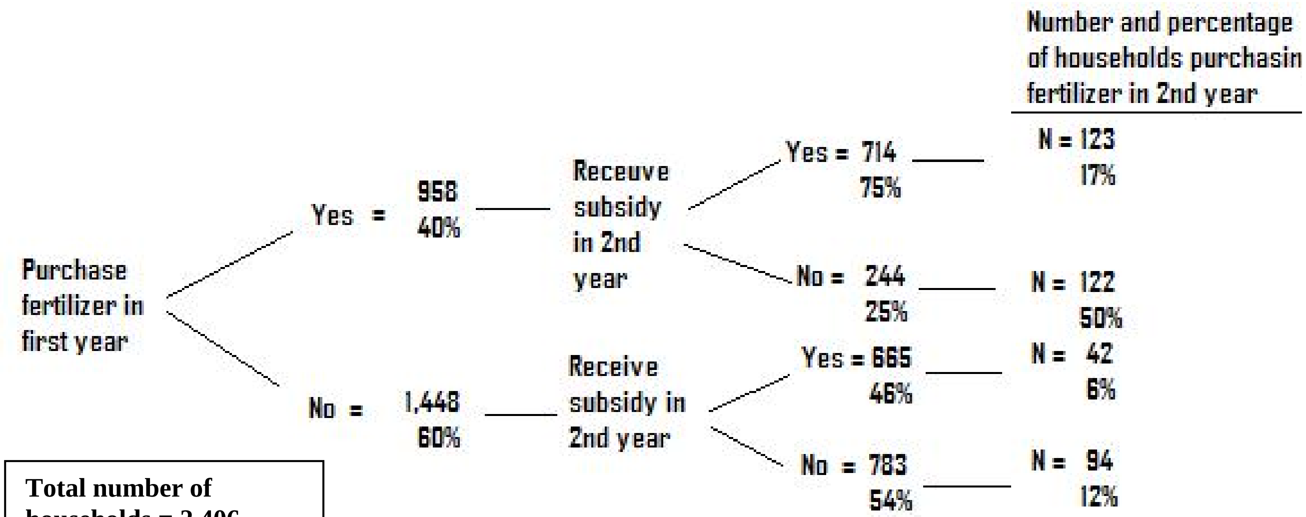
Table 1: Distribution of Variables Used in the Analysis

VARIABLE	Value at the different percentiles of the Distribution					MEAN
	10th	25th	50th	75th	90th	
Use commercial fertilizer (binary), dependent variable in hurdle 1	0.00	0.00	0.00	1.00	1.00	0.28
Commercial fertilizer purchased , dependent variable in hurdle 2	0.00	0.00	0.00	25.00	100.00	41.53
Subsidized fertilizer acquired by household in kg	0.00	0.00	0.00	50.00	100.00	29.56
# of commercial fertilizer dealers in village	0.00	0.00	0.00	1.00	2.00	0.64
Farm credit organization in the village[1] (binary)	0.00	0.00	0.00	1.00	1.00	0.33
Distance from village to nearest paved road in km[1]	0.10	3.00	13.50	32.00	60.00	22.11
Asset Value in 1,000 Malawian Kwacha	0.60	2.20	7.11	17.85	48.60	29.25
Landholding in ha	0.41	0.69	1.13	1.82	2.84	1.49
Female headed household (binary)	0.00	0.00	0.00	0.00	1.00	0.21
Age of household head during first survey year	25.00	31.00	42.00	57.00	70.00	45.17
# of males over 65 in household	0.00	0.00	0.00	0.00	1.00	0.13
# of females over 65 in household	0.00	0.00	0.00	0.00	1.00	0.13
# of adult males under 65 in household	0.00	1.00	1.00	2.00	3.00	1.50
# of adult females under 65 in household	1.00	1.00	1.00	2.00	3.00	1.52
# of children under 12 in the household	0.00	1.00	2.00	3.00	4.00	2.02
death in family during the past year (binary)	0.00	0.00	0.00	0.00	1.00	0.11
Cumulative rainfall over past growing season in 100 cm (Oct-May)	664.90	768.40	986.70	1,228.40	1,630.90	1,100.53
Long run cumulative rainfall (during past five growing seasons) at district level in 100 cm	734.96	824.96	878.02	1,068.58	1,256.65	946.02
Standard deviation of average rainfall over the past five growing seasons at district level in 100 cm	125.31	147.18	215.96	269.91	381.53	226.47
Last season's mean harvest maize price at district level (May - Oct)	21.85	28.74	35.50	39.43	44.28	35.18
Median fertilizer price during planting season (Oct-Dec)	49.70	53.10	64.00	70.00	74.30	62.17
Household in northern region (binary)	0.00	0.00	0.00	1.00	1.00	0.29
house hold in central region (binary)	0.00	0.00	0.00	1.00	1.00	0.48
Years household head has lived in village during first year of survey	4.00	13.00	28.50	45.00	62.00	30.91

Table 2: Aggregate Fertilizer Purchases from the Sample (in Kg)

Source of Fertilizer	**First Panel Year** 2002/03 2003/04	**Second Panel Year** 2006/07	**Difference**
Subsidized	10,333	184,252	173,919
Commercial	158,209	60,648	- 97,561
Total Fertilizer per Year	**168,542**	**244,900**	**76,358**

Table 3: Fertilizer Acquisition at the Household Level



Total number of households = 2,406

Table 4: Double Hurdle Model of Factors Influencing Demand for Commercial Fertilizer (Subsidized Fertilizer Treated as Exogenous)

	Hurdle 1 Probit estimation of decision to participate in commercial fertilizer market (1 if purchase commercial fertilizer)	**Hurdle 2** Truncated Normal regression of commercial fertilizer purchases (in kg)
Independent Variables: The coefficients displayed are the conditional Average Partial Effects (APE)	N = 4,812 Pseudo R^2 = .19	N = 1,339 Correlation^2 = .11
Subsidized Fertilizer acquired by HH in kg	-0.002***	-1.34*
	(0.000)	(0.067)
# of commercial fertilizer dealers in village[1]	0.001	-
	(0.903)	-
Distance in km to nearest paved road[1]	0.0002	-
	(0.574)	-
Farm credit organization in the village (binary) [1]	-0.047***	-
	(0.004)	-
Value of Assets in 1000 Malawian Kwacha	-0.0003*	4.12**
	(0.054)	(0.020)
Landholding in ha	0.037***	451.33***
	(0.000)	(0.000)
age of household head in first survey year[1]	-0.002***	-9.49
	(0.000)	(0.584)
Female headed household (binary)	-0.04	-17.78
	(0.382)	(0.803)
# of males over 65 in household	0.04	32.22
	(0.445)	(0.413)
# of females over 65 in household	0.06	-8.57
	(0.208)	(0.784)
# of adult males under 65 in household	-0.004	6.64
	(0.743)	(0.628)
# of adult females under 65 in household	-0.007	2.63
	(0.554)	(0.797)
# of children under 12 yrs in household	-0.02**	7.11
	(0.019)	(0.442)
Death in the family in the past two years (binary)	0.013	8.29
	(0.591)	(0.759)
Last seasons mean harvest maize price at district level (May - Oct)	-0.004*	11.37**

	(0.062)	(0.032)
Median fertilizer price at district level during planting season (Oct - Dec)	0.005***	-1.94
	(0.000)	(0.13)
Cumulative rainfall over past growing season in 100 cm (Oct-May)	0.000	-0.172
	(0.878)	(0.428)
Long run annual average cumulative rainfall	0.000***	2.702*
	(0.000)	(0.076)
Standard deviation of long run cumulative rainfall	0.000	15.94*
	(0.133)	(0.073)
North Region	-0.009	129.83***
	(0.623)	(0.001)
Central Region	0.16***	104.80***
	(0.000)	(0.000)
First survey (Year 1) dummy	0.29***	188.40***
	(0.000)	(0.001)
First survey (Year 2) dummy	0.15***	80.61**
	(0.000)	(0.028)

Note: *, **, *** indicates that the corresponding coefficients are significant at the 10%, 5% and 1% level respectively; P-values in parentheses; [1] indicates variable does not vary over time; Both hurdles include time averages of all time varying explanatory variables except the year dummies.

Table 5: Reduced Form Model of Factors Influencing Access to Subsidized Fertilizer Using Tobit Estimator

	Dependent Variable: Amount of subsidized fertilizer the household receives
Independent Variables: The coefficients displayed are the Average Partial Effects (APE)	N = 4,812 Pseudo R2 = .04
Years Household head has lived in village during first survey year[1,2]	0.09** (0.032)
# of commercial fertilizer dealers in village[1]	-0.78 (0.364)
Farm credit organization in the village (binary) [1]	-9.60*** (0.000)
Distance in km to nearest paved road[1]	0.08*** (0.010)
Value of Assets in 1000 Malawian Kwacha	0.02* (0.085)
Landholding in ha	3.16*** (0.000)
Female headed household (binary)	-10.96* (0.059)
age of household head in first survey year[1]	0.22 (0.308)
# of males over 65 in household	13.62** (0.032)
# of females over 65 in household	-11.21** (0.047)
# of adult males under 65 in household	-0.85 (0.632)
# of adult females under 65 in household	0.26 (0.876)
# of children under 12 yrs in household	-1.56 (0.159)
Death in the family in the past two years (binary)	4.73 (0.128)
Last seasons mean harvest maize price at district level (May - Oct)	-0.97*** (0.001)
Median fertilizer price at district level during planting season (Oct - Dec)	-0.98*** (0.000)
Cumulative rainfall over past growing season in 100 cm (Oct-	0.0005

May)	(0.292)
Long run annual average cumulative rainfall	0.08*** (0.000)
Standard deviation of long run cumulative rainfall	-0.04** (0.014)
North Region	-6.39*** (0.005)
Central Region	-1.27 (0.484)
First survey (Year 1) dummy	-67.44*** (0.000)
First survey (Year 2) dummy	-63.54*** (0.000)

Note: *, **, *** indicates that the corresponding coefficients are significant at the 10%, 5% and 1% level respectively; P-values in parentheses; [1] indicates variable does not vary over time; [2] indicates that variable is used as instrument and is not included in the structural model presented in Table 6; Model includes time averages of all time varying explanatory variables except the year dummies.

Table 6: Double Hurdle Model of Factors Influencing Demand for Commercial Fertilizer (Subsidized Fertilizer Treated as Endogenous)

	Hurdle 1 Probit estimation of decision to participate in commercial fertilizer market (1 if purchase commercial fertilizer) and subsidized fertilizer >0	Hurdle 2 Truncated Normal regression of commercial fertilizer purchases (in kg)
Independent Variables: The coefficients displayed are the conditional Average Partial Effects (APE)	N = 2,126 Pseudo R^2 = .13	N = 1,339 $Correlation^2$ = .12
Residual from reduced form equation $\hat{\omega}_{it}$	-0.002**	-
	(0.011)	-
Subsidized Fertilizer acquired by HH in kg	-0.0005***	-1.34*
	(0.006)	(0.067)
# of commercial fertilizer dealers in village[1]	0.003	-
	(0.638)	-
Distance in km to nearest paved road[1]	-0.001**	-
	(0.012)	-
Farm credit organization in the village (binary) [1]	0.023	-
	(0.309)	-
Value of Assets in 1,000 Malawian Kwacha	-0.0003**	4.12**
	(0.013)	(0.020)
Landholding in ha	0.011	451.33***
	(0.387)	(0.000)
Female headed household (binary)	-0.024	-9.49
	(0.690)	(0.584)
age of household head in first survey year[1]	-0.001*	-17.78
	(0.072)	(0.803)
# of males over 65 in household	-0.038	32.22
	(0.549)	(0.413)
# of females over 65 in household	0.199***	-8.57
	(0.001)	(0.784)
# of adult males under 65 in household	-0.009	6.64
	(0.607)	(0.628)
# of adult females under 65 in household	-0.014	2.63
	(0.409)	(0.797)
# of children under 12 yrs in household	0.009	7.11
	(0.476)	(0.442)
Death in the family in the past two years (binary)	0.009	8.29
	(0.797)	(0.759)
Last seasons mean harvest maize price at district level (May - Oct)	0.005	11.37**
	(0.204)	(0.032)

Median fertilizer price at district level during planting season (Oct - Dec)	0.010***	-1.94
	(0.001)	(0.13)
Cumulative rainfall over past growing season in 100 cm (Oct-May)	0.000	-0.172
	(0.335)	(0.428)
Long run annual average cumulative rainfall	0.000	2.702*
	(0.937)	(0.076)
Standard deviation of long run cumulative rainfall	0.000	15.94*
	(0.890)	(0.073)
North Region	0.07*	129.83***
	(0.064)	(0.001)
Central Region	0.10***	104.80***
	(0.000)	(0.000)
First survey (Year 1) dummy	0.73***	188.40***
	(0.000)	(0.001)
First survey (Year 2) dummy	0.57***	80.61**
	(0.000)	(0.028)
Note: *, **, *** indicates that the corresponding coefficients are significant at the 10%, 5% and 1% level respectively; P-values in parentheses; [1] indicates variable does not vary over time; Both hurdles include time averages of all time varying explanatory variables except the year dummies.		

Table 7: Average Partial Effects (APE) of Subsidized Fertilizer on Commercial Fertilizer Demand at Different Quintiles of Asset Distribution Using the Full Sample

	Asset Quintile	APE of Subsidized Fertilizer	P-value	Mean Asset Value in US $
Lowest	1	-0.164	(0.00)	4.70
	2	-0.172	(0.00)	21.17
	3	-0.199	(0.00)	50.35
	4	-0.201	(0.00)	105.82
Highest	5	-0.254	(0.00)	858.16

[i] Corner solution means that the variable 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)

[ii] Estimating a nonlinear model by fixed effects results in "the incidental parameters problem" which generates inconsistent estimates (Wooldridge, 2002).