# Measuring the Impacts of Malawi's Farm Input Subsidy Program

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Abstract. We measure the impacts of Malawi's 2009 Farm Input Subsidy Program (FISP) on fertilizer use and maize yields in central and southern Malawi. Using three rounds of panel data and instrumental variables regression strategies to control for endogenous selection into the subsidy program we find positive and statistically significant correlations between participation in the FISP and fertilizer use intensity. Fertilizer use is found to be higher among households that plant improved maize varieties than among those that plant traditional varieties. Results are broadly robust to the inclusion of previous fertilizer intensity to control for household-specific differences in fertilizer use. We combine these results with those from a maize production function to calculate program-generated changes in average maize availability, accounting for estimated subsidy-induced changes in crop area. Our findings have implications for the way input subsidy programs are designed and implemented.

Key words: Farm input subsidy program, maize yields, fertilizer use, Malawi

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## 1. Introduction

Agricultural input subsidies have long been used to promote smallholder farmers' use of inputs, increase wages, reduce food prices, and promote economic growth (Crawford et al., 2003). Oftentimes, the implicit justification for doing so has been a concern that market failures preventing private transactions in inputs undermine overall economic performance, which has public good characteristics (e.g Kydd and Dorward, 2004). In Malawi, general price subsidies coupled with subsidized credit were used in the 1970s and 80s in an effort to stimulate production of food crops. During that period, the country achieved a high degree of self-reliance in maize, Malawi's main staple. Following pressure from the World Bank to deregulate through a Structural Adjustment Program (SAP), the Malawi Government eliminated the use of subsidies in the early 1990s.

Following this removal of subsidies, Malawi suffered from a series of severe and persistent food crises in the years leading up to 1998. Agricultural subsidies were reintroduced in 1998, following years of perennial food shortages, through what the government termed the Starter Pack Scheme (SPS). Under the SPS, which evolved into a Targeted Inputs Program (TIP), all smallholders in Malawi were entitled to a package containing sufficient fertilizer and seed to plant about 0.1 hectare of maize. The purpose of the SPS was to promote food security, increase agricultural productivity and improve soil fertility. Evaluation studies suggest that the SPS succeeded in increasing food production, thereby helping to promote national food security in the short-term (Levy and Barahona, 2002). However, critics have argued that the SPS and TIP led to the crowding out of commercial supply of chemical fertilizers and seed. Despite the perceived benefits of the SPS, most of Malawi's donors were opposed to the program. The program was criticized for undermining the development of private sector input delivery, creating an overdependence on maize and creating welfare losses due to resource use, administrative burden and operational problems (Harrigan, 2008). However, Nyirongo (2005) found no evidence of crowding out of private traders for fertilizer, although he did document some degree of crowding out of private suppliers for maize seed. He argues that, at the time the SPS was implemented, the market for fertilizer and seed was nearly non-existent and that there was no demand for inputs. Nyirongo et al. (2003) also found that purchases of fertilizer were higher for beneficiaries of the Targeted Inputs Program (which succeeded the SPS) than they were for non-beneficiaries. Supporters of the program use these findings to argue that the SPS and TIP helped to address the problem of weak demand by providing inputs to farmers who may not have bought them otherwise, thereby giving them experience with high quality inputs in a manner that subsequently stimulated commercial demand (Harrigan, 2008).

Bad weather in the 2004/5 agricultural season, coupled with a scaling down of the TIP, resulted in very low national maize production by recent standards. This translated into very acute food shortages and very high maize prices in 2005/06. In the hope of avoiding a recurrence of this problem, the government reintroduced large-scale input subsidies for maize in the 2005/6 season, targeting 1.3 million farm households during the first season. Evaluation studies have shown that this Farm Input Subsidy Program (FISP), a successor to the SPS and TIP, helped increase food production and promote food security at the national level, despite its high implementation cost (Dorward et al., 2008).

The present study uses data collected over the period 2002-2009 in central and southern Malawi to investigate how fertilizer subsidies influence fertilizer use among smallholder farmers. Although designed as a targeted program with exogenous selection criteria, Malawi’s FISP has been criticised for uneven roll out and widespread leakage (Doward et al., 2008; Ricker-Gilbert and Jayne, 2008; Holden and Lunduka, 2010a). Unfortunately, from a research design point of view, program participation cannot be interpreted as exogenously determined because in some instances the criteria for selecting households seem to have been ignored or adjusted to meet local goals. In addition, subsidies have been heterogeneous, consisting of either seed or fertilizer, or some combination of the two that does not reflect program guidelines. For these reasons, we use a two-stage, instrumental variables regression approach to analyze the effect of the FISP on fertilizer use. In the first stage, selection into the subsidy program is treated as endogenous and conditional on household- and village-specific factors. In the second stage, we estimate the parameters of a series of regression models, using the fertilizer intensity per hectare as the dependent variable. Effects on fertilizer use of the FISP are measured as instrumented versions of the participation probabilities. The two-stage approach accounts for the latent characteristics of participants, and provides a clear perspective on the pathway by which the FISP impacted fertilizer use. We conclude the analysis by estimating a production function for maize to measure sample average differences in maize yields between participating and non-participating households. The results suggest that farmers who obtained subsidized inputs used more fertilizer for maize production than those who did not receive any coupon. After adjusting for observed land use changes, we conclude that the fertilizer subsidy was associated with an average increase in maize output of approximately 250 kg per household.

## 2. Background

### *2.1 An overview of agricultural policy in Malawi*

Agriculture is the single most important sector of Malawi's economy. The sector employs about 80% of the country's total workforce, accounts for 39% of gross domestic product (GDP), and contributes more than 80% of foreign exchange earnings (Malawi Government, 2009a). The agricultural sector is divided into a smallholder sub-sector and an estate sub-sector, which contribute about 70% and 30% to agricultural GDP, respectively (Malawi Government, 2006). The smallholder sub-sector is primarily subsistence-oriented. Farmers in this sector mostly grow staple food crops, such as maize, cassava, and sweet potatoes. Estates focus on exportable, high-value cash crops, such as tobacco, tea, sugar, coffee, and macadamia nuts. Smallholder agriculture is characterized by small, highly fragmented land holdings under customary land tenure, and by lower yields than the estate sector, in which most of the land is under freehold and leasehold tenures.

Due to the importance of agriculture, Malawi's development strategies and policies have been heavily oriented towards this sector. The initial policy stance, following independence in 1964, included significant government involvement in the agricultural sector in production, extension, technology development and marketing of agricultural produce. The Government established a grain marketing board, the Agricultural Development and Marketing Corporation (ADMARC), which sold inputs to and bought produce from farmers. ADMARC also administered an inputs credit facility that was extended to those smallholder farmers who were considered creditworthy. Most of the resulting profits were channelled into the development of the estate sub-sector, which at the time was considered the main engine of growth. In addition, maize prices were kept low to reduce the price of food and encourage production of cash crops for export.

These early government policies had limited success. The collapse in the terms-of-trade towards the end of the 1970s (by up to 35%), drought in 1979-80, and the outbreak of civil war in neighbouring Mozambique (which led to an influx of refugees) highlighted the failure of the government's estate-led export strategy. By the mid-1980s, it was apparent that most Malawian households could not afford to buy the maize that filled ADMARC's warehouses (Harrigan, 2003). The country experienced a food crisis in 1987, as a result of declining per capita maize production and the inability of ADMARC to purchase maize (Sahn et al., 1990). The result was chronic and widespread malnutrition, which is reported to have affected nearly half of Malawi's children (Malawi Government, 2009a).

In 1990, the Malawi Government adopted a recommendation by the World Bank and the International Monetary Fund (IMF) to reform agriculture. This was aimed at reversing the worsening macroeconomic condition in the country. Legislation that barred smallholder farmers from growing burley tobacco and other commercial crops was revised through the resulting Agricultural Sector Adjustment Program (ASAP). A series of adjustment programs continued through the 1990s, which were supported by successive standby arrangements with the IMF and by loans provided by the World Bank (Harrigan, 2003). The stated aim was to remedy the policy bias against the smallholder sub-sector. Smallholder farmers were encouraged to produce exportable, high-value cash crops, such as tobacco, groundnuts, and cotton, through the raising of prices offered for these crops by ADMARC. Maize prices were deliberately kept low to discourage its production, and long-standing maize fertilizer subsidies were discontinued. An agricultural adjustment credit facility that was approved by the World Bank in 1990 included the partial removal of a restriction on the production of burley tobacco by smallholder farmers. As a result, overall smallholder output grew by 15.8% in 1995, reflecting increased tobacco production, as well as a bumper maize harvest (Harrigan, 2001).

The recovery was temporary, however, as it was interrupted by severe drought in 1992 and 1994, a growing influx of refugees from neighboring Mozambique, and a freeze in Western non-humanitarian aid in 1992-93 in protest against President Banda's suppression of the pro-democracy movement (Harrigan, 2003). It is generally acknowledged that the sequencing of policies on agricultural production by government during this period contributed to the worsening of poverty (Cromwell, 1992; Harrigan, 1988, 1997; Kherallah & Govindan, 1999; Sahn and Arulpragasam, 1991; Sahn, et al., 1990). The removal of fertilizer subsidies for maize significantly reduced the profitability of maize production (Harrigan, 1995), and cash crops displaced maize.[1]

During the period 1994-2000, Malawi registered generally positive growth in per capita GDP, per capita agricultural GDP, and per capita smallholder agricultural GDP, largely due to an increase in production of root crops (cassava and sweet potato) and other cash crops (Dorward and Kydd, 2004). This growth was also attributable, in part, to the introduction of the US$23.5 million Starter Pack Scheme (SPS) in 1998, which provided free seed and fertilizer to all Malawian smallholder farmers, enough to plant 0.1 hectare of staples (maize and legumes). The aim of the SPS was to increase food self-sufficiency, and – generally speaking – reflected a return to the government interventions and subsidies of former years. The SPS was drastically scaled down in 2001, as the Targeted Inputs Program (TIP). Smallholder maize production declined sharply following the scaling down of the SPS, although some observers attribute the decline to bad weather conditions during that period. Regardless of the cause, smallholder per capita GDP declined during 2000-05. The SPS and TIP were ultimately criticized for creating and perpetuating widespread dependency on maize, based on the concern that this could

[1] Although the displacement of maize raised numerous concerns, Sahn, van Frausum and Shively (1994) argued that a shift towards tobacco would have the potential to raise incomes and reduce levels of malnutrition among smallholder farmers who adopted tobacco as a crop. More recently, Binswanger et al. (2010) have argued that Malawi's comparative advantage vis-á-vis her neighbours rests with tobacco and other cash crops rather than maize.

eventually lead to a maize poverty trap (Harrigan, 2008), or increase smallholder vulnerability to drought (Holden and Lunduka, 2010b). Nevertheless, by 2008-09, the subsidy program was primarily targeted at maize production, with a small provision for tobacco fertilizer and pesticides for cotton.

### *2.2 Malawi's Farm Input Subsidy Program (FISP)*

To date, the FISP has been administered via a series of coupon-vouchers that enable households to purchase fertilizer, hybrid seed, and/or pesticides at greatly reduced prices (Dorward and Chirwa, 2009). Four main criteria were articulated to be used to identify beneficiaries in 2007-08 and 2008-09: (1) that the household owned land being cultivated during the relevant season; (2) that the household was a bona fide resident of the village; (3) that only one beneficiary would be eligible in a household; and (4) that vulnerable groups, especially households headed by children and women would be given priority.

In 2008-09, each voucher entitled a household to 50 kg of maize fertilizer at 8% of market price, and 2 kg of hybrid maize seed (or 4 kg of open pollinated maize) for free. Some households also received coupons entitling them to 50 kg of tobacco fertilizer. The Ministry of Agriculture distributed the coupons to districts, and traditional authorities (TAs) then allocated them to villages. Village heads, in collaboration with Village Development Committees (VDCs), identified beneficiary households within their jurisdictions, based on the stated criteria.
There appears to have been great variation in the criteria applied at the local level, the number of beneficiaries, and the number of coupons that were received by each household (Doward et al., 2008). A total of 150,000 tons of maize fertilizer and 20,000 tons of tobacco fertilizer were acquired by the government in 2008-09 for distribution to smallholder farmers.  The 2008-09

program cost around MK31 billion (MK140 = US$1), 95% of which was financed through the government budget and 5% by Malawi's development partners.

The Malawi Government recognizes low input use as one of the major factors contributing to low smallholder agricultural productivity in Malawi (Malawi Government, 2009a). Over time, prices for major inputs such as fertilizers and seeds have increased substantially while incomes for smallholder farmers have remained persistently low. Credit options are very limited due to the high risk of agricultural production and a shortage of farmer organizations. One of the objectives of the subsidy was to remedy the weak demand for inputs by increasing smallholder farmers' access to and use of chemical fertilizers and improved maize seed. We pick up this thread of argument, asking whether, in the context of our sample, the program boosted smallholder farmers' use of chemical fertilizer and whether the program lifted maize yields. We attempt to answer these questions using field data from Kasungu and Machinga Districts in central and southern Malawi, respectively, which were collected in 2009. These data catalogue the experiences of 380 farm households and, when combined with data from 2002 and 2006 surveys from the villages, allows us to construct a balanced three-round panel for a subset of the farms.

## 3. Empirical approach

### *3.1 Participation in the FISP*

Our empirical approach relies on a series of two-stage, instrumental variables regressions to examine impacts of the FISP on fertilizer use.[2] In the first stage, selection into the subsidy

[2] Using propensity score matching techniques Chirwa (2010) evaluates the FISP and a previous program in Malawi and finds mixed results, with negative impacts in 2006 and positive impacts in 2009.

program (i.e. coupon receipt) is treated as endogenous and conditional on a range of household- and village-specific factors. The second stage uses the fertilizer application rate (in maize production) as the dependent variable. Selection of instruments and tests of exclusion restrictions are discussed in relevant sections below.

In choosing an appropriate indicator of coupon receipt, several choices present themselves. One approach (not used here) would be to treat coupon receipt in a simple binary fashion, with 1 indicating receipt of a coupon of any kind and 0 indicating otherwise. Instead, we use two methods that account for heterogeneity in program roll-out and the fact that different households received different quantities and combinations of coupons for seed and fertilizer. Our first estimation strategy is to use a multinomial logistic (MNL) regression to predict the probability of participation in mutually exclusive categories of the program. Our second strategy relies on computing the aggregate value of all coupons received by a household. This constructed variable has the virtue of providing a household-specific, scalar measure of the magnitude of the program treatment. It also can be easily incorporated into standard IV estimation methods. In both cases the regression takes the form:

$$C_i = \beta_0 + \beta_1 Z_i + \beta_2 P_i + \beta_3 D_k + \beta_4 S_i + \beta_5 V_j + \varepsilon_i \qquad [1]$$

where the dependent variable $C_i$ represents our indicator of household $i$'s participation in the FISP. $\boldsymbol{Z}$ is a vector of control variables that represents household socio-demographic and economic factors that could influence coupon receipt, including the age, gender, and education of the household head; the number of household residents; the size of the household's landholding; and the wealth position of the household. Vector $\boldsymbol{P}$ represents participation in the subsidy program during the previous season, which could increase or decrease a household's chances of receiving coupons in the current season. $D$ is a binary variable, indicating whether the household resides in Kasungu district. Finally, ε is an error term, representing random and unobservable measurement error.

Estimating program effects in the fertilizer use regression requires that we include at least one identifying variable in the participation equation that does not enter the fertilizer use equation. For identification, we employ four variables which we hypothesize affect participation in the FISP, but which do not directly affect the amount of fertilizer used by the household. In terms of program design, the subsidy program was specifically targeted at (i) female headed households, (ii) the poor and (iii) permanent residents. For this reason we use these three selection variables (*S*) for identification in the first stage regression. Residency represents the household's social capital, measured as the number of years the household head has resided in the village. We hypothesize that the longer the householder was a village resident, the more likely he or she is to be recognized by the village chief and the Village Development Committee during selection of coupon recipients. Poor households are defined as those in the bottom 40% of the asset distribution. In addition, we also use the population of the village (*P*) as a fourth instrument. Since the inception of the FISP in 2005, a number of new, small villages have arisen, many as breakaways from larger villages. While some growth is expected, the rate of village formation has been much higher than before the subsidy program. Some of these new villages consist entirely of family members of the new village heads, who use control of coupon distribution to benefit their own extended families. Some of the new villages were not recognized by the local District Assembly and were less likely to receive coupons. Therefore, we hypothesize that residents of old, larger villages may have had a higher probability of receiving coupons than residents of small, newly established villages. The relevance of these instruments is indicated by their pair-wise and group-wise correlation with various coupon receipt indicators.

These variables are excluded from the subsequent stage fertilizer regression on the grounds that they exert no independent influence over fertilizer purchase decisions, except through their impact via coupons. Although using MNL regressions for the first stage provides us with no convenient procedure for testing exclusions restrictions, none of the chosen instruments has an estimated coefficient statistically different from zero at the 95% confidence level when included as an explanatory variable in the fertilizer use regression. When we switch to a set of standard IV regressions as an alternative, we report results from overidentification tests that confirm their validity as a set of instruments

### *3.2 Fertilizer use regression*

Previous studies have attempted to understand the factors affecting fertilizer use decisions by smallholder farmers (Green and Ng'ong'ola, 1993; Nkonya et al., 1997; Isham, 2002; Abdoulaye and Sanders, 2005; Chirwa, 2005). Among the factors found to be correlated with greater fertilizer adoption are characteristics of the farming system, crop variety, education, family headship, farm size, credit access, and income from off-farm employment. In this study, we estimate the subsidy's effects on the use of fertilizer for maize production during the 2008/9 agricultural season. The dependent variable is the total quantity in kilograms per hectare of fertilizer that the household applied to maize.  This may consist of both subsidized and unsubsidized fertilizer.  The regressions take the form:

$$F_i = \phi_0 + \phi_1 P_i + \phi_2 J_i + \phi_3 K_i + \phi_4 C_i + \phi_5 R_i + \phi_6 M_i + \phi_7 H_i + \phi_8 L_i + \mu_i \qquad [2]$$

where $F_i$ is the quantity of fertilizer (in kg/ha) applied to both improved and traditional maize in the 2008/9 agricultural season by household $i$.[3] The explanatory variables are described below.

Vector ***J*** represents variables that describe the household's socio-demographic and economic characteristics (age and education of the household head; number of household residents; farm size; maize self-sufficiency status, and the household's wealth status). We include a variable for householder age as younger household heads have been found to be more inclined to experiment with fertilizer (Doss and Morris, 2001; Feder and Umali, 1993; Feder, Just and Ziberman, 1985). We also expect educated householders to be more inclined to use more fertilizer than the less educated (Feder, Just and Ziberman, 1985; Feder and Umali, 1993; Doss and Morris, 2001). To proxy labor availability in the household, we use household size. Households that were not self sufficient in maize during the previous season should have the need to use more fertilizer during the current season. A household is identified as a net buyer of maize if in 2008 it purchased more maize than it sold, following the definition of the World Food Program (2009). We include a control variable representing the household's wealth status under the assumption that wealthier households may have a greater capacity to purchase fertilizer than poor households.

While fertilizer use is expected to be scale-neutral, we include a variable for farm size under the assumption that farmers that have more land (and are therefore wealthier) might use more fertilizer (Doss and Morris, 2001; Feder 1980). It can also be argued that the incentive to intensify by using fertilizer would be greater for households that are land constrained. We include a squared term for land size to test for potential non-linearities in the relationship

[3] A small number of households ($n$=12) did not apply any fertilizer, whether subsidized or not. Our results are insensitive to whether we use OLS or a Tobit model to account for lower-truncation in the range of the fertilizer variable.

between farm size and the intensity of fertilizer use. *P* is a variable for the fertilizer-maize price ratio, which should negatively correlate with the use of fertilizer. Since 57% of households in the sample were net buyers of maize, we use the average purchase price they faced for maize in 2008, the year prior to the fertilizer purchase decision. We postulate that such households would have been motivated to produce their own maize and use fertilizer if the buying price they faced in the preceding season was high. We use the average selling price of maize in 2008 for households that were net sellers of maize. For households that were self-sufficient in maize, the village average price of maize is used.

As in the coupon receipt equations estimated earlier, we include a district-level binary indicator *K* to control for agro-ecological differences that might drive fertilizer use. We include a dummy variable *H* for improved maize use in the fertilizer use equation as we expect farmers that grow improved maize will be more likely to use more fertilizer. Vector ***R*** contains a set of indicator variables for shocks encountered before and/or during the 2008/9 agricultural season. They are grouped into three broad categories: shocks that resulted in labor loss, financial loss and physical crop loss. All these would be negatively correlated with the quantity of fertilizer purchased by the household. We also include a variable, *M* for market access – the distance between the village and the market for inputs under the assumption that transaction costs play a role in input purchase decisions.

***C*** represents receipt of a coupon, i.e. the farmer's participation in the FISP in the 2008/9 agricultural season. This is the primary variable of policy interest. In the first set of models we use observed and predicted values from the first-stage MNL participation equations, since these variables can be most easily interpreted in terms of policy impacts. In the second set of models we employ IV techniques directly, using the value of coupons received as the indicator of program participation. While interpretation of this variable is more cumbersome, it provides us with the ability to test the validity of our exclusion restrictions and gain greater assurance that we have properly dealt with endogeneity issues. These regressions thereby serve as a robustness check for the first set of regressions. We expect the receipt of a fertilizer coupon in the current season to be positively correlated with the quantity of fertilizer used in the current season.

Finally, we include in some reported regressions one or more lagged variables, corresponding to household use of fertilizer in the 2002/03 and 2006/07 growing season. The inclusion of these variables reduces the size of our sample, since the 2- and 3-round balanced panels are somewhat smaller than the 2009 sample. However, these regressions provide us with additional checks of robustness, and help to ensure that the pattern of greater fertilizer use among coupon recipients does not simply reflect greater rates of coupon receipt among households that tended to use fertilizers at high rates in all periods.

### *3.3 Impacts of the FISP on maize yields*

Finally, to place the FISP into a productivity context, we estimate a very simple plot-level yield response function for maize to fertilizer to measure the potential gains from the subsidy program. We compare yields realized by beneficiary and non-beneficiary households. Farmers in the sample planted either traditional maize or improved maize or both. For this analysis we stack observations for traditional and improved maize. The yield (in kg/hectare) for household $i$ on plot $j$ is estimated using a linear-in-logs production function as follows:

$$y_{ij} = \beta_0 + \beta_1 f_{ij} + \beta_2 I_{ij} + \beta_3 h_{ij} + \epsilon_{ij} \qquad [3]$$

where $f_{ij}$ is the amount of fertilizer applied (in kg/ha), which is expected to have a positive, but diminishing effect on yield. Previous studies have estimated polynomial production functions in developing countries and have found diminishing returns to fertilizer use (Traxler and Byerlee 1993, Kouka et al. 1995, Ricker-Gilbert and Jayne 2008). $I_{ij}$ is a binary indicator of whether the plot was intercropped with another crop; we expect its estimated coefficient to be negative. $h_{ij}$ is a binary indicator of whether improved maize was used on the plot. Given differences in the genetic potential of the two varieties, plots planted with improved maize should produce higher yields than those planted with traditional maize. $\epsilon_{ij}$ is a random term for unobserved plot level heterogeneity. We exclude labor from the estimation as the survey did not attempt to collect detailed plot level data on allocation of household labor.[4] Table 1 presents descriptive statistics for the variables used in the regression analyses.

## 4. Model results and discussion

### *4.1 MNL Results for participation in the FISP*

Results from the MNL regression are presented in Table 2. Variables are grouped such that instruments appear below the dashed line. Contrary to program design and targeting guidelines, we find that the most vulnerable people in our sample were less likely to have received FISP coupons during the 2008-2009 agricultural year. Controlling for other characteristics of the household, those headed by females, one of the target groups, were less likely to have received a coupon in our sample than those headed by males. In addition, asset-poor households were more likely to receive no coupon than better-off households, which is consistent with reports by Ricker-Gilbert and Jayne (2008) and Xu et al. (2009) for Malawi and Zambia, respectively. Among the other instruments, we find no strong pair-wise correlation between coupon receipt

[4] In the absence of labor allocation data, we attempted to approximate labor use for maize production from household composition but obtained unreliable results. The estimated regression coefficients are robust to the inclusion of this excluded labor variable.

and size of village.  However, households that had been residents of their villages for longer periods had a higher probability of receiving coupons for more than the recommended packet of inputs (100 kg fertilizer and seed). This result points to the possibility of the head having established, over time, close friendship with the village chief and/or other members of the Village Development Committee who were responsible for identifying subsidy beneficiaries at the village level.

Among the other correlates with coupon receipt, we find that older households were more likely to have received a complete input subsidy packet than younger households. These were likely considered to be established full-time farmers. Households where the head had some education were more likely to have received more coupons than the recommended packet size. This could suggest that they might have had more bargaining power with village chiefs, who in most settings played a key role in identifying beneficiary households, than those without any form of education.  In general, larger farm families were less likely to receive any coupon. The sign on the family size variable is consistently negative in all coupon receipt categories where the farmer received some form of the coupon. This is inconsistent with the hypothesis that larger households would be targeted because they have higher nutritional needs than smaller families. A plausible explanation for this inconsistency would be that larger households are probably considered as having enough labor to support off-farm work during months of calorie shortfalls. We earlier posited that households with very small landholdings should have been considered ineligible for the subsidy program while those with very large landholdings should have been considered too well off to be eligible; however, we find no strong relationships between farm size and coupon receipt in the MNL regressions.

The participation regression results reveal district-level differences in administration of the subsidy program: farmers in Kasungu district were more likely to have received coupons for 100 kg of maize fertilizer or a full packet of coupons (100 kg fertilizer and seed). In Machinga, farmers had a higher probability of receiving either a half packet of coupons or more than the recommended packet size. While the two districts received equal amounts of fertilizer relative to the size of the target population in each district, it could be that coupons were distributed unevenly in Machinga.[5] There appears to be continuity in the receipt of coupons for maize inputs as households that received coupons during the previous agricultural season were more likely to receive the same coupons during the current season. However, receipt of a tobacco coupon in the previous agricultural season is negatively correlated with a household's chances of receiving coupons for maize seed and fertilizer in the current year. We suspect village chiefs attempted to have as many households as possible benefit from the program by "unbundling" sets of coupons before distributing them.

### *4.2 Results for impacts of coupon receipt on fertilizer use based on MNL approach*

Table 3 presents results for three fertilizer use regressions that use the MNL results to provide instrumented values of coupon receipt. Fertilizer use is here measured as intensity: total kg applied to a hectare of maize. Model 1 was estimated using the observed coupon receipt variables and models 2 and 3 use the instrumented versions of these variables. Controlling for the possible endogeneity of coupon receipt lowers the sizes of some of the point estimates in the

[5] 13,012mt of NPK fertilizer were planned for distribution to 101,109 farm families in Kasungu, or 128kg per household. In Machinga, 10,186mt of NPK fertilizer were to benefit 74,447 registered farmers, an equivalent of 136kg per farmer (Malawi Government, 2009b).

second and third models, but does not change the signs or significance of most estimated coefficients.

Looking models 1 and 2 we find that, in general, larger households used significantly more fertilizer per hectare for maize production than smaller households. This is consistent with previous research, which shows that the use of improved maize technology (hybrid maize and chemical fertilizers) accentuates seasonal peaks in labor demand and is therefore more easily adopted in households with surplus labor (Byerlee and Heisey, 1996). Households that were classified as net buyers of maize in the 2007/8 season used less fertilizer per acre in 2009 than those that were either self-sufficient in or were net sellers of maize. This may suggest a cash constraint since fertilizer purchases are made during food deficit months (September-December/January) when grain prices are rising. Farmers with smaller farms used more fertilizer per hectare for maize production than those with larger farms, suggesting an inverse farmsize-farm productivity relationship rather than any wealth effect in accessing inputs (Doss and Morris, 2001). The correlation between planting improved maize and fertilizer use for maize production is positive and statistically significant. Farmers who planted improved maize used 64 kg more fertilizer per hectare for maize production than those who planted traditional maize. This could be indicative of patterns in adoption behavior – farmers adopt improved maize production technologies as a package. In addition, improved maize technologies have always been promoted as a package comprising seed and fertilizer.

Although the coefficient on the input-output price ratio is positive it is statistically not different from zero. Xu et al. (2009) report a positive relationship between fertilizer purchases and the ratio of fertilizer to maize grain prices. A positive correlation may be explained by lower maize prices rather than higher fertilizer prices given that the majority of households in the sample are net buyers of maize. There appears to be no significant relationship between fertilizer use for maize and household shock variables, although cash losses are negatively correlated with fertilizer use. Households that were further from the main market for inputs used more fertilizer, but the size of the correlation is small (0.58 kg).

The relationships between the various forms of coupon receipt and fertilizer use for maize are mixed. As expected, households that did not receive any coupon used less fertilizer, as did those that received seed only. Households that received two coupons for 100 kg of fertilizer used 190 kg more fertilizer per hectare for maize on average than those that received no coupon. Receipt of a complete packet of coupons (100 kg fertilizer and seed) is correlated with 124 kg greater use of fertilizer, on average. Unsurprisingly, households that received a seed coupon and more than two fertilizer coupons used more fertilizer. Overall, the results suggest that the FISP increased fertilizer use among benefiting households, which is consistent with the findings of Ricker-Gilbert and Jayne (2008).

While models 1 and 2 appear to provide evidence of a positive correlation between the subsidy program and fertilizer use for maize production, the result does not imply causality. To reach more robust conclusions regarding the program's causal effects, we introduce in the final column of Table 3 results from an additional regression in which we add as an explanatory variable an indicator of observed per-hectare fertilizer use in the 2006/2007 growing season, roughly 24 months prior to the fertilizer use decisions that constitute the dependent variable in the regression. These data come from an earlier survey conducted in the same area by CIFOR's PEN project.  Although there was complete geographic overlap between the CIFOR survey and our own, we do not have a completely matched panel.  Model 3 is based instead on observations from 298 households that were visited in both 2006 and 2009.  The logic behind including this lagged endogenous variable in the regression is that it should help to control for underlying household-specific variation in fertilizer use that is affected by unobservables such as soil quality or farmer attitudes and experience. The results reported in the final column of Table 3 reveal no strong correlation between average levels of fertilizer use in the 2006 and 2009 surveys. More importantly from the current perspective, including the lagged measure of fertilizer use has little or no impact on the signs, magnitudes or significance of the policy variables of interest. This increases our confidence that the measured impacts of coupon receipt on fertilizer use in models reported in Table 3 are causal, rather than reflections of shared correlation with past fertilizer use.

### *4.3 IV Results for impacts of coupon receipt on fertilizer use*

To further check the robustness of these results, we now shift attention to a set of IV regressions, estimated using the same dependent variable as above, namely per-hectare fertilizer use on all maize in 2009. We drop the household-specific shock variables used above and replace the set of instrumented coupon variables will a scalar measure of the market value of all coupons received by the household. We employ the same instumentating strategy, employing female headedness, asset poverty, years of residency and village population as our instruments for the FISP variable, excluding these from the second stage regression for fertilizer use. We report the results from 3 models in Table 4. Model 1 uses explanatory variables from the 2009 survey only. Models 2 and 3 add to these a set of indicators for household fertilizer intensity in 2006 and 2002, respectively. Test statistics reported in the final row of the table support the exclusion restrictions that we use in identifying the model.

Broadly speaking, the IV regressions perform well and reinforce the findings reported above. Controlling for a range of household characteristics, coupon receipt is positively correlated with fertilizer use at statistically significant levels. Inclusion of indicators for previous levels of fertilizer use, however, diminish the magnitude of the estimated coefficient on the FISP variable considerable – reducing its size by more than half across the three models from 1.21 to 0.50. This pattern strongly suggests that a sizable amount of fertilizer use in 2009 can be explained by household farming proclivities, as proxied by previously observed fertilization rates, leaving a smaller proportion to be attributed to coupon receipt. Other patterns observed in the regression include the inverse relationship between farm size and fertilizer intensity and moderately strong distance and price effects.

### *4.4 Results for impacts of the FISP on maize yields*

Table 5 presents results for a parsimonious production function for maize, estimated for plot-level data (i.e. a stacked dataset in which individual households may be represented more than once). As expected, we find a positive and significant correlation between the amount of fertilizer used and yield. The results support the hypothesis of diminishing returns to fertilizer use. As posited earlier, maize plots that were intercropped with other crops registered yields that were significantly lower (by about 18%) than those that were mono-cropped. The results also show that plots that were planted with improved maize registered yields that were 17% higher than those planted with traditional maize. Thus farmers producing improved maize are at a higher intercept on the production function than traditional maize producers.

Figure 2 sketches the purported average relationship between fertilizer and maize yield. Consistent with the sample data and regression results, households producing improved maize are placed at a higher intercept than those producing traditional maize. Points $\boldsymbol{t_0}$ and $\boldsymbol{h_0}$ on the diagram show the yield from traditional maize and from improved maize, respectively, at average fertilization rates for farmers who did not access subsidized fertilizer. Points $\boldsymbol{t_1}$ and $\boldsymbol{h_1}$ represent the yield from traditional maize and improved maize, respectively, at mean fertilization rates for farmers who used subsidized fertilizer. Access to subsidized fertilizer and no seed moves traditional maize producers from point $\boldsymbol{t_0}$ on the production function to $\boldsymbol{t_1}$. Producers of improved maize who accessed subsidized fertilizer move to $\boldsymbol{h_1}$ from $\boldsymbol{h_0}$. Access to a complete packet of coupons (for seed and fertilizer) shifts production from $\boldsymbol{t_0}$ to $\boldsymbol{h_1}$. The total yield gain can be calculated as

$$\Delta y = y_{h1} - y_{t0} \qquad [4]$$

where $\Delta y$ represents the yield gain from the subsidy program per hectare. The average gain in maize yield from accessing subsidized maize seed and fertilizer is 447 kg/ha. The gain from accessing fertilizer only and no improved maize seed (i.e. moving from $\boldsymbol{t_0}$ to $\boldsymbol{t_1}$) is 249 kg/ha, about half the gain from receiving a complete subsidy packet of improved seed and fertilizer. Thus in terms of impact, including improved maize seed in the FISP results in the highest net benefit as the yields from improved maize are higher at each level of fertilization than the yields from traditional maize.

In a related study of the land allocation impacts of the FISP, Chibwana, Fisher and Shively (2010) find for the same sample of farmers that each complete set of subsidy coupons was associated with a 16% increase in the area that farmers allocated to maize during the 2008/9 agricultural season. Using results from the production function represented in Figure 2, the total direct impact of receiving a coupon for seed and two coupons for fertilizer can be calculated as:

$$(Y_{h1} - Y_{t0}) * {}^{\partial L}/_{\partial C} * L_m \qquad [5]$$

where $Y_{h1}$ (=1,510 kg) represents the yield per hectare from improved maize obtained by farmers who applied chemical fertilizer obtained through the subsidy program and $Y_{t0}$ (=1,063 kg) represents the yield per hectare from traditional maize for farmers who received no coupon. $\partial L / \partial C$ (=1.16) is the partial change in maize area resulting from receiving coupons for maize seed and fertilizer and $L_m$ is the average amount of land planted to maize (0.88 hectares). The average farm-level impact on maize production, accounting for both yield and area changes, is therefore 456 kg for each complete set of coupons (seed and fertilizer). However, we note that output from other crops would likely decline as a result of a shift toward maize. The size of this decline is not derived here, but Chibwana, Fisher and Shively (2010) report that farmers who received coupons for maize seed and fertilizer allocated about 20% less land to other crops than those who did not receive any coupon. Valuing this reduced crop area based on average areas and yields for cassava (the representative crop most likely displaced), and using the prevailing farm gate price of cassava and retail price of maize, we calculate that the maize-equivalent value of offset production was roughly 250 kg of maize, on average, slightly more than half of the observed gain.[6]

## 5. Conclusions and policy implications

The maize subsidy program was intended to benefit in each community both the most vulnerable farm households as well as those having sufficient land to make use of the subsidized seed and fertilizer. However, results for the two models of coupon receipt suggest that the most vulnerable people in the communities were not the main recipients of the coupons. In fact, female heads

[6] Chibwana, Jumbe and Shively (2010) measure the effects of the subsidy program on forest use, and conclude that maize subsidies appear to have reduced expansion modestly, although tobacco subsidies delivered as part of the FISP generated a derived demand for timber (to construct tobacco drying sheds) and therefore may have a detrimental impact on forest cover.

were intended to be targeted, yet findings for both models indicate they were less likely to benefit from the program compared to male-headed households. In addition, asset-poor households were less likely to participate in the FISP compared to non-poor households. These results are consistent with research by Holden and Lunduka (2010a), Doward et al. (2008) and Ricker-Gilbert and Jayne (2008) regarding the FISP. The selection of beneficiaries appears to have mainly reflected political and regional factors such as whether a household received coupons in the previous year, or if the village was a new and possibly illegitimate entity.

Critics argue that to be effective, subsidies need to be targeted at the right people. The FISP has been widely cited as a smart subsidy success story (Minot and Benson, 2009).[7] Given that the poor and vulnerable in the two communities we sampled were not the primary beneficiaries of the subsidized inputs, questions remain about the targeting effectiveness of the program. Could the program have been more effective at increasing fertilizer use had the poor been targeted? Results from the fertilizer use regression show that households that were net buyers of maize used less fertilizer for maize production during the study year. One of the goals of FISP has been to jumpstart the use of improved maize technologies among resource-poor smallholder farmers. To achieve this goal, the poor and vulnerable need to be the primary targets for the input vouchers. A revision of the system for distributing the coupons to households could help to achieve this.

Nevertheless, the results suggest that the subsidy program for maize may have helped increase fertilizer use among benefiting households. This finding is consistent with previous research by Ricker-Gilbert and Jayne (2008) about the effects of the Malawi subsidy program on

[7] Minot and Benson (2009) define "smart subsidies" as mechanisms to provide subsidized goods and services designed both to promote market development and to enhance the welfare of the poor. Such subsidies are often phased out once the market infrastructure has been developed and markets for the supply of the relevant goods and services are functioning.

fertilizer use. Fertilizer use intensity is negatively correlated with farm size, and positively correlated with the planting of improved maize. Households that were classified as net buyers of maize used less fertilizer, suggesting competition for cash between immediate consumption and purchases of fertilizer.

The effect of the FISP on maize yields is only through the program's effect on fertilizer use and maize varietal choice. Farmers planting improved maize obtained higher yields than those producing traditional maize. Results show that the average increase in maize yields from accessing a standard FISP package of maize seed and fertilizer was 447 kg/ha, about twice the yield gain from receiving coupons for fertilizer only. By design, the program may be placing too much emphasis on fertilizer for maize. Under the FISP, farmers were given the choice between 2 kg of hybrid maize seed or 4 kg of OPV seed in addition to 100 kg of fertilizer (50 kg basal and 50 kg side-dressing). Given the yield differentials between the two varieties, shifting emphasis to promoting the use of hybrid seed in the subsidy program would most likely help to generate greater returns to the program. In the long run, ensuring food security may rest on policies that seek to improve the delivery of improved seed to farming communities.

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Table 1 Values of variables used in the regression analyses

| Variable | Description | Mean | SD |
|---|---|---|---|
| Age | Age of household head (years) | 46.8 | 14.9 |
| Female-headed | Female headed household (1=yes; 0=no) | 0.15 | 0.35 |
| Education | Education of household head (1=some; 0=none) | 0.85 | 0.35 |
| Household size | Number of residents in the household | 6.33 | 2.77 |
| Farm size | Total land owned by household (hectares) | 1.61 | 1.44 |
| Farm size squared | Square of total land owned by household (hectares$^2$) | 4.77 | 12.4 |
| Adults | Number of adults (aged 15 years and over) | 3.34 | 1.67 |
| Net buyer of maize | Household was a net buyer of maize in 2008 (0=no, 1=yes) | 0.57 | 0.50 |
| Poorest | Asset-poor household (0=no, 1=yes) | 0.47 | 0.50 |
| Residency | Number of years head has been resident in the village | 35.7 | 17.2 |
| Tobacco coupon 2008 | Received tobacco fertilizer coupon in 2008 (0=no, 1=yes) | 0.04 | 0.19 |
| Maize seed coupon 2008 | Received maize seed coupon in 2008 (0=no, 1=yes) | 0.05 | 0.21 |
| Maize fertilizer coupon 2008 | Received maize fertilizer coupon in 2008 (0=no, 1=yes) | 0.26 | 0.44 |
| Maize seed & fertilizer 2008 | Received maize seed & fertilizer coupons in 2008 (0=no, 1=yes) | 0.51 | 0.50 |
| Kasungu | Household resides in Kasungu District (0=no, 1=yes) | 0.56 | 0.50 |
| Village size | Number of households in the village | 117 | 79 |
| Improved maize | Household planted improved maize (0=no, 1=yes) | 0.44 | 0.50 |
| Fertilizer-maize price ratio | Ratio of price of fertilizer to the price of maize grain (MK/kg) | 1.37 | 1.61 |
| Distance to market | Distance from village to market for ag. inputs (walking minutes) | 64 | 49 |
| Labor loss | Household experienced a labor loss in 2008 (1=yes; 0=no) | 0.17 | 0.37 |
| Crop loss | Household suffered crop loss in 2008 (1=yes; 0=no) | 0.40 | 0.49 |
| Financial loss | Household suffered financial loss in 2008 (1=yes; 0=no) | 0.29 | 0.45 |
| Maize fertilizer price | Price of maize fertilizer (MK/kg) | 53.3 | 54.5 |
| Tobacco fertilizer price | Price of tobacco fertilizer (MK/kg) | 107 | 57.7 |
| Seed coupon only | Predicted prob. of receiving a coupon for seed only | 0.06 | 0.09 |
| 50 kg fertilizer coupon | Predicted prob. of receiving a coupon for 50 kg fertilizer | 0.08 | 0.08 |
| Seed & 50 kg fert. coupons | Predicted prob. of receiving coupons for seed and 50 kg fert. | 0.16 | 0.08 |
| 100 kg fertilizer coupons | Predicted prob. of receiving two coupons for 100 kg fert. | 0.09 | 0.11 |
| Seed and 2 x 100 kg fert. | Predicted prob. of receiving coupons for seed and 200 kg fert. | 0.37 | 0.20 |
| Seed and >100 kg fert. | Predicted prob. of receiving coupons for seed & 100kg fert. | 0.09 | 0.09 |
| Fertilization rate | Quantity of fertilizer applied per hectare of maize (kg/ha) | 184 | 161 |
| Seed per hectare | Quantity of maize seed used (kg/hectare) | 19.7 | 15.1 |
| Seed per hectare squared | Square of quantity of maize seed used (kg/hectare)$^2$ | 613 | 1119 |
| Intercrop | Maize was grown as an intercrop (1=yes; 0=no) | 0.45 | 0.50 |
| Number of observations | | 380 | |

Table 2 Regression results for model of coupon receipt

| | Multinomial logit | | | | | |
|---|---|---|---|---|---|---|
| Variable | Seed only | 50kg fertilizer | 50kg fertilizer and seed | 100kg fertilizer | 100kg fertilizer & seed | > 100kg fertilizer & seed |
| Constant | -0.162 | 0.623 | -0.484 | -3.201 | -1.273 | -5.379*** |
| | (-0.208) | (0.952) | (-0.447) | (-1.290) | (-0.807) | (-18.20) |
| Age | -0.0157** | 0.0282*** | 0.00805*** | 0.0159 | 0.0282*** | 0.0280** |
| (years) | (-2.117) | (4.056) | (21.04) | (1.413) | (3.003) | (2.157) |
| Education | -0.563 | -0.251** | 0.389 | -0.0694 | -0.118 | 1.610** |
| (0=none, 1=some) | (-1.634) | (-2.521) | (0.830) | (-0.383) | (-0.274) | (1.999) |
| Farm size | -0.298*** | -0.231 | -0.107 | 0.131 | 0.00164 | 0.0734 |
| (hectares) | (-3.861) | (-0.502) | (-0.579) | (0.375) | (0.0303) | (0.795) |
| Farm size sq. | 0.0113*** | -0.0131 | 0.00242 | -0.0151 | -0.00204*** | -0.00198** |
| (hectares$^2$) | (4.873) | (-0.306) | (0.369) | (-0.891) | (-3.872) | (-2.013) |
| Household size | -0.0470 | -0.125*** | -0.0850*** | -0.115 | -0.176** | -0.0287 |
| (number) | (-0.339) | (-6.709) | (-3.552) | (-1.411) | (-2.020) | (-0.490) |
| 2009 tobacco | -1.013** | -15.02*** | -0.623 | -14.63*** | -0.385 | -1.168 |
| coupon (0/1) | (-2.306) | (-12.29) | (-1.084) | (-10.08) | (-1.573) | (-0.578) |
| 2008 seed | 2.714** | 0.316 | 1.686 | -15.13*** | 1.431** | 1.573*** |
| coupon (0/1) | (2.370) | (0.894) | (1.109) | (-15.05) | (1.970) | (46.56) |
| 2008 MZ fert. | 0.969 | 1.290*** | 1.935* | 3.371*** | 1.692* | 1.357 |
| coupon (0/1) | (0.580) | (3.761) | (1.675) | (984.7) | (1.797) | (1.129) |
| 2008 MZ seed | 0.789*** | 0.206 | 1.731*** | 1.445*** | 2.728*** | 1.830*** |
| & fert. (0/1) | (11.03) | (0.379) | (4.641) | (3.477) | (7.887) | (5.867) |
| Kasungu | 1.153*** | -0.218*** | -0.311*** | 0.351** | 1.325*** | -0.682*** |
| (0=no, 1=yes) | (4.787) | (-4.461) | (-9.780) | (2.139) | (5.926) | (-4.069) |
| Female-headed | -0.981 | -0.863*** | -0.689*** | 0.0863 | -1.194*** | -0.612 |
| (0=no, 1=yes) | (-0.823) | (-5.642) | (-3.688) | (0.235) | (-3.161) | (-0.669) |
| Poorest | -1.027*** | -0.571 | -0.309*** | -0.630* | -0.755** | -0.989 |
| (0=no, 1=yes) | (-2.983) | (-1.080) | (-6.542) | (-1.935) | (-2.469) | (-1.239) |
| Village size | 0.00119 | 0.00313** | 0.00225 | 0.00626 | 0.00701 | 0.00721 |
| (# hholds) | (0.315) | (2.251) | (0.337) | (0.613) | (0.920) | (1.019) |
| Residency | 0.0235 | -0.0190 | -0.00512 | 0.00839 | -0.0144*** | 0.0278*** |
| (years) | (1.068) | (-0.722) | (-0.699) | (1.200) | (-3.438) | (3.284) |
| *N* | 23 | 34 | 62 | 35 | 139 | 36 |

Notes: For MNL, "received no coupon" is the base outcome ($n$=51); $t$ statistics in parentheses; $^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$; MNL pseudo $R^2 = 0.16$

Table 3 Regression results for the effect of coupon receipt on maize fertilizer use

| | Model 1<br>Observed coupon variables | Model 2<br>Instrumented coupon variables | Model 3<br>Instrumented coupon; lagged fertilizer |
|---|---|---|---|
| Constant | 128.0* | 63.37 | 111.38 |
| | (2.536) | (0.592) | (1.05) |
| Age | -0.173 | -0.564 | -0.920 |
| (years) | (-0.299) | (-0.736) | (-1.27) |
| Education | 19.46 | 34.29 | 30.02 |
| (0=none, 1=some) | (0.827) | (1.097) | (0.97) |
| Household size | 6.004 | 8.712* | 7.51* |
| (number of persons) | (1.831) | (2.352) | (2.02) |
| Net buyer of maize in 2008 | -21.62 | -30.12* | -21.22 |
| (0=no, 1=yes) | (-1.273) | (-1.774) | (-1.23) |
| Farm size | -92.85* | -84.58* | -85.53* |
| (hectares) | (-6.689) | (-4.832) | (-4.65) |
| Farm size squared | 6.416* | 6.388* | 6.22* |
| (hectares$^2$) | (4.452) | (3.601) | (3.51) |
| Kasungu | 14.12 | 18.05 | 33.27 |
| (0=no, 1=yes) | (0.668) | (0.449) | (0.92) |
| Improved maize | 55.73* | 63.94* | 69.13* |
| (0=no, 1=yes) | (3.063) | (3.553) | (3.73) |
| Fertilizer-maize price ratio | 8.658 | 1.878 | 0.467 |
| ($P_F/P_M$) | (1.450) | (0.328) | (0.08) |
| Labor loss | 1.279 | 5.081 | 13.50 |
| (0=no, 1=yes) | (0.0614) | (0.240) | (0.66) |
| Crop loss | 11.11 | 16.50 | 2.63 |
| (0=no, 1=yes) | (0.694) | (1.015) | (0.15) |

*Table 3 continues*

*Table 3 completed*

| | | | |
|---|---|---|---|
| Financial loss (0=no, 1=yes) | -15.13 (-0.885) | -9.207 (-0.536) | -4.704 (-0.28) |
| Distance to market (walking minutes) | 0.595* (3.544) | 0.579* (3.254) | 0.532* (2.93) |
| Seed coupon only (0=no, 1=yes) | -4.214 (-0.108) | -60.81 (-0.406) | -50.54 (-0.36) |
| 50kg fertilizer coupon (0=no, 1=yes) | 44.30 (1.259) | 385.9* (2.031) | 696.97* (3.20) |
| Seed and 50kg fertilizer coupons (0=no, 1=yes) | 43.00 (1.439) | -32.04 (-0.162) | -351.20 (-1.84) |
| 100kg fertilizer coupons (0=no, 1=yes) | 135.5* (3.964) | 189.6** (2.011) | 161.82 (1.74) |
| Seed and 100kg fertilizer coupons (0=no, 1=yes) | 73.13* (2.647) | 124.1 (1.545) | 97.17 (1.23) |
| Seed and >100kg fertilizer coupons (0=no, 1=yes) | 117.3* (3.187) | 139.3 (0.847) | 189.90 (1.14) |
| Fertilizer use in 2006/07 growing season (kg/ha) | — | — | 0.012 (0.025) |
| *N* | 380 | 380 | 298 |
| Likelihood Ratio $>\chi^2(24)$ | 142.45 | 106.27 | 72.35 |
| Prob $> \chi^2$ | 0.0000 | 0.0000 | 0.0000 |

Notes:

dependent variable is the total quantity of fertilizer used per hectare of maize (kg/ha)

t-statistics in parentheses; * $p < 0.05$.

Model 1 uses observed values of coupon variables; Models 2 and 3 use instrumented values of coupon variables based on MNL regression reported in Table 2.

Table 4 IV regression results for the effect of coupon receipt on maize fertilizer use

| | Model 1<br>2009 variables only | Model 2<br>with 2006 fertilizer | Model 3<br>2002 and 2006 fertilizer |
|---|---|---|---|
| Constant | 10.22<br>(84.82) | 18.65<br>(50.95) | 99.44*<br>(26.36) |
| Age<br>(years) | -0.87*<br>(0.53) | -0.64<br>(0.46) | -0.34*<br>(0.17) |
| Education<br>(0=none, 1=some) | -10.76<br>(1.60) | -5.78<br>(4.47) | 11.54<br>(14.36) |
| Household size<br>(number of persons) | -0.05<br>(0.62) | 0.74<br>(0.79) | 1.63<br>(1.95) |
| Net buyer of maize in 2008<br>(0=no, 1=yes) | -20.22<br>(28.34) | 13.68<br>(23.39) | 1.77<br>(2.72) |
| Farm size<br>(hectares) | -51.54*<br>(2.37) | -50.39*<br>(0.49) | -28.06*<br>(4.87) |
| Farm size squared<br>(hectares$^2$) | 3.29*<br>(0.05) | 3.27*<br>(0.13) | 1.85*<br>(0.30) |
| Kasungu<br>(0=no, 1=yes) | 1.65<br>(10.16) | 2.02<br>(4.04) | -15.63*<br>(4.58) |
| Improved maize<br>(0=no, 1=yes) | -7.85<br>(13.51) | -1.45<br>(9.51) | 24.57*<br>(7.51) |
| Fertilizer-maize price ratio<br>($P_F/P_M$) | 23.11*<br>(7.52) | 19.41*<br>(3.00) | -0.33<br>(2.83) |
| Distance to market<br>(walking minutes) | 0.28*<br>(0.15) | 0.25*<br>(0.06) | 0.13*<br>(0.02) |
| Coupon value[†]<br>(100 Mk) | 1.21*<br>(0.68) | 0.97*<br>(0.49) | 0.50*<br>(0.25) |
| Fertilizer use in 2006/07<br>growing season (kg/ha) | — | -0.01<br>(0.01) | 0.01<br>(0.04) |
| Fertilizer use in 2002/03<br>growing season (kg/ha) | — | — | 0.02*<br>(0.01) |
| *N* | 380 | 352 | 178 |
| Sargan N*R2 test | 2.19 | 2.22 | 4.84 |
| Basmann test | 2.11 | 2.13 | 4.50 |

Notes: dependent variable is the total quantity of fertilizer used per hectare of maize (kg/ha); District-clustered standard errors in parentheses; * $p < 0.10$; [†] Instrumented value. Tests of overidentifying restrictions for the full set of instruments (female headedness, asset poor, years of residency and village population) are reported in the final rows of the table; 95% critical value of the $\chi^2(3)$ test statistic is 7.81.

Table 5 Production function for maize, dependent variable is natural log of yield (kg/ha)

| | Estimated Coefficient |
|---|---|
| Constant | 4.94* |
| | (0.090) |
| Fertilizer per hectare | 0.293* |
| (kg/hectare) | (0.021) |
| Intercrop | -0.185* |
| (0=no, 1=yes) | (0.051) |
| Improved maize | 0.167* |
| (0=no, 1=yes) | (0.050) |
| *N* | 562 |
| $R^2$ | 0.28 |

District-clustered robust standard errors in parentheses; * $p < 0.05$.

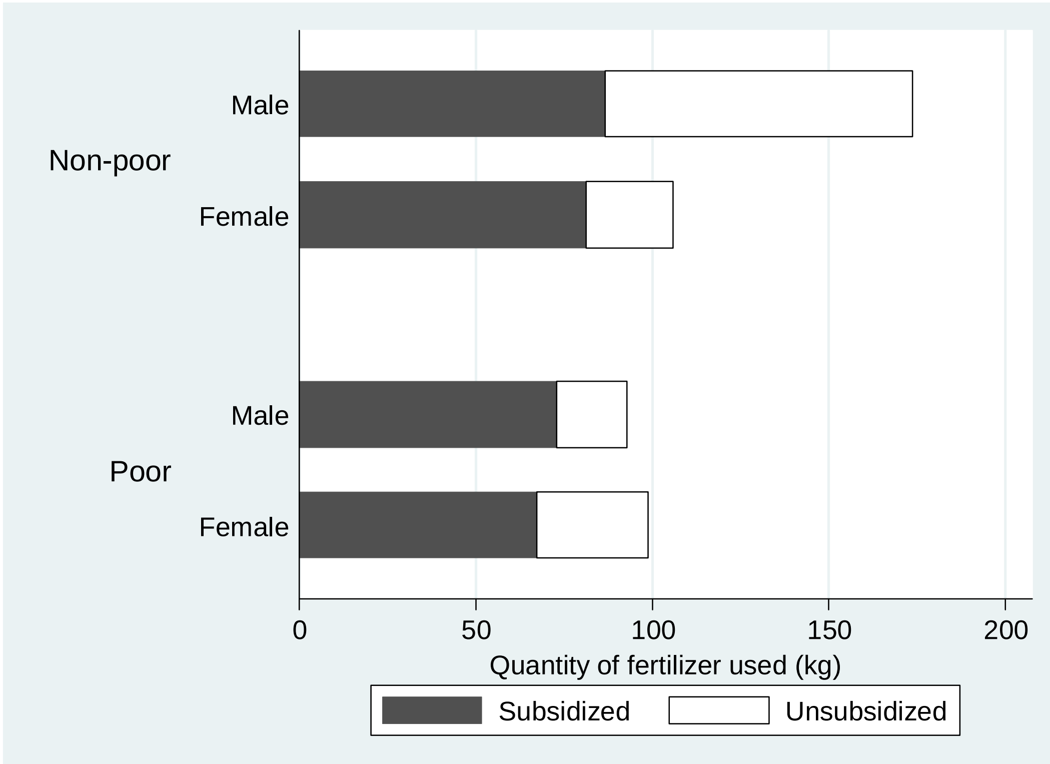


Figure 1 Share of subsidized fertilizer in total fertilizer used for maize

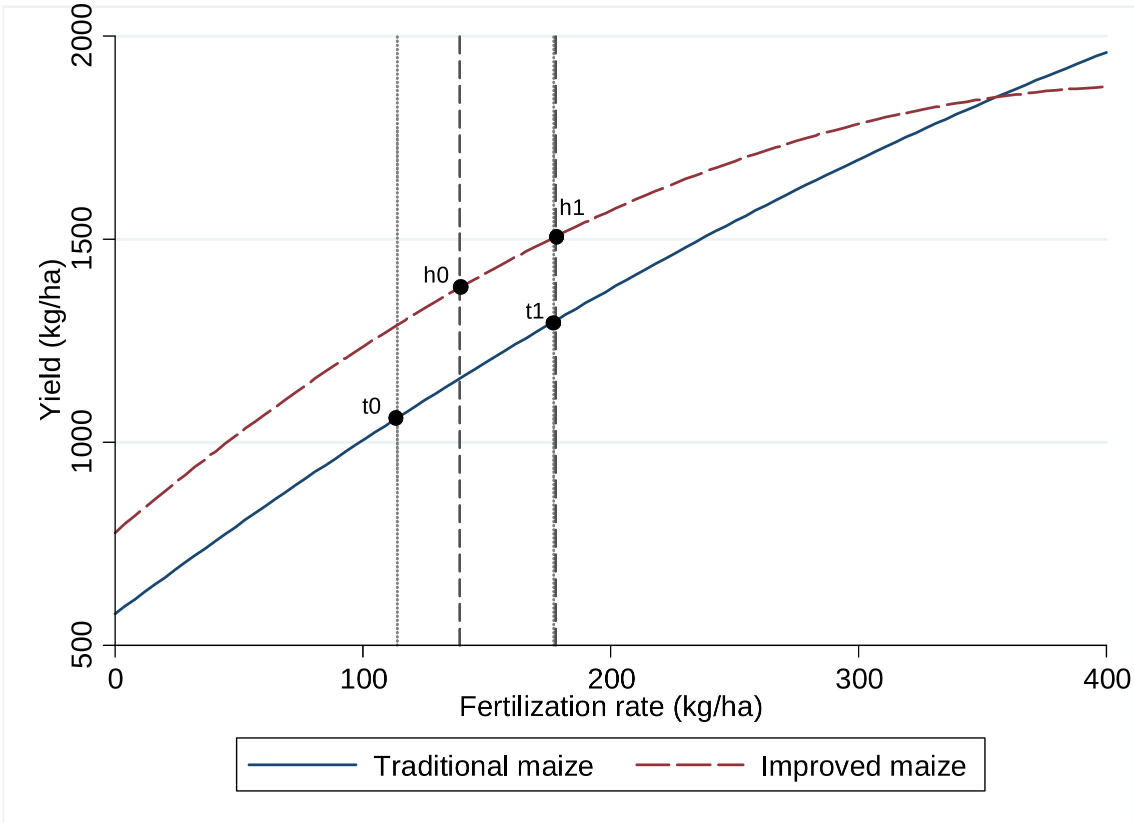


Figure 2 Maize yield response to fertilizer

Note: Marked points on the graph correspond to the following (fertilizer-yield) combinations:

$t_0$ (114, 1063); $t_1$ (177, 1312); $h_0$ (139, 1389); $h_1$ (178, 1510)