Do input subsidies reduce poverty among smallholder farm households?
Evidence from Zambia

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Abstract: Many of the 'new' agricultural input subsidy programs (ISPs) in sub-Saharan Africa list raising farm incomes and reducing rural poverty among their objectives, but are ISPs achieving these objectives? We use data from two nationally-representative surveys of smallholder farm households in Zambia to estimate the effects of an increase in ISP fertilizer on household incomes, poverty severity, and the probability of household income falling below the US$2 and US$1.25/capita/day poverty lines. Results suggest that although ISP fertilizer raises smallholder incomes, the increase is not large or widely distributed enough to substantively reduce the probability or severity of poverty.

Key words: fertilizer subsidies, smallholder farmers, income, poverty, Zambia, sub-Saharan Africa

JEL codes: H2, I38, D31, Q12, Q18

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1. Introduction

After being scaled back during structural adjustment in the 1980s and 1990s, a new wave of agricultural input subsidy programs (ISPs) is currently sweeping sub-Saharan Africa (SSA). The programs' objectives vary from country to country but the most common are: (1) improving smallholder farmers' access to inorganic fertilizer, improved seed, and other modern inputs, (2) increasing crop yields and production, (3) improving food security, and (4) raising incomes and reducing poverty (see, *inter alia*, Jayne & Rashid, 2013; Lunduka, Ricker-Gilbert, & Fisher, 2013; Mason, Jayne, & Mofya-Mukuka, 2013). Although there is a relatively large body of empirical evidence on the effects of ISPs in SSA on the first two objectives, much less is known about the effects of the programs on the latter two objectives.[1] Understanding the effects of ISPs on food security, incomes, and poverty is important because ISPs may succeed in increasing smallholder farmers' access to inputs and crop yields but this may not be sufficient to improve their economic well-being and food security. Moreover, while it is sometimes suggested that the ISPs in Malawi and Zambia, two of the largest in SSA, have had little impact on rural poverty because rural poverty rates remain more or less unchanged despite many years of large-scale ISPs in the two countries (Jayne et al., 2011; Lunduka et al., 2013; Mason et al., 2013), such claims fail to consider the counterfactual – what would rural poverty rates have been *without* these ISPs?

In this paper, we focus on the case of Zambia where the rural poverty rate has been 'stuck' at close to 80% for more than a decade in spite of continuous and expanding government subsidies for hybrid maize seed and inorganic fertilizer (see Figure 1; CSO, 2009, 2011; Jayne et al., 2011; Mason et al., 2013). We draw on data from two large, nationally representative surveys of smallholder farm households – one panel and one cross-section – to estimate the effects of Zambia's ISPs on smallholders' incomes (total, crop, and other income), poverty headcount index, and poverty severity. (A companion paper that estimates the impacts of Zambia's ISPs on food security is in preparation.) We use the first dataset, which is a panel covering the 1999/2000, 2002/03, and 2006/07 agricultural years, to estimate the effects on these outcomes of the Fertilizer Support Program, which ran from 2002/03 through 2008/09. We use the second dataset, which is a cross-section and covers the 2010/11 agricultural year, to estimate the effects of the Farmer Input Support Program, which replaced the Fertilizer Support Program in 2009/10 and continues to run to date. Both programs are targeted ISPs that provide subsidized hybrid maize seed and inorganic fertilizer to selected beneficiaries at a fraction of the market price.[2]

In terms of methods, we estimate the average partial effect (APE) of an additional kg of subsidized fertilizer on the aforementioned household outcome variables using econometric models that are appropriate for the distribution of each outcome variable: ordinary least squares (OLS) for total income and crop income (continuous variables), Tobit models for other income (a corner solution variable with many observations equal to zero), probit and logit models for the

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[1] See the November 2013 special issue of *Agricultural Economics* on "Input Subsidy Programs in sub-Saharan Africa" and Chirwa and Dorward (2013) for recent syntheses.

[2] The programs are discussed in detail in section 3.

poverty headcount index (binary variable), and fractional response models for the poverty severity (proportion) dependent variable. When using the panel dataset, we also use the fixed effects (FE) approach for linear models (OLS) and the correlated random effects (CRE) approach for nonlinear models (Tobit, probit, logit, and fractional response) to control for time-*invariant* unobserved effects that could be correlated with a household's receipt of subsidized fertilizer, and which could bias our APE estimates if not accounted for (Mundlak, 1978; Chamberlain, 1984; Wooldridge, 2010). Although these panel data methods help control for the potential endogeneity of subsidized fertilizer to smallholders' poverty and income outcomes, these methods are not an option in the case of the cross-sectional data and, even in the case of the panel data, subsidized fertilizer may be correlated with time-*varying* unobserved factors that also affect smallholders' economic well-being. We therefore employ the control function approach (CFA) to test and control for the endogeneity of subsidized fertilizer (Wooldridge, 2010, 2013). We follow Mason and Jayne (2013) and use the results of the last presidential election in the household's constituency as instrumental variables for the kg of subsidized fertilizer received by the household. Whether or not the ruling party won the last election in a household's constituency and the closeness of the race are strongly correlated with the quantity of subsidized fertilizer that a household receives but we do not expect these results to affect smallholders' poverty and income outcomes except through subsidized fertilizer (ibid).

The article builds on previous studies and contributes to the literature on ISPs in SSA in three main ways. First, to our knowledge, it is the first to estimate the effects of Zambia's *fertilizer* subsidy programs on smallholder incomes and poverty. Mason and Smale (2013) estimate the effects of the seed subsidy component of the Fertilizer Support Program on these outcomes but do not consider the effects of the fertilizer component of the program.[3] They find that an additional 10 kg of subsidized hybrid maize seed raises smallholder maize growers' incomes by 1.1% and reduces their poverty severity by 0.7 percentage points. Jayne et al. (2011) and Mason et al. (2013) present descriptive statistics showing that subsidized fertilizer in Zambia goes disproportionately to households that cultivate more land and are less likely to fall below the US$1.25/capita/day poverty line. Although this is expected to reduce the ISP's impact on poverty, these studies do not estimate the *causal* effects of the programs on smallholder incomes or poverty status.

Second, the study adds to the relatively thin evidence base regarding the impacts of ISPs on poverty and incomes in SSA. Most of the work done on this topic to date has focused on the case of Malawi. For example, early propensity score matching estimates from Chirwa (2010) suggest that receipt of two subsidized fertilizer coupons increases beneficiary households' annual per capita expenditures by US$11.19 (8.2%). Using nationally-representative household survey data, panel data methods, and CFA, Ricker-Gilbert and Jayne (2011) find that an additional kg of subsidized fertilizer raises Malawian smallholders' net crop income by approximately US$1.16 but find no statistically significant effects of subsidized fertilizer on total income, off-farm income, or asset wealth. In a related study, Ricker-Gilbert and Jayne (2012) estimate quantile regressions with CRE and CFA and find that an additional kg of subsidized fertilizer raises the total value of crop output by US$0.80 at the 90th percentile of the outcome variable distribution but that subsidized fertilizer has no statistically significant effect at the 10th percentile. Lunduka et al. (2013, p. 576) argue that the lack of change in rural poverty rates in Malawi between 2003/04 (55.9%) and 2009/10 (56.6%) "raise[s] serious questions about whether the FISP has

[3] Future iterations of the current paper will attempt to estimate the effects of *both* the fertilizer *and* seed components of Zambia's ISPs.

made any substantive contribution toward reducing poverty" and "call for a rigorous investigation that directly measures the causal impacts of the FISP program on poverty in Malawi".

Perhaps in response to this call and propositions by Chirwa and Dorward (2013) that the general equilibrium effects of Malawi's ISPs could be substantial, Arndt, Pauw, and Thurlow (2013) estimate an economy-wide (computable general equilibrium) model and find that Malawi's 2006/07 Farm Input Subsidy Program reduced the national, rural, and urban poverty rates by 1.5-3.0 percentage points. Most recently, Beck, Mussa, and Pauw (2014) attempt to solve "Malawi's poverty puzzle" (i.e., the lack of change in the rural poverty rate despite Malawi's large-scale ISP) by calculating new regional poverty lines based on a cost of basic needs approach. Based on these new poverty lines, the rural poverty rate appears to have declined by 6.8 percentage points between 2004/05 and 2010/11.

Although not focused directly on the income and poverty effects of ISPs, Jayne, Mather, Mason, and Ricker-Gilbert (2013), building on work by Ricker-Gilbert, Jayne, and Chirwa (2011) and Mason and Jayne (2013), find that an additional kg of subsidized fertilizer only raises total fertilizer use by 0.55 kg in Malawi, 0.58 kg in Zambia, and 0.57 kg or less in Kenya. These less than one-to-one effects are due to displacement (crowding out) of households' commercial fertilizer purchases by poorly targeted subsidized fertilizer and to diversion and resale on commercial markets of fertilizer intended for the ISPs. Moreover, in all three countries, smallholder households with larger landholdings (who tend to have higher incomes and are less likely to fall below the poverty line) get systematically more subsidized fertilizer. Maize-yield response rates to inorganic fertilizer are also very low (on the order of 3-4 kg of maize per kg of fertilizer in Malawi and Zambia, and 6-7 kg per kg in Kenya) (Jayne et al., 2013). The effects of fertilizer subsidies on retail maize prices in Malawi and Zambia (Ricker-Gilbert, Mason, Darko, & Tembo, 2013), and on wage rates in Malawi (Ricker-Gilbert, 2014) have also been very small, suggesting that the spillover effects of the programs on non-beneficiary households are likely to be minimal. Together, these results indicate that the impacts of fertilizer subsidies on rural poverty are likely to be muted in these countries.

Outside of Malawi, Zambia, and Kenya, Awotide, Karimov, Diagne, & Nakelse, 2013 evaluate Nigeria's certified improved rice seed voucher system (SVS) using a randomized-controlled trial. Their results suggest that the SVS (which entitles beneficiaries for up to 20 kg of seed at subsidized prices) raises annual (total) household income and per capita consumption expenditure by US$464.60 and US$46.92, respectively, implying a large, 24% reduction in poverty.

The third contribution of the current study is that, beyond adding to the body of empirical evidence related to the impacts of ISPs in Zambia and SSA on smallholder incomes and poverty, it also improves upon previous studies by controlling for the potentially confounding effects of parastatal maize marketing board activities on smallholders' economic well-being. Previous studies on this topic for Malawi and Zambia do not control for such effects. However, in both countries (and several others in SSA), the resurgence of ISPs has gone hand-in-hand with a scaling up or revival of parastatal grain marketing board or strategic grain reserve activities (Mason, Jayne, and Myers, 2014). Like ISPs, these activities have been found to affect smallholder maize production (ibid) and thus may affect their incomes and poverty. Failure to control for such activities could bias estimates of the effects of ISPs on these outcomes.

The results of this paper suggest that receipt of subsidized fertilizer raises smallholders' total incomes through its effects on their crop incomes (there are no spillover effects on other, non-crop income) but that the income increase is not large or widely distributed enough to substantively reduce the severity of poverty nor households' probability of falling below the poverty line.

The remainder of the paper is organized is follows. Section 2 describes the data used in the analysis. Section 3 provides an overview of Zambia's Fertilizer Support Program and the Farmer Input Support Program, and briefly discusses the maize marketing activities of the country's strategic grain reserve/maize marketing board, the Food Reserve Agency. Sections 4, 5, and 6 present the methodology, results, and conclusions and policy implications, respectively. The paper concludes in section 7 with a brief discussion of planned next steps for this study.

2. Data

The data come mainly from two nationally-representative surveys of smallholder farm households in Zambia: (i) the Supplemental Survey (SS), a three-wave panel survey conducted in June/July of 2001, 2004, and 2008, and (ii) the Rural Agricultural Livelihoods Survey (RALS), a cross-sectional survey conducted in June/July 2012.[4] Each of these surveys covers the previous agricultural year (October through September of 1999/2000, 2002/03, 2006/07, and 2010/11, respectively) and the corresponding crop marketing year (May through April of 2000/01, 2003/04, 2007/08, and 2011/12). The Zambia Central Statistical Office (CSO), the Ministry of Agriculture and Livestock (MAL, formerly the Ministry of Agriculture and Cooperatives), and the Indaba Agricultural Policy Research Institute (formerly the Food Security Research Project) jointly carried out all four surveys. See Megill (2005) and IAPRI (2012) for details on the sampling designs of the SS and RALS. The surveys collected detailed information on household demographics and farm assets; agricultural activities (crops and livestock); off-farm income-generating activities (including work on others' farms, other formal and informal wage/salaried employment and business activities, pensions, and the value of cash and in-kind remittances and gifts received); and household receipt of fertilizer and maize seed from government ISPs.

The sample sizes for these surveys were large. A total of 6,922 smallholder farm households were interviewed for the 2001 SS, of which 5,358 (77.4%) were successfully re-interviewed during the 2004 SS. Of these 5,358 households, 4,286 (80.0%) were successfully re-interviewed during the 2008 SS. Our analytical sample for the SS data consists of the balanced panel of 4,261 households interviewed in all three waves of the survey and that reported non-zero gross household income.[5] Given household attrition between rounds of the SS, attrition bias is a potential concern. However, regression-based tests per Wooldridge (2010, p. 837) allay these concerns as we consistently fail to reject the null hypothesis of no attrition bias (p-value > 0.10). The main SS analysis uses data from the 2004 and 2008 SSs only, with the 2001 SS data reserved for robustness checks that involve controlling for lagged (previous survey) variables.[6]

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[4] In Zambia, smallholder households are those that cultivate less than 20 hectares of land.

[5] The full balanced panel is 4,286 households. We drop from the analytical sample all 25 households (0.6% of the total number of households in the balanced panel) that reported zero gross household income in one or more years of the panel survey. Because the surveys captured data on *all* sources of income (including the gross value of agricultural production and the value of remittances and gifts received), non-zero gross income responses are not valid.

[6] Given our plans to explore the impacts of both subsidized fertilizer *and* subsidized seed in subsequent iterations of this paper, we also exclude the 2001 SS from our main analysis because it did not collect information on subsidized seed.

A total of 8,839 smallholder farm households were interviewed for the 2012 RALS. Our analytical sample for the RALS data consists of the 8,833 households that reported non-zero gross household income.

Other data used in the analysis are: lagged crop prices from the 1998/99, 2001/02, 2005/06, and 2009/10 Post-Harvest Surveys conducted by CSO and MAL; geo-referenced dekadal (10-day) rainfall data from Tropical Applications of Meteorology using SATellite data (TAMSAT) (Tarnavsky et al., 2013; Maidment et al., 2013; Grimes, Pardo-Igúzquiza, & Bonifacio, 1999; and Milford & Dugdale, 1990); constituency-level results from the 1996, 2001, 2006, and 2008 elections from the Electoral Commission of Zambia; administrative data from MAL on district-level allocations of subsidized fertilizer during the period of analysis; administrative data from the Food Reserve Agency on district-level maize purchases by the Agency during the period of analysis; and Purchasing Power Parity (PPP) conversion factors and Consumer Price Index (CPI) values from the World Bank World Development Indicators database (used for the poverty rate calculations).

3. Zambia's Fertilizer Support Program, Farmer Input Support Program, and Food Reserve Agency

As Zambia's ISPs and the activities of the Food Reserve Agency (FRA) are described in great detail elsewhere (see Mason et al., 2013 and 2014), we focus here on the features of the programs that are most relevant to the current study. The Farmer Input Support Program (formerly the Fertilizer Support Program) and the FRA are the Zambian government's flagship agricultural sector programs. Since 2004, these ISPs and the FRA have accounted for an average of 30% and 28% of total agricultural sector expenditures, respectively, and each consumed nearly 50% of total spending on agricultural sector Poverty Reduction Programs (ibid).

3.1. The Fertilizer Support Program, 2002/03-2008/09

After downscaling its ISPs during structural adjustment from the late 1980s through the mid-1990s, and experimenting with providing inorganic fertilizer and hybrid maize seed to smallholder farmers on credit from 1997/98 through 2001/02, the Zambian government established the Fertilizer Support Program during the 2002/03 agricultural season. (See Figure 1 for the metric tons (MT) of fertilizer distributed through Zambia's ISPs each year from 1997/98 through 2013/14.) The Fertilizer Support Program, which ran through 2008/09, provided inorganic fertilizer and hybrid maize seed to selected beneficiary farmers at subsidized prices and was a cash-based (not credit-based) program. The subsidy rate varied from year to year but was 50% in 2002/03 (the agricultural year captured in the 2004 SS data used here) and 60% in 2006/07 (the agricultural year captured in the 2008 SS data used here). The program was administered through farmer cooperatives. Approximately 9% and 11% of Zambian smallholder households received subsidized fertilizer through the program in 2002/03 and 2006/07, respectively (Mason et al., 2013). Although in theory all Fertilizer Support Program beneficiaries were to a receive 400 kg of inorganic fertilizer (200 kg each of basal and top dressing) and 20 kg of hybrid maize seed to be used to plant one hectare (ha) of maize, in practice, the quantities received varied considerably across beneficiaries. For example, the median Fertilizer Support Program participating household received 200 kg of fertilizer in 2002/03 and 300 kg in 2006/07 (Mason et al., 2013). Official program eligibility requirements stipulated that beneficiaries: be small-scale farmers (i.e., cultivate less than 5 ha of land total); have the capacity to grow at least 1 ha of maize; be members of a cooperative or other farmer group; and be able to pay the farmer share of the inputs costs (e.g., 50% in 2002/03 and 40% in 2006/07) (MACO, various years). Household survey evidence, however, suggests that these eligibility requirements are not strictly enforced, and some technically ineligible households acquire subsidized inputs (Mason et al., 2013).

According to the Zambian Minister of Agriculture and Livestock, the overall goals of the Fertilizer Support Program (and its successor, the Farmer Input Support Program) were "to increase production of staple food commodities and to contribute to poverty reduction particularly among the rural population, through the supply of agricultural inputs to small-scale farmers. That exercise was to contribute to increased household food security and to improve incomes, [and] hence reduce poverty amongst them" (MAL, 2013, p. 4). See Mason et al. (2013) for further details on the Fertilizer Support Program.

3.2. The Farmer Input Support Program, 2009/10-present

The Fertilizer Support Program was renamed the Farmer Input Support Program in 2009/10, and the program continues to run to the present day. At 200 kg of fertilizer and 10 kg of hybrid maize seed, the official input pack size under the Farmer Input Support Program is half that under the Fertilizer Support Program. This reduction in pack size and an increase in the total tonnage of inputs distributed through the program (see Figure 1) have enabled the Farmer Input Support Program to reach more households than its predecessor. For example, in 2010/11 (the agricultural year captured in the 2012 RALS data used here), approximately 30% of Zambian smallholders received subsidized fertilizer through the Farmer Input Support Program. The median beneficiary household received the official pack size, 200 kg. That year, the subsidy rate was 76% for fertilizer and 50% for maize seed. The program objectives and eligibility criteria remained largely unchanged compared to the Fertilizer Support Program, the main exception being that the minimum capacity for maize cultivation was reduced from 1 ha to 0.5 ha (MAL, 2010). See Mason et al. (2013) for further details on the Farmer Input Support Program.

3.3. The Food Reserve Agency

Since the 2002/03 crop marketing year, the Food Reserve Agency has purchased maize directly from smallholder farmers at a pan-territorial price that typically exceeds market prices for maize in surplus production areas and in surplus production years (Mason et al., 2014).[7] The FRA usually announces its pan-territorial purchase price at the beginning of the maize harvest in May, and buys maize from July through October. Therefore, when farmers make planting decisions in November-December, they do not know what maize price the FRA (or private buyers, for that matter) will be offering at the subsequent harvest. Although the FRA's maize purchases amounted to only 16-32% of smallholders' marketed maize in the 2002/03 through 2004/05 marketing years, since 2005/06 the FRA has been the dominant single buyer of smallholder maize in most years (ibid). Approximately 1%, 10%, and 27% of Zambian smallholders sold maize to the FRA in the 2003/04, 2007/08, and 2011/12 maize marketing years, respectively

[7] The FRA was established in 1996 but purchased only very small quantities of maize through private traders (i.e., not directly from farmers) in 1996/97 and 1997/98, and did not purchase any maize (directly or indirectly from farmers) from 1998/99-2001/02 due to funding shortfalls (Mason et al., 2014).

(Mason et al., 2014; CSO/MAL/IAPRI, 2012). (Recall that these are the marketing years captured in the 2004 SS, 2008 SS, and 2012 RALS.) Like Zambia's ISPs, improving food security and incomes are key FRA goals and FRA is considered a Poverty Reduction Program. Maize purchased by the FRA is stored and sold domestically (typically to select large-scale millers) or exported. See Mason et al. (2014) for further details on the Food Reserve Agency.

4. Methodology

In this section, we begin by describing the income and poverty measures analyzed in the study, and then discuss the conceptual framework, empirical models, and identification strategy used to estimate the effects of subsidized fertilizer on these indicators of economic well-being.

4.1. Income and poverty measures analyzed

Our main research question is do fertilizer subsidies raise incomes and reduce poverty among smallholder farm households? In total, we estimate the effects of subsidized fertilizer on 10 different income measures and eight different poverty measures. The first five income measures are gross total, crop, and other (non-crop) income, and total and crop income net of fertilizer costs.[8] Gross crop income is defined as the gross value of crop production (kg harvested of each crop multiplied by the district median price for maize and the provincial median price for other crops). Gross total income is gross crop income plus income from live and slaughtered livestock and poultry sales, the gross value of milks and eggs produced, and income from formal and informal wage/salaried employment, pensions, business activities, and remittances and gifts received. Gross other income is gross total income minus gross crop income. Fertilizer costs are calculated as the kg of subsidized fertilizer received by the household multiplied by the subsidized price per kg (per subsidy program implementation manuals) plus the kg of fertilizer purchased from commercial retailers by the household multiplied by the market fertilizer price paid. The second five income measures are the first five income measures divided by the number of adult equivalent household members. All income variables are converted to real 2011/12 Zambian Kwacha and are for the period May 1 through April 30 of the corresponding marketing year (2003/04 for the 2004 SS, 2007/08 for the 2008 SS, and 2011/12 for the 2012 RALS). See Tables A.1 and A.2 in the Appendix for summary statistics for the income variables for the two SSs and RALS, respectively.

The poverty measures considered are the Foster-Greer-Thorbecke (FGT) poverty headcount index (a binary variable equal to one if household income falls below the poverty line, and equal to zero otherwise), and FGT poverty severity (equal to the squared percentage difference between household income and the poverty line if household income falls below the poverty line, and equal to zero otherwise) (Foster, Greer, & Thorbecke, 1984). The poverty headcount index and poverty severity are each computed for the US$2/capita/day poverty line and the US$1.25/capita/day extreme poverty line, and for both gross total household income and total household income net of fertilizer costs, for a total of eight poverty measures.[9] We follow

[8] We do not have good data on other input costs. Moreover, since we are only netting out fertilizer costs, there is no difference between "gross" and "net" other (non-crop) income.

[9] We report summary and bivariate statistics for the poverty gap (the square root of poverty severity) but we do not econometrically analyze the poverty gap because doing so would yield few, if any, additional insights beyond our analysis of total household income per adult equivalent.

US Agency for International Development Feed the Future Indicators guidelines and convert household income from Zambian Kwacha to US$ based on the 2005 PPP conversion factor for private consumption, adjusted for inflation using the CPI for each year in our analysis (2003/04, 2007/08, and 2011/12).[10] Summary statistics for the poverty variables are also included in Tables A.1 and A.2 in the Appendix.

Although not the focus of the study, we also consider subsidized fertilizer impacts on household maize production, the main channel through which subsidized fertilizer is likely to affect household income and poverty. Such effects have already been estimated by Mason et al. (2014) using the SS data (all three waves) and are discussed in Mason et al. (2013). We re-estimate the effects here using only the 2004 and 2008 waves of the SS data and the 2012 RALS data to hone in on the effects of the Fertilizer Support Program and Farmer Input Support Program. (Mason et al.'s (2014) estimates also capture the effects of fertilizer distributed through a fertilizer credit program in place during the agricultural year captured in the 2001 SS.) Summary statistics for maize kg harvested are reported in Tables A.1 and A.2 in the Appendix.

4.2. Conceptual framework

Our conceptual framework is grounded in the work of Otsuka, Cordova, and David (1992, p. 730), who posit that an agricultural household, such as the Zambian smallholder households studied here, "maximizes utility by allocating labor time of family members to various farm tasks and nonfarm jobs, cultivable lands to the production of various crops, and capital inputs to various farm activities, subject to budget and time constraints, ownership of land and capital stocks, and the crop production functions". Solving the first-order conditions of this utility maximization problem yields a reduced form for household income (y) as a function of factor prices (e.g., wage rates and variable input prices, $\boldsymbol{w}$), expected crop prices at the next harvest ($\boldsymbol{p}^e$), land and other farm assets owned by the household ($\boldsymbol{k}$), household labor supply and proxies for labor quality and management ability ($\boldsymbol{l}$), and other variables that affect the household's production environment ($\boldsymbol{z}$):

$$y = y(\boldsymbol{w}, \boldsymbol{p}^e, \boldsymbol{k}, \boldsymbol{l}, \boldsymbol{z}, FISP, \boldsymbol{FRA}^e) \quad (1)$$

To adapt this general income equation to the current application, we add two additional sets of variables: *FISP*, the quantity of subsidized fertilizer received by the household through the Fertilizer Support Program or the Farmer Input Support Program (the main variable of interest in this study), and $\boldsymbol{FRA}^e$, a vector of variables capturing household expectations about FRA activities at the next harvest that could affect their agricultural activities and income. *FISP* is treated as a quasi-fixed factor rather than a variable input because households cannot freely choose how much subsidized fertilizer they receive. Below, for simplicity we occasionally refer to the right-hand size variables in equation (1) collectively as $\boldsymbol{X}$. We also use y to refer generically to the income and poverty outcomes variables described in section 4.1.

4.3. Empirical models

[10] The PPP conversion factor for private consumption (2005=100) was equal to approximately 2,830 Kwacha per US$ in 2005.

To bring equation (1) to the data, we begin by specifying an analogous unobserved effects linear panel data model:

$$y_{i,t} = \beta_0 + \boldsymbol{w}_{i,t}\boldsymbol{\beta_1} + \boldsymbol{p}_{i,t-1}\boldsymbol{\beta_2} + \boldsymbol{k}_{i,t}\boldsymbol{\beta_3} + \boldsymbol{l}_{i,t}\boldsymbol{\beta_4} + \boldsymbol{z}_{i,t}\boldsymbol{\beta_5} + \beta_6 FISP_{i,t} + \boldsymbol{FRA}_{i,t-1}\boldsymbol{\beta_7} + c_i + u_{it} \quad (2)$$

where i indexes the household and t indexes the year; c_i captures time-constant unobserved effects; u_{it} captures time-varying unobserved effects; the other variables are defined, in general terms, as in equation (1); and the $\boldsymbol{\beta}$*'s* are parameters to be estimated. (We can think of the t subscripts as dropping out of the model when we use the cross-sectional RALS data.) We use values at the most recent harvest ($\boldsymbol{p}_{i,t-1}$ and $\boldsymbol{FRA}_{i,t-1}$) to proxy for household expectations of crop output prices and FRA activities at the next harvest. The main partial effect that we seek to estimate is $\frac{\partial E(y_{i,t} \mid \boldsymbol{X}_{i,t}, c_i)}{\partial FISP_{i,t}}$ (β_6 in equation (2)); that is, how does expected household income or poverty change given an increase in subsidized fertilizer acquired by the household, holding other factors constant?

In the empirical application, $\boldsymbol{w}$ includes agricultural wage rates, market prices for fertilizer, and, for RALS only, market prices for hybrid maize seed. (Seed prices were not captured in the SS data.) $\boldsymbol{p}$ includes lagged producer prices for maize, mixed beans, groundnuts, and sweet potatoes, the most commonly crops marketed by smallholders for which spatially-varying prices are available. $\boldsymbol{k}$ includes the household's landholding size (in hectares) and the value of plows, harrows, and ox-carts owned as of May 1 (the beginning of the period for which income is captured). $\boldsymbol{l}$ includes the number of household members (children and adults) in different age brackets, a binary variable equal to one if the household is female-headed, the age of the household head, and the highest level of education completed by the household head. $\boldsymbol{z}$ includes distances to the nearest district town, tarred or main road, and feeder road; variables proxying for the income-generating opportunities available in the household's district (namely, the percentage of households in the district (i) earning income on others' farms, (ii) engaged in formal or informal business activities, and (iii) engaged in non-farm wage or salaried employment); variables capturing rainfall conditions in current and past agricultural seasons (see Tables A.3 and A.4 in the Appendix for details); agro-ecological region dummies; provincial dummies; and, in the case of the SS data, a year dummy equal to one for the 2008 SS, and zero otherwise, and interacted with the provincial dummies.[11] *FISP* is the kg of subsidized fertilizer acquired through the Fertilizer Support Program (for the SS data) or through the Farmer Input Support Program (for the RALS data). Note that *FISP* is the kg of subsidized fertilizer acquired during the 2002/03, 2006/07, or 2010/11 agricultural years, and the dependent variable ($y_{i,t}$) is the household's income or poverty outcome during the subsequent marketing year (i.e., from May 1, the beginning of maize harvest time, through April 30). This is the period during which we would expect *FISP* to affect household income and poverty through its direct effect on the household's maize production and through indirect effects on the household's other activities and resource allocation. $\boldsymbol{FRA}_{i,t-1}$ includes two variables related to FRA activities during the most recent marketing year: (i) the quantity of maize bought by the FRA in the household's district (based on

[11] There were 72 districts and nine provinces in Zambia during the SS years, and 74 districts and 10 provinces in Zambia as of the 2012 RALS.

FRA administrative records and in kg per smallholder farm household), and (ii) an estimate of the FRA farmgate maize price in Kwacha per kg (i.e., the FRA pan-territorial price adjusted for maize transports costs from the homestead to the nearest FRA depot). All price and value variables in equation (2) are in real 2011/12 Kwacha. See Tables A.3 and A.4 in the Appendix for summary statistics for the SS- and RALS-based explanatory variables, respectively.

A final point to note regarding our empirical models is that these models do not capture spillover effects of subsidized fertilizer received by other households on the economic well-being of a given household, nor do the models capture potential effects of fertilizer subsidies on economic well-being through the subsidies' effects on maize prices or general equilibrium effects. While these effects may exist, we expect them to be very small. Fertilizer is a private good so we expect spillovers from one household to the next to be limited. Moreover, as discussed in the introduction, empirical evidence from Zambia (and Malawi) suggests that fertilizer subsidies have had only minimal price-reducing impacts on retail maize prices, and evidence from Malawi suggests statistically significant but very small impacts of the subsidies on agricultural wage rates (Ricker-Gilbert et al., 2013; Ricker-Gilbert, 2014).

4.4. Estimation and identification strategy

We estimate analogues of equation (2) using different econometric models depending on the distribution of the dependent variable. Although several of the dependent variables are continuous (e.g., total and crop income) and their models are estimated via ordinary least squares (OLS), many of the other dependent variables are discontinuous. Other (non-crop) income is equal to zero for the roughly 12% of the SS sample, creating a pile-up of observations at zero. We therefore use Tobit models for this outcome variable for the SS data.[12] The poverty headcount index is a binary variable and poverty severity is a proportion bound between zero and one, so we use binary response models (probit or logit) and fractional response models, respectively, for these dependent variables (Papke and Wooldridge, 1996, 2008). Given skewness in the income variables, we estimate models for these variables in both levels and in logs. See Table A.5 in the Appendix for a summary of the econometric models used for each outcome variable examined in the study.

Regardless of the econometric model, a major challenge when estimating equation (2) is that subsidized fertilizer distributed through the Fertilizer Support Program and the Farmer Input Support Program (henceforth referred to as FISP fertilizer) is not randomly allocated to smallholder households, and previous studies suggest that FISP recipient households tend to be wealthier (in terms of land, non-land assets, incomes and poverty) than non-recipient households (Jayne et al., 2011; Mason et al., 2013). Bivariate statistics using our analytical samples for the SS data and RALS also confirm that FISP recipients have systematically higher incomes and lower poverty rates than non-recipients (see Table 1, which is discussed further in section 5). Thus, a major concern is that the *FISP* variable in equation (2) may be endogenous, due to reverse causality (i.e., wealthier households get more FISP fertilizer) and/or due to omitted variables bias (i.e., unobserved factors affect both how much FISP fertilizer a household gets and its economic well-being).

One way we address this concern in both the SS and RALS applications is through use of the control function approach (CFA), which enables us to test and control for the potential endogeneity of *FISP* in equation (2). We prefer the CFA to the instrumental variables (IV) or

[12] Only 3% of households reported zero other (non-crop) income in the RALS data, so we use OLS for that dataset.

two-stage least squares approaches (2SLS) because in the current application, several of our dependent variables are discontinuous and because our potentially endogenous explanatory variable, *FISP*, is a corner solution (i.e., many households receive zero kg of FISP fertilizer). The CFA is more useful and flexible than IV/2SLS in such situations (Wooldridge, 2010, 2013). Like the IV/2SLS approach, in order to employ the CFA, we need at least one IV that is partially correlated with *FISP* but that is uncorrelated with the unobserved factors that affect y. We follow previous peer-reviewed studies of the impacts of FISP on smallholder behavior (Mason & Ricker-Gilbert, 2013; Mason and Jayne, 2013; Mason et al., 2014) and use three IVs for FISP: (i) a binary variable equal to one if the ruling party won the household's constituency in the last presidential election, and equal to zero otherwise; (ii) the absolute value of the percentage point spread between the share of votes won by the ruling party versus the lead opposition in the household's constituency (a measure of the closeness of the race); and (iii) the interaction of (i) and (ii). The CFA in the current application entails estimating a Tobit regression of FISP fertilizer on the three IVs and the other explanatory variables in equation (2), obtaining the generalized Tobit residuals, and then including these residuals as additional regressors when estimating equation (2) (Wooldridge, 2010, 2013). When the residuals are statistically significant in equation (2), then the standard errors are bootstrapped to account for the fact that the residuals are estimated in a first stage regression. A t-test of the residuals tests the null hypothesis that FISP is exogenous against the alternative hypothesis that it is endogenous. If we fail to reject exogeneity, then we can safely exclude the residuals and use equation (2) for inference. Conveniently, if we reject exogeneity in favor of endogeneity, including the residuals in equation (2) also controls for the endogeneity of FISP (ibid).

As shown in Table 2, the results of the last presidential election in the household's constituency are indeed strong predictors of the kg of FISP fertilizer acquired by the household. Based on the SS and RALS results, respectively, holding other factors constant, households in constituencies won by the ruling party in the last election receive an average of 20.1 kg and 23.9 kg more FISP fertilizer than households in constituencies lost by the ruling party (p-value < 0.01). Moreover, both sets of results suggest that there is an interaction effect between the ruling party's winning and its margin of victory: for each percentage point increase in the ruling party's margin of victory, households in constituencies won by the ruling party get an average of 0.5 kg and 1.7 kg more FISP fertilizer based on the SS and RALS results, respectively (p-value < 0.04).[13] The percentage point spread is also individually statistically significant in the RALS results (p-value < 0.03). These results suggest that the IVs are strong predictors of FISP fertilizer receipt. We argue that these IVs, which are the results of the voting decisions of thousands of voters in the household's constituency, should be uncorrelated with the unobserved factors in equation (2) that affect household-level income and poverty outcomes, especially after controlling for observed covariates and, in the case of the SS panel data, after controlling for time-invariant unobserved effects via panel data methods (discussed further below). Tests for over-identifying restrictions generally support the validity of the IVs in the SS data but less so in the RALS data. We therefore consider estimates from equation (2) using the cross-sectional RALS data as *correlations* and not *causal* effects.

With the SS panel data, a second way that we attempt to address concerns about endogeneity of *FISP* is through the use of panel data methods, i.e., the fixed effects (FE) approach for continuous dependent variables/linear models and the correlated random effects

[13] See Mason, Jayne, and van de Walle (2013) for a detailed discussion of the political economy of FISP as suggested by these findings.

(CRE) approach for discontinuous dependent variables/nonlinear models. As discussed in the introduction, the CRE approach is used with the nonlinear models because an FE approach is inconsistent in such cases due to the incidental parameters problem (Wooldridge, 2010). Both the FE and CRE approaches allow the unobserved, time-constant heterogeneity (c_i) to be *correlated* with the observed covariates ($\boldsymbol{X}$),[14] and require the assumption of strict exogeneity of the regressors conditional on $\boldsymbol{X}$ and c_i. (We address threats to this assumption for the *FISP* variable by combining FE or CRE with the CFA.) The CRE approach requires an additional assumption about the distribution of the unobserved heterogeneity, namely that $c_i = \psi + \bar{\boldsymbol{X}}_i \boldsymbol{\xi} + a_i$ and $c_i \mid \boldsymbol{X}_i \sim Normal(\psi + \bar{\boldsymbol{X}}_i \boldsymbol{\xi}, \sigma_a^2)$. Under this assumption, the CRE approach allows us to control for c_i in equation (2) by including the household-level time averages of the observed explanatory variables ($\bar{\boldsymbol{X}}_i$) as additional regressors in equation (2). Controlling for time-constant unobserved effects via the FE or CRE approach should reduce the scope for the quantity of FISP fertilizer received by a household to be endogenous to its income and poverty outcomes.

5. Results

In this section, we begin by discussing trends in rural/smallholder poverty rates vis-à-vis ISPs in Zambia, then discuss bivariate results for mean poverty and income outcomes for FISP fertilizer recipients vs. non-recipients, and conclude with the econometric estimates of the average partial effects (APEs) of FISP fertilizer on poverty and incomes. The results generally suggest that receipt of FISP fertilizer is highly *correlated* with higher incomes and lower poverty but that FISP fertilizer *causes* only small reductions in poverty among smallholder farmers in Zambia.

5.1. Descriptive results

As noted in the introduction and shown in Figure 1, the official rural poverty rate in Zambia changed little between 1998 and 2010 despite sustained government subsidies for inorganic fertilizer and hybrid maize seed. Between 2006 and 2010, for example, the scale of Zambia's ISPs doubled from 50,000 MT of subsidized fertilizer to 100,000 MT but the rural poverty rate dropped by only two percentage points (from 80% in 2006 to 78% in 2010). The scale of the Farmer Input Support Program has been even larger since 2010 (Figure 1). A Living Conditions Monitoring Survey (LCMS) is underway in mid-2014 and will be used to estimate 2014 poverty rates. It will indeed be interesting to see how the rural poverty rate changes between 2010 and 2014 given the expansion of FISP since 2010.

The LCMS-based rural poverty rates in Figure 1 are constructed using estimates of total household consumption expenditure, are based on the national poverty line (calculated using a cost of basic needs approach), and are for all rural households (smallholder farm households, large-scale farm households, and non-farm households). Figure 2 presents trends in poverty among smallholder farm households based on the SS and RALS data. Note that these poverty measures are based on total household income (not consumption expenditure), are based on the US$2 and US$1.25 per capita per day poverty lines (not the national poverty line), and exclude rural large-scale farm households and non-farm households, and are therefore not directly comparable to the LCMS-based poverty rates in Figure 1. There are, however, some similar

[14] Note that this is in stark contrast to the 'regular' random effects estimator, which assumes that c_i and $\boldsymbol{X}$ are *uncorrelated*.

trends between the two sets of poverty rates, particularly between the 2000/01 and 2007/08 crop marketing years. Like the LCMS-based rural poverty rates in Figure 1, the SS-based smallholder poverty rates in Figure 2 are very high (88% or above) and essentially stagnant between 2000/01 and 2007/08 despite the establishment and scaling up of the Fertilizer Support Program (Figure 1). The RALS-based estimates for 2011/12 are significantly lower (though still high in absolute terms) but we need to exercise extreme caution because these estimates are not directly comparable to the SS estimates due to methodological differences in the two surveys. In general, the *prima facie* evidence seems to suggest that the Fertilizer Support Program and Farmer Input Support Program failed to put a substantial dent in rural and smallholder poverty during the first decade of the 2000s, but it is possible that poverty rates could have been higher had there been no ISPs during the period.

These results beg the question, to what extent are poor smallholder households participating in FISP? Table 3 disaggregates households into quintiles based on total gross income per adult equivalent and shows FISP participation rates, mean kg of FISP fertilizer received by beneficiary households, and the share of total FISP fertilizer acquired by households in the quintile. Smallholder households in the lower income quintiles are significantly less likely to receive FISP fertilizer than those in the higher income quintiles (section C). In the 2002/03 and 2006/07 agricultural years, for example, less than 5% of smallholder households in the lower 40% of the income distribution acquired subsidized fertilizer compared to 20% or more of households in the highest 20% of the income distribution. Significantly more households participated in FISP in the 2010/11 agricultural year (because the program was much larger that year) but participation rates are still far higher among the highest income quintile (49%) than among the lowest two income quintiles (11% and 20%, respectively). Not only are poorer households less likely to participate in FISP but poor beneficiaries get substantially less FISP fertilizer than richer beneficiaries (section D). Even in 2010/11, when more poor households participated in FISP than in previous years, the average quantity of subsidized fertilizer received by households in the poorest quintile (169 kg) was roughly half the average quantity received by households in the richest quintile (334 kg). Putting these participation rates and quantities received together, section E shows that a disproportionately high share of FISP fertilizer is allocated to the wealthiest households: although they represent only 20% of the smallholder population, the wealthiest quintile received 62-63% of subsidized fertilizer in 2002/03 and 2006/07, and 42% of it in 2010/11. Poor smallholders acquire very little FISP fertilizer, so it is not surprising that rural poverty rates remain essentially unchanged despite years of large-scale fertilizer subsidy programs. Although not strictly enforced (Mason et al., 2013), Burke et al. (2012) suggest that the area cultivated and cooperative/farmer group membership FISP eligibility requirements, as well as the cash needed to make the farmer payment for subsidized inputs, make it difficult for many poor households to participate in the program.

5.2. Bivariate results

Our main research question is does FISP fertilizer raise incomes and reduce poverty among smallholders? Before turning to the econometric results, we first test whether there are statistically significant differences in mean income and poverty outcomes between smallholder FISP fertilizer recipients and non-recipients. These results are summarized in Table 1 for both the SS and RALS data. Based on the SS data, all indicators suggest statistically higher levels of economic well-being (higher incomes and lower poverty) among FISP recipients; mean incomes (total, crop, and other) are roughly twice as large for FISP recipients than non-recipients. Based on the RALS data, all of the poverty measures are lower for FISP recipients but among the income variables, only crop income is statistically different between the two groups (and higher among FISP recipients); mean total and other income are not statistically different for the two groups of households (p-values > 0.10). In general, these results suggest better income and poverty outcomes for FISP recipients but as discussed in the methods section and shown in Table 3, this could be because relatively wealthy households are more likely to receive FISP fertilizer, not necessarily because receipt of FISP fertilizer makes households wealthier. To untangle these relationships, we need to hold other factors constant. For this, we turn to the econometric results.

5.3. Econometric (multivariate) results

The econometric results are summarized in Table 4.[15] The left panel of Table 4 shows the SS results and the right panel shows the RALS results. Because the RALS data are cross-sectional, we consider the RALS results to be only *correlations* between FISP fertilizer and the income and poverty outcomes. All RALS regressions (except those for total and other income, gross and net, in levels, which are not statistically significant overall) suggest highly statistically significant (p-value < 0.01) positive (negative) correlations between FISP fertilizer and smallholder household incomes (poverty). In constant semi-elasticity terms, a 200-kg increase in subsidized fertilizer (the official pack size under the current Farmer Input Support Program) is correlated with average total, crop, and other incomes that are 15%, 22%, and 8% higher, respectively. This increase in subsidized fertilizer is also correlated with US$2/day and US$1.25/day poverty headcount rates that are roughly 3 percentage points and 5-6 percentage points lower, respectively, on average, and poverty severity that is 7-8 percentage points lower.

The SS panel data results, which are arguably more reliable estimates of the *causal effects* of FISP fertilizer on smallholder incomes and poverty, suggest more modest impacts. At 2.01 kg, our estimate of the APE of a 1-kg increase in Fertilizer Support Program fertilizer on households' maize quantity harvested is very similar to Mason et al.'s (2013, 2014) 1.88 kg/kg estimate.[16] We find evidence of statistically significant positive effects of FISP fertilizer on total income and crop income (gross, net, and per adult equivalent, AE) but not on other income, and only when the models are estimated in levels (not logs). In some ways, the lack of impact on

[15] Due to the large number of models estimated (33 for each dataset) and space constraints, the full regression results are not reported here but are available from the authors upon request. We find little if any evidence of FRA impacts on outcomes other than maize production, and the main findings of the paper are robust to the inclusion of lagged income as an explanatory variable and to the exclusion of household socio-economic characteristics (e.g., landholding, livestock, farm equipment, age, gender, and education of the household head, and household size).

[16] Recall that Mason et al.'s estimate is based on all three waves of the SS, while ours is based on the 2004 and 2008 SS only. Sianjase and Seshamani (2013) also find evidence of positive FISP effects on maize production in Zambia using a small panel dataset (N=570) from Gwembe District.

logged income makes sense because we would not expect a constant semi-elasticity effect but rather a linear effect of subsidized fertilizer on households' incomes.[17] FISP fertilizer affects total income only through its impact on crop production; there are no (positive or negative) spillover effects on other (non-crop) income. For example, an additional 200 kg of FISP fertilizer raises net total income per adult equivalent by K224,400, or roughly US$46 per year in real 2011/12 Kwacha terms This represents a 33.7% increase over median net total income per adult equivalent during the 2004 and 2008 SSs (K665,363).[18] As a second example, a 200-kg increase in FISP fertilizer raises real gross total household income by K1,119,800 (US$228), on average. This is a sizeable (37.2%) increase relative to real median incomes in Zambia during the 2004 and 2008 SSs (K3,010,009).

To contrast this increase in gross total household income to the cost of the fertilizer, in 2006/07 (captured in the 2008 SS), 200 kg of fertilizer through the subsidy program cost approximately K737,485 (US$151) in real 2011/12 Kwacha terms including the farmer's and government's contributions but excluding administrative costs. This suggests a back-of-the-envelope benefit-cost ratio for 2006/07 for subsidized fertilizer of 1.52 (excluding administrative costs). This is in a similar range as Mason and Smale's (2013) back-of-the-envelope benefit-cost ratios for 2006/07 for subsidized seed (excluding administrative costs) of 1.09 to 2.18. Jayne et al. (forthcoming) present detailed calculations of economic benefit-cost ratios for the fertilizer subsidy component of the program for the 2006/07 through 2010/11 agricultural years and find a 2006/07 economic BCR of 1.57 but a 5-year economic BCR of 0.97.[19]

Although the SS results suggest fairly large impacts on household income, these increases in household income are not sufficient to substantially lower households' probability of falling below the poverty line or to substantially reduce their poverty severity. Rather, the SS results suggest statistically significant but extremely small-in-magnitude FISP fertilizer effects on poverty among smallholders. On average, receiving 200 kg more subsidized fertilizer reduces the probability of being in *extreme* poverty (US$1.25/day) by 1-2 percentage points and of being in poverty (US$2/day) by 0.5 percentage points (Table 4). It also reduces extreme poverty severity by 2 percentage points and (regular) poverty severity by 1 percentage point. Given the very high poverty and extreme poverty headcount rates (95% and 90%, respectively) and poverty severity rates (medians of 74% and 60%, respectively) in our sample, the results indicate very small, almost economically meaningless, reductions in poverty as a result of the fertilizer subsidy program. These disappointingly small effects on poverty are likely due to the fact that relatively little FISP fertilizer reaches the poorest households (Table 3).

6. Conclusions and policy implications

Motivated by the observation that the rural poverty rate in Zambia in 2010 (78%) was unchanged from its 2004 level despite government's devoting nearly 50% of its agricultural sector Poverty Reduction Program spending to agricultural input subsidies during the intervening years, this paper seeks to answer the question, do fertilizer subsidies raise incomes and reduce poverty

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[17] Control function test results also suggest that FISP fertilizer is endogenous to most of the logged outcome variables.

[18] The exchange rate during the 2011/12 marketing year was roughly K4,899 per US$.

[19] The benefits in Jayne et al.'s (forthcoming) calculations are based on the value of maize produced as a result of increased fertilizer use stimulated by the subsidy program after accounting for crowding out and diversion, whereas here we are basing the benefits on the increase in gross household income resulting from the subsidy program.

among smallholder farmers in Zambia? Using data from two nationally-representative surveys (a two-year panel survey and a cross-section), we estimate the average partial effects of increases in subsidized fertilizer acquired through Zambia's Fertilizer Support Program and Farmer Input Support Program (FISP) on numerous indicators of smallholder economic well-being. The results suggest that while FISP fertilizer raises smallholder incomes (by raising maize production and crop incomes) and is correlated with lower poverty rates, the increase in incomes is insufficient to substantively reduce households' probability of falling below the poverty line or the severity of poverty. For example, a 200-kg increase in FISP fertilizer (the current input pack size) raises gross household income by approximately US$228 (a 37% increase from the median) and net household income per adult equivalent by US$46 (a 34% increase from the median). However, a 200-kg increase in FISP fertilizer only reduces the probability of falling below the US$2/capita/day (US$1.25/capita/day) poverty line by 0.5 percentage points (1 percentage point) and reduces poverty severity by 1-2 percentage points. These are very small reductions in poverty given US$2 and US$1.25 poverty headcount rates of 95% and 90%, respectively, and corresponding median poverty severity levels of 74% and 60%, respectively, during the period of analysis.

Poverty is wide and deep among smallholder farmers in Zambia, so FISP fertilizer would have to have a very large impact on the incomes of many poor farmers to substantively change the poverty rate. A major explanation for the limited impact of the program on smallholder poverty is that very little FISP fertilizer reaches poor households. For example, in 2002/03, only 7% of FISP fertilizer went to the poorest 40% of the smallholder population, whereas the richest 20% garnered 63% of FISP fertilizer. The situation improved somewhat in 2010/11 but FISP fertilizer still went disproportionately to wealthier households: the poorest 40% of smallholders got 15% of the fertilizer while the richest 20% of smallholders got 42% of it. If FISP aims to reduce poverty by directly targeting poor farmers, it has largely failed (Mason et al., 2013). Nor has the program likely affected poverty among smallholder maize net buyers by reducing retail maize prices, as results from Ricker-Gilbert et al. (2013) suggest that the program has only reduced retail maize prices in Zambia by 2-3%.

To increase FISP participation among poor smallholders without increasing the subsidy rate, the Zambian government could consider removing the cooperative/farmer group membership requirement (poor smallholders may not be able to afford to join or pay annual dues, (Burke et al., 2012)) and capping the maximum area cultivated for beneficiary households at 2 ha instead of 5 ha (currently 78% of poor households cultivate less than 2 ha but households cultivating more than 2 ha capture most (55%) of the FISP fertilizer (Mason et al., 2013)). Government could also consider recapitalizing the Food Security Pack Program, a program that targets free seed and fertilizer to the poorest of the poor but that has been starved for funds since the mid-2000s (ibid).

To boost the effects of FISP on household maize production and incomes, government could seek to improve the timeliness of delivery of FISP fertilizer (late delivery is a perennial problem) and provide extension support to farmers on best agronomic and soil fertility management practices, both of which could help raise currently paltry maize-yield response rates (Jayne et al., 2013; Mason et al., 2013). Improving the targeting of FISP fertilizer so that it is allocated to households that cannot afford fertilizer at commercial prices could reduce displacement/crowding out; coupled with efforts to reduce diversion of FISP fertilizer to resale on commercial markets, this should increase the incremental fertilizer use and maize production resulting from the program, and, in turn, put greater downward pressure on market prices for maize to the benefit of poor net maize buyers (Ricker-Gilbert et al., 2011; Mason & Jayne, 2013; Jayne et al., 2013). Although beyond the scope of this paper, flexible electronic vouchers may be another promising innovation to improve FISP's performance (Sitko et al., 2012; Mason et al., 2013).

Finally, approximately 50% of Zambia's agricultural sector Poverty Reduction Program funds are currently being spent on FISP but as results in this paper demonstrate, FISP is not very effective at reducing poverty. If reducing rural poverty is a priority, then government should consider other approaches to poverty reduction that may be more cost-effective than FISP, such as social cash-transfer programs and investments in rural infrastructure, agricultural research and development, health, and education (Fan, Gulati, & Thorat, 2008; EIU, 2009).

7. Next steps

In subsequent iterations of the paper, we plan to revisit the RALS data to compute income and poverty measures that are directly comparable to those in the SS data to enable us to draw conclusions about changes in smallholder poverty between the 2008 SS and the 2012 RALS. We also plan to attempt to control for and estimate the effects of subsidized seed (not just subsidized fertilizer) in our income and poverty regressions. Given the somewhat puzzling findings of fairly large increases in incomes as a result of FISP but virtually non-existent impacts on poverty, we will also explore a quantile regression approach for the income dependent variables. We suspect this will reveal large FISP impacts on the incomes of wealthier households (who are more likely to receive FISP) but relatively small impacts on the incomes of poorer households. Lastly, we are considering applying Otsuka et al.'s (1992) counterfactual Gini decomposition analysis to assess the effects of FISP on income inequality among Zambian smallholders.

We welcome comments and feedback on this draft paper (masonn@msu.edu).

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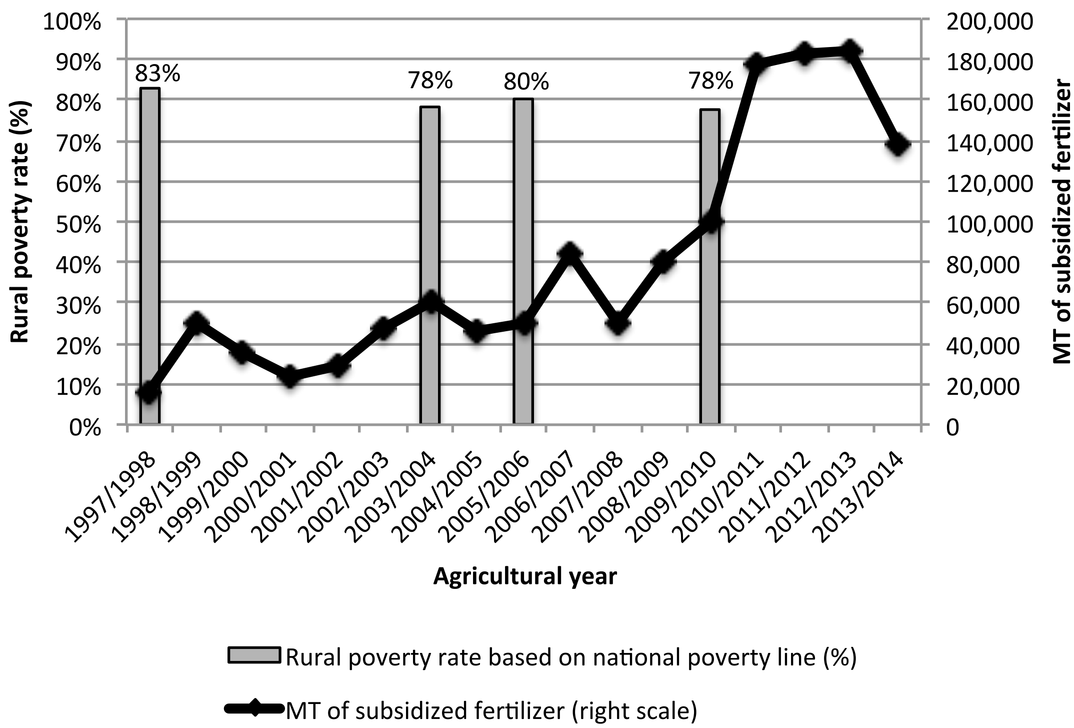
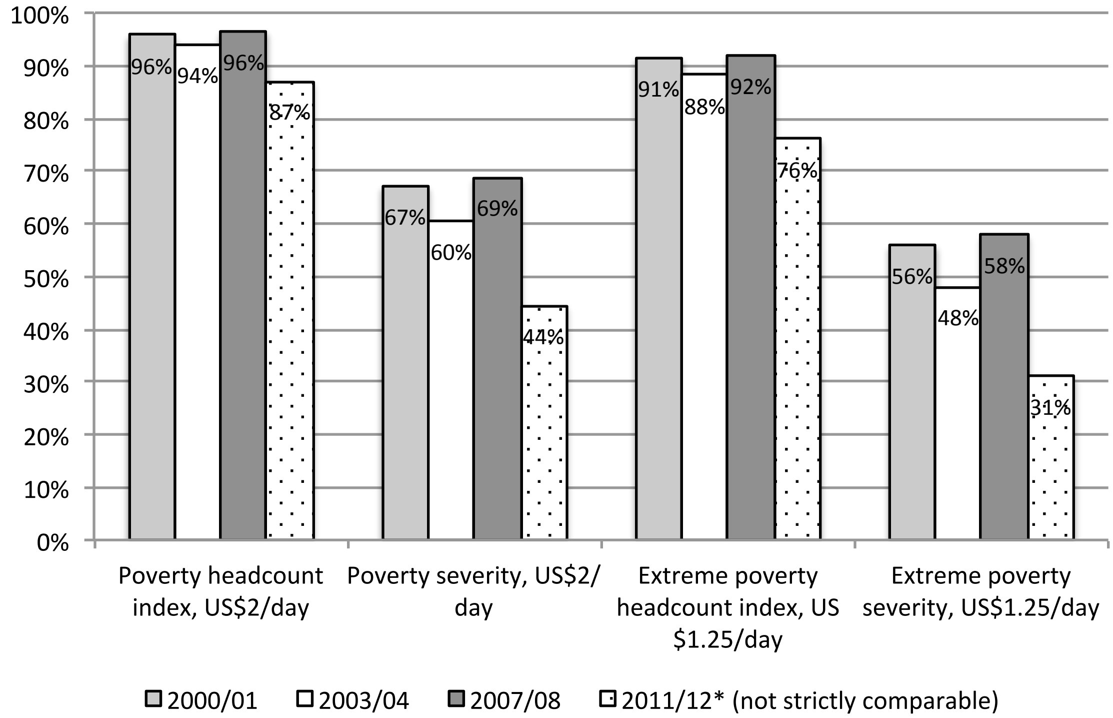
FIGURES & TABLES

Figure 1. Trends in the official rural poverty rate and the quantity of subsidized fertilizer distributed through government programs, 1997/98-2013/14 agricultural years



Sources: CSO (2009, 2011), MACO (various years), MAL (various years).
Note: The official rural poverty rates are based on the national poverty line and consumption expenditures, and come from Zambian government reports based on the Living Conditions Monitoring Surveys. The poverty rates are for 1998, 2004, 2006, and 2010. The MT of subsidized fertilizer is for a fertilizer-on-credit program run by the FRA from 1997/98-2001/02, the Fertilizer Support Program from 2002/03-2008/09, and the Farmer Input Support Program for 2009/10-2013/14.

Figure 2. Trends in SS- and RALS-based measures of poverty among smallholder farm households, 2000/01, 2003/04, 2007/08, and 2011/12 marketing years



Sources: Authors' calculations based on the 2001, 2004, and 2008 CSO/MACO/FSRP Supplemental Surveys and the 2012 CSO/MAL/IAPRI Rural Agricultural Livelihoods Survey.
Note: *Due to some differences among the surveys, the 2011/12 figures, which are based on the RALS data, are not strictly comparable to the 2000/01, 2003/04, and 2007/08 figures, which are based on the SS data. The poverty severity figures are mean poverty severity across all households (poor and non-poor). Also note that these poverty figures are based on income, whereas those in Figure 1 are based on expenditures.

Table 1. Comparisons of mean values of income and poverty outcomes between FISP recipient and non-recipient households, SS and RALS data

	SS data (2003/04 and 2007/08 marketing years)					RALS data (2011/12 marketing year)				
		Received FISP fertilizer?					Received FISP fertilizer?			
Outcome variables	**All HHs**	**Yes**	**No**	**Difference (Yes – No)**	**p-value**	**All HHs**	**Yes**	**No**	**Difference (Yes –No)**	**p-value**
Maize kg harvested	1,259	3,381	1,021	2,360	0.000	1,887	3,506	1,193	2,313	0.000
Gross total income ('000 ZMK)	7,272	13,536	6,571	6,964	0.000	24,748	48,447	14,577	33,870	† 0.254
Gross crop income ('000 ZMK)	2,575	5,233	2,278	2,955	0.000	4,241	6,577	3,238	3,339	0.000
Gross other income ('000 ZMK)	4,697	8,302	4,293	4,009	0.000	20,508	41,870	11,339	30,531	† 0.304
Gross total income/AE ('000 ZMK)	1,492	2,563	1,373	1,191	0.000	6,437	13,198	3,535	9,663	† 0.288
Gross crop income/AE ('000 ZMK)	584	999	537	462	0.000	1,110	1,555	919	636	0.000
Gross other income/AE ('000 ZMK)	909	1,564	835	729	0.000	5,327	11,643	2,616	9,027	† 0.321
Net total income ('000 ZMK)	7,052	12,841	6,404	6,437	0.000	24,382	47,828	14,319	33,510	† 0.259
Net crop income ('000 ZMK)	2,355	4,539	2,110	2,428	0.000	3,874	5,959	2,980	2,979	0.000
Net total income/AE ('000 ZMK)	1,448	2,432	1,338	1,094	0.000	6,346	13,057	3,465	9,592	† 0.292
Net crop income/AE ('000 ZMK)	540	868	503	365	0.000	1,019	1,414	849	565	0.000
Binary poverty (US$2/day, gross)	0.953	0.885	0.961	-0.076	0.000	0.870	0.803	0.899	-0.096	0.000
Poverty gap (US$2/day, gross)	0.764	0.632	0.779	-0.147	0.000	0.589	0.489	0.632	-0.143	0.000
Poverty severity (US$2/day, gross)	0.648	0.494	0.666	-0.171	0.000	0.445	0.343	0.489	-0.146	0.000
Binary extreme poverty (US$1.25/day, gross)	0.903	0.793	0.915	-0.122	0.000	0.761	0.655	0.806	-0.151	0.000
Extreme poverty gap (US$1.25/day, gross)	0.664	0.504	0.682	-0.178	0.000	0.448	0.338	0.495	-0.157	0.000
Extreme poverty severity (US$1.25/day, gross)	0.531	0.361	0.550	-0.189	0.000	0.311	0.213	0.353	-0.140	0.000
Binary poverty (US$2/day, net)	0.956	0.896	0.963	-0.067	0.000	0.875	0.811	0.902	-0.091	0.000
Poverty gap (US$2/day, net)	0.771	0.651	0.784	-0.133	0.000	0.599	0.505	0.640	-0.135	0.000
Poverty severity (US$2/day, net)	0.657	0.518	0.672	-0.154	0.000	0.457	0.360	0.498	-0.139	0.000
Binary extreme poverty (US$1.25/day, net)	0.907	0.807	0.919	-0.112	0.000	0.770	0.672	0.813	-0.141	0.000
Extreme poverty gap (US$1.25/day, net)	0.672	0.529	0.688	-0.159	0.000	0.461	0.357	0.506	-0.149	0.000
Extreme poverty severity (US$1.25/day, net)	0.541	0.390	0.558	-0.168	0.000	0.323	0.230	0.363	-0.134	0.000

Sources: Authors' calculations based on the 2004 & 2008 CSO/MACO/FSRP Supplemental Surveys and the 2012 CSO/MAL/IAPRI Rural Agricultural Livelihoods Survey.

Note: AE = adult equivalent. Binary poverty refers to the poverty headcount index. All Zambian Kwacha (ZMK) values are in 2011/12 terms. For the poverty measures, gross and net refer to whether the measures are based on gross total income or total income net of fertilizer costs, respectively. The p-value is for a t-test of the null hypothesis that the mean values of FISP recipient and non-recipient households are the same, versus the alternative hypothesis that the means are different. † indicates cases where we fail to reject the null that the means are the same.

Table 2. Reduced form Tobit regressions for the kg of FISP fertilizer received, SS & RALS data

	SS data (CRE Tobit)			RALS data (Tobit)		
Explanatory variables	**APE**	**Sig.**	**p-value**	**APE**	**Sig.**	**p-value**
IV: =1 if ruling party won constituency in last election	20.140	***	0.008	23.914	***	0.001
IV: | %-pt. spread b/w ruling party & lead opposition |	-0.0632		0.629	0.295	**	0.025
IV: Interaction effect – ruling party won × %-pt. spread	0.516	**	0.033	1.703	***	0.000
District-level FRA maize purchases (t-1, kg/ag HH)	0.00335		0.655	-0.00816		0.179
Farmgate FRA maize price (t-1, ZMK/kg)	3.456		0.868	240.495	***	0.001
Maize producer price (t-1, ZMK/kg)	-7.324		0.720	82.359	***	0.010
Groundnut producer price (t-1, ZMK/kg)	-215.420		0.114	-33.638	***	0.000
Mixed beans producer price (t-1, ZMK/kg)	51.163		0.348	-11.649		0.566
Sweet potato producer price (t-1, ZMK/kg)	99.766	**	0.013	-21.334	*	0.085
Inorganic fertilizer price (ZMK/kg)	6.985		0.721	N/A		
Basal fertilizer price (ZMK/kg)	N/A			-6.960		0.772
Top dressing fertilizer price (ZMK/kg)	N/A			23.988		0.294
Hybrid maize seed price (ZMK/kg)	N/A			-16.538		0.280
Weeding wage per 0.25 ha (ZMK)	4.045		0.571	-18.411		0.203
Land preparation wage per 0.25 ha of maize (ZMK)	N/A			5.546		0.698
Landholding size (ha)	1.097		0.289	18.819	***	0.000
Value of farm equipment ('000 ZMK)	-0.000487		0.824	0.00610	**	0.017
Value of livestock ('000 ZMK)	0.000475		0.225	0.000794	**	0.020
Number of children age 4 and under	-2.354		0.253	1.519		0.488
Number of children age 5 to 14	-0.502		0.787	4.595	***	0.000
Number of prime age adults (age 15 to 59)	0.113		0.930	7.227	***	0.000
Number of adults age 60 and above	1.492		0.765	12.370	***	0.010
Age of the HH head	0.506		0.151	0.539	***	0.003
=1 if female-headed HH	-1.580		0.850	9.365	*	0.053
Highest level of education completed by the HH head (no formal education is base):						
=1 if some lower primary education (grades 1-4)	-5.802		0.409	-1.416		0.828
=1 if some upper primary education (grades 5-7)	-3.393		0.660	24.661	***	0.000
=1 if some secondary education (grades 8-12)	6.045		0.530	54.092	***	0.000
=1 if some post-secondary education	-10.193		0.434	118.768	***	0.000
Km to the nearest district town	0.0453		0.663	-0.136	**	0.024
Km to the nearest tarred/main road	-0.122	**	0.022	-0.168	***	0.005
Km to the nearest feeder road	-2.567	***	0.000	-0.738	**	0.042
% of HHs in district with income from:						
Non-farm salaried/wage employment	-0.342		0.434	0.985	***	0.005
Formal/informal business activities	-0.035		0.915	-0.799	***	0.000
Work on others' farms	-0.137		0.601	1.047	**	0.021
Moisture stress (# of 20-day periods w/ <40 mm rain)	-11.090	***	0.001	-7.350	*	0.065
Growing season rainfall (t, mm)	-0.146	***	0.000	0.0493		0.259
Growing season rainfall (t-1, mm)	-0.0143		0.710	0.0999	**	0.011
Growing season rainfall (t-2, mm)	-0.0235		0.484	0.182	***	0.000
Growing season rainfall (t-3, mm)	0.0370		0.420	-0.0673		0.264
Long-run average number of moisture stress periods	-2412.703	*	0.091	13.646		0.208
Long-run average growing season rainfall (mm)	*Dropped due to collinearity*			-0.153		0.242
Long-run CV of growing season rainfall (%)	*Dropped due to collinearity*			-1.8167		0.273
Agro-ecological regions dummies?	Yes			Yes		
Provincial dummies?	Yes			Yes		
2006/07 agricultural year dummy?	Yes			N/A		
2006/07 ag. year × provincial dummies?	Yes			N/A		
Overall model F-statistic	4.31	***	0.000	10.60	***	0.000
Observations	8,522			8,833		

Source: Authors' calculations.

Notes: APE = Average Partial Effect. N/A = variable not available in the SS data or not applicable for the RALS data. CV = coefficient of variation. HH = household. ***, **, and * indicate that the corresponding APEs are statistically significant at the 1%, 5%, and 10% levels, respectively. All ZMK values are in real 2011/12 terms.

Table 3. Distribution of FISP fertilizer among smallholder households by total gross income per adult equivalent quintiles, 2002/03, 2006/07, and 2010/11 agricultural years (2003/04, 2007/08, and 2011/12 marketing years)

Extreme poverty or FISP fertilizer receipt	Agricultural Year (Crop Marketing Year)	Total gross income per adult equivalent quintile: 1 (lowest)	2	3	4	5 (highest)	All HHs
(A) Extreme poverty rate (% of HHs in quintile with income below the US$1.25/capita/day extreme poverty line)	2002/03 (2003/04)	100.0%	100.0%	98.9%	93.8%	50.2%	88.1%
	2006/07 (2007/08)	100.0%	100.0%	98.7%	98.5%	62.9%	92.0%
	2010/11 (2011/12)	99.7%	96.4%	92.1%	74.8%	17.3%	76.1%
(B) % of total HHs below the extreme poverty line	2002/03 (2003/04)	22.6%	22.6%	22.3%	21.2%	11.3%	100.0%
	2006/07 (2007/08)	21.7%	21.7%	21.4%	21.4%	13.7%	100.0%
	2010/11 (2011/12)	26.2%	25.4%	24.2%	19.7%	4.5%	100.0%
(C) % receiving FISP fertilizer	2002/03 (2003/04)	2.0%	4.6%	7.9%	9.8%	19.9%	8.8%
	2006/07 (2007/08)	1.7%	4.9%	11.1%	14.5%	24.4%	11.3%
	2010/11 (2011/12)	11.3%	19.9%	29.8%	39.9%	49.2%	30.0%
(D) Mean kg of FISP fertilizer per recipient HH	2002/03 (2003/04)	101	144	188	256	421	300
	2006/07 (2007/08)	107	183	214	296	508	356
	2010/11 (2011/12)	169	198	218	251	334	259
(E) % of total FISP fertilizer	2002/03 (2003/04)	1.6%	5.0%	11.2%	19.0%	63.3%	100.0%
	2006/07 (2007/08)	0.9%	4.4%	11.8%	21.4%	61.5%	100.0%
	2010/11 (2011/12)	4.9%	10.2%	16.8%	25.8%	42.4%	100.0%

Sources: Authors' calculations based on the 2004 & 2008 CSO/MACO/FSRP Supplemental Surveys and the 2012 CSO/MAL/IAPRI Rural Agricultural Livelihoods Survey.

Note: Results based on the balanced panel of 4,261 households interviewed in both the 2004 and 2008 SSs, and the 8,833 households reporting non-zero income on the 2012 RALS. Note that the quintiles are based on *per adult equivalent* income, while the extreme poverty rate is based on *per capita* income.

Table 4. Summary of econometric results: average partial effects (APEs) of a 1-kg increase in FISP fertilizer on smallholder maize production, incomes, and poverty (SS & RALS data)

	SS Panel Results						RALS Cross-Sectional Results					
Dependent variable	APE	Sig.	p-val.	FISP fertilizer endo-genous?	Tobit residuals p-val.	Estimated Δ per 200 kg FISP fertilizer (stat. sig. only)	APE	Sig.	p-val.	FISP fertilizer endo genous?	Tobit residuals p-val.	Estimated Δ per 200 kg FISP fertilizer (stat. sig. only)
Maize kg harvested	2.006	***	0.000	No	0.146	401.2 kg	3.828	***	0.000	No	0.735	756.6 kg
Gross total income (‘000 ZMK)	5.954	+	0.108	No	0.269	K1,119,800	*Overall model & FISP fertilizer not statistically significant*					
Log gross total income	0.000125		0.407	Yes	0.000		0.000757	***	0.000	No	0.673	15.1%
Gross crop income (‘000 ZMK)	3.546	***	0.003	No	0.405	K709,200	6.320	***	0.000	No	0.463	K1,264,000
Log gross crop income	0.000205		0.241	Yes	0.000		0.00110	***	0.000	No	0.185	22.0%
Gross other income (‘000 ZMK)	1.15505		0.513	No	0.937		*Overall model & FISP fertilizer not statistically significant*					
Log gross other income	0.000080		0.619	No	0.243		0.000417	***	0.001	No	0.968	8.3%
Gross total income/AE (‘000 ZMK)	1.252	**	0.034	No	0.381	K250,400	*Overall model & FISP fertilizer not statistically significant*					
Log gross total income/AE	0.0000664		0.679	Yes	0.000		0.000764	***	0.000	No	0.781	15.3%
Gross crop income/AE (‘000 ZMK)	0.702	***	0.000	No	0.932	K140,400	1.313	***	0.000	No	0.516	K262,600
Log gross crop income/AE	0.000140		0.459	Yes	0.000		0.00110	***	0.000	No	0.219	22.0%
Gross other income/AE (‘000 ZMK)	0.27170		0.375	No	0.741		*Overall model & FISP fertilizer not statistically significant*					
Log gross other income/AE	0.000041		0.802	No	0.232		0.000420		0.002	No	0.974	8.4%
Net total income (‘000 ZMK)	5.725	+	0.123	No	0.271	K1,145,000	*Overall model & FISP fertilizer not statistically significant*					
Log net total income	0.000103		0.503	Yes	0.000		0.000745	***	0.000	No	0.702	14.9%
Net crop income (‘000 ZMK)	3.317	***	0.004	No	0.399	K663,400	5.980	***	0.000	No	0.302	K1,196,000
Log net crop income	0.000219		0.198	Yes	0.000		0.00111	***	0.000	No	0.367	22.2%
Net total income/AE (‘000 ZMK)	1.122	*	0.064	No	0.410	K224,400	*Overall model & FISP fertilizer not statistically significant*					
Log net total income/AE	0.0000423		0.794	Yes	0.000		0.000752		0.000	No	0.807	15.0%
Net crop income/AE (‘000 ZMK)	0.573	***	0.002	No	0.833	K114,600	1.251	***	0.000	No	0.356	K250,200
Log net crop income/AE	0.000152		0.398	Yes	0.000		0.00111	***	0.000	No	0.426	22.2%
Binary poverty (US$2/day, gross) - probit	-2.94E-7		0.984	Yes	0.070		-0.0001409	***	0.000	No	0.170	-2.8 pp
Binary poverty (US$2/day, gross) - logit	-0.0000193		0.208	No	0.116		-0.0001422	***	0.000	No	0.208	-2.8 pp
Poverty severity (US$2/day, gross)	-0.000103	***	0.002	Yes	0.000	-2.1 pp	-0.000360	***	0.000	No	0.793	-7.2 pp
Binary extreme poverty (US$1.25/day, gross) - probit	-0.0000498	***	0.010	No	0.173	-1.0 pp	-0.0002818	***	0.000	No	0.575	-5.6 pp
Binary extreme poverty (US$1.25/day, gross) - logit	-0.0000566	**	0.027	No	0.425	-1.1 pp	-0.0002748	***	0.000	No	0.743	-5.5 pp
Extreme poverty severity (US$1.25/day, gross)	*Model does not converge*						-0.0003985	***	0.000	No	0.998	-8.0 pp
Binary poverty (US$2/day, net) – probit	-0.0000226	**	0.036	No	0.105	-0.5 pp	-0.0001378	***	0.000	No	0.407	-2.8 pp
Binary poverty (US$2/day, net) – logit	-0.0000249	*	0.092	No	0.130	-0.5 pp	-0.0001388	***	0.000	No	0.495	-2.8 pp
Poverty severity (US$2/day, net)	-0.0000669	*	0.053	Yes	0.000	-1.3 pp	-0.0003375	***	0.000	No	0.853	-6.8 pp
Binary extreme poverty (US$1.25/day, net) - probit	-0.0000481	***	0.009	No	0.160	-1.0 pp	*Model does not converge*					
Binary extreme poverty (US$1.25/day, net) - logit	-0.0000531	**	0.033	No	0.338	-1.1 pp	-0.0002554	***	0.000	No	0.547	-5.1 pp
Extreme poverty severity (US$1.25/day, net)	-0.000100	***	0.008	Yes	0.000	-2.0 pp	-0.0003726	***	0.000	No	0.974	-7.5 pp

Source: Authors’ calculations

Note: pp = percentage points. ***, **, *, and + indicate that the corresponding APEs are statistically significant at the 1%, 5%, 10%, and 15% levels, respectively. All Kwacha values are in real 2011/12 terms. The average exchange rate that marketing year was K4,899 per US$. For cases where there is evidence that FISP fertilizer is endogenous, the reported APEs and p-values are from models that include the Tobit residuals and are based on bootstrapped standard errors that account for the first stage estimation of the Tobit residuals.

APPENDIX

Table A.1. Summary statistics: SS dependent & related variables (2003/04 & 2007/08 marketing years)

			Percentile		
Dependent & related variables	**Mean**	**Std. dev.**	**25th**	**50th**	**75th**
=1 if HH harvested maize	0.823				
Kg of maize harvested	1,259	2,897	173	575	1,380
Total income (gross, '000 ZMK)	7,272	30,000	1,486	3,010	6,450
=1 if HH had crop income	0.973				
Crop income (gross, '000 ZMK)	2,575	4,349	717	1,581	2,976
=1 if HH had other (non-crop) income	0.876				
Other (non-crop) income (gross, '000 ZMK)	4,697	29,190	120	717	3,066
Total income per full-time adult equivalent (gross, '000 ZMK)	1,492	4,251	343	692	1,431
Crop income per full-time adult equivalent (gross, '000 ZMK)	584	958	160	342	678
Other (non-crop) income per full-time adult equivalent (gross, '000 ZMK)	909	4,045	28	170	662
Total income (net of fertilizer costs, '000 ZMK)	7,052	29,841	1,427	2,892	6,210
Crop income (net of fertilizer costs, '000 ZMK)	2,355	3,994	647	1,459	2,754
Total income per full-time adult equivalent (net of fertilizer costs, '000 ZMK)	1,448	4,206	329	665	1,382
Crop income per full-time adult equivalent (net of fertilizer costs, '000 ZMK)	540	905	145	315	628
Poverty headcount index (=1 if gross income < US$1.25/capita/day)	0.953				
Poverty gap (gross income, US$1.25/capita/day)	0.764	0.254	0.707	0.860	0.932
Poverty severity (gross income, US$1.25/capita/day)	0.648	0.283	0.499	0.740	0.868
Extreme poverty headcount index (=1 if gross income < US$1.25/capita/day)	0.903				
Extreme poverty gap (gross income, US$1.25/capita/day)	0.664	0.301	0.531	0.777	0.891
Extreme poverty severity (gross income, US$1.25/capita/day)	0.531	0.309	0.282	0.603	0.793
Poverty headcount index (=1 if net income < US$2/capita/day)	0.956				
Poverty gap (net income, US$2/capita/day)	0.771	0.250	0.717	0.865	0.934
Poverty severity (net income, US$2/capita/day)	0.657	0.281	0.515	0.749	0.873
Extreme poverty headcount index (=1 if net income < US$1.25/capita/day)	0.907				
Extreme poverty gap (net income, US$1.25/capita/day)	0.672	0.299	0.548	0.785	0.895
Extreme poverty severity (net income, US$1.25/capita/day)	0.541	0.309	0.300	0.616	0.801

Source: Authors' calculations based on the 2004 and 2008 CSO/MACO/FSRP Supplemental Surveys.
Note: N=8,522. All ZMK values are in real 2011/12 terms.

Table A.2. Summary statistics: RALS dependent & related variables (2011/12 marketing year)

			Percentile		
Dependent & related variables	**Mean**	**Std. dev.**	**25th**	**50th**	**75th**
=1 if HH harvested maize	0.835				
Kg of maize harvested	1,887	4,090	230	863	2,013
Total income (gross, '000 ZMK)	24,748	2.28E+6	2,895	5,581	10,975
=1 if HH had crop income	0.972				
Crop income (gross, '000 ZMK)	4,241	5,671	1,300	2,717	5,177
=1 if HH had other (non-crop) income	0.955				
Other (non-crop) income (gross, '000 ZMK)	20,508	2.28E+6	400	1,665	5,263
Total income per full-time adult equivalent (gross, '000 ZMK)	6,437	6.54E+5	754	1,454	2,862
Crop income per full-time adult equivalent (gross, '000 ZMK)	1,110	1,605	323	694	1,337
Other (non-crop) income per full-time adult equivalent (gross, '000 ZMK)	5,327	6.54E+5	110	423	1,343
Total income (net of fertilizer costs, '000 ZMK)	24,382	2.28E+6	2,778	5,330	10,612
Crop income (net of fertilizer costs, '000 ZMK)	3,874	4,995	1,130	2,560	4,825
Total income per full-time adult equivalent (net of fertilizer costs, '000 ZMK)	6,346	6.54E+5	717	1,402	2,753
Crop income per full-time adult equivalent (net of fertilizer costs, '000 ZMK)	1,019	1,413	290	641	1,260
Poverty headcount index (=1 if gross income < US$1.25/capita/day)	0.870				
Poverty gap (gross income, US$1.25/capita/day)	0.589	0.313	0.401	0.692	0.839
Poverty severity (gross income, US$1.25/capita/day)	0.445	0.303	0.161	0.479	0.705
Extreme poverty headcount index (=1 if gross income < US$1.25/capita/day)	0.761				
Extreme poverty gap (gross income, US$1.25/capita/day)	0.448	0.331	0.041	0.507	0.743
Extreme poverty severity (gross income, US$1.25/capita/day)	0.311	0.291	0.002	0.257	0.552
Poverty headcount index (=1 if net income < US$2/capita/day)	0.875				
Poverty gap (net income, US$2/capita/day)	0.599	0.312	0.423	0.703	0.847
Poverty severity (net income, US$2/capita/day)	0.456	0.304	0.179	0.494	0.718
Extreme poverty headcount index (=1 if net income < US$1.25/capita/day)	0.770				
Extreme poverty gap (net income, US$1.25/capita/day)	0.461	0.332	0.077	0.525	0.756
Extreme poverty severity (net income, US$1.25/capita/day)	0.323	0.294	0.006	0.276	0.571

Source: Authors' calculations based on the 2012 CSO/MAL/IAPRI Rural Agricultural Livelihoods Survey.
Note: N=8,833.

Table A.3. Summary statistics: SS explanatory variables (2003/04 & 2007/08 marketing years)

Explanatory variables	Mean	Std. dev.	Percentile 25th	Percentile 50th	Percentile 75th
=1 if HH acquired Fertilizer Support Program fertilizer	0.101				
Kg of Fertilizer Support Program fertilizer acquired	33.353	155.982	0	0	0
District-level FRA maize purchases (t-1, kg/ag HH)	129	242.6815	0	0	141.8341
Farmgate FRA maize price (t-1, ZMK/kg)	1,299	370	973	1,120	1,696
Maize producer price (t-1, ZMK/kg)	1,142	360	829	1,029	1,455
Groundnut producer price (t-1, ZMK/kg)	2,533	465	2,241	2,517	2,626
Mixed beans producer price (t-1, ZMK/kg)	2,354	226	2,254	2,340	2,408
Sweet potato producer price (t-1, ZMK/kg)	482	156	346	462	629
Inorganic fertilizer price (ZMK/kg)	3,616	592	3,323	3,684	4,016
Weeding wage per 0.25 ha (ZMK)	59	20	43	58	72
Landholding size (ha)	2.078	2.382	0.875	1.500	2.506
Value of farm equipment ('000 ZMK)	325	1,092	0	0	0
Value of livestock ('000 ZMK)	3,079	14,014	0	0	1,084
Number of children age 4 and under	1	0.935	0	0	1
Number of children age 5 to 14	2	1.588	1	2	3
Number of full-time equivalent prime age adults (age 15 to 59)	2.957	1.750	2.000	2.917	4.000
Number of full-time equivalent adults age 60 and above	0.410	0.651	0	0	1.000
Age of household head	51	14.984	38	49	62
=1 if female-headed HH	0.228				
=1 if HH head has no formal education	0.181				
=1 if HH head completed some lower primary education (grades 1-4)	0.264				
=1 if HH head completed some upper primary education (grades 5-7)	0.347				
=1 if HH head completed some secondary education (grades 8-12)	0.188				
=1 if HH head completed some post-secondary education	0.019				
Km from the SEA to the nearest district town	34.247	22.256	16.200	28.800	46.500
Km from the SEA to the nearest tarred/main road	26.246	36.736	4.000	12.400	29.600
Km from the SEA to the nearest feeder road	3.244	3.147	1.100	2.300	4.300
% HHs in dist. with income from non-farm salaried/wage employment	13.467	7.677	8.027	11.893	16.992
% HHs in dist. earning income from formal/informal business activities	34.672	15.246	24.063	35.575	45.888
% HHs in district earning income from work on others' farms	9.628	9.708	3.671	6.642	10.983
=1 if agro-ecological region I (< 800 mm rainfall)	0.054				
=1 if agro-ecological region IIa (800-1000 mm rainfall, clay soils)	0.443				
=1 if agro-ecological region IIb (800-1000 mm rainfall, sandy soils)	0.084				
=1 if agro-ecological region III (> 1000 mm rainfall)	0.419				
Number of moisture stress periods (20-day periods w/ <40 mm rainfall)	1.490	1.166	1.000	1.000	2.000
Growing season rainfall (t, mm)	863	118	790	867	952
Growing season rainfall (t-1, mm)	867	145	777	888	971
Growing season rainfall (t-2, mm)	880	143	787	890	992
Growing season rainfall (t-3, mm)	845	107	770	829	904
Long-run average # of moisture stress periods (16-year moving average)	1.931	0.013	1.918	1.931	1.943
Long-run average growing season rainfall (mm, 16-year moving average)	825	6	820	825	831
Long-run CV of growing season rainfall (%, 16-year moving average)	18.716	0.270	18.446	18.716	18.985
=1 if Central Province	0.113				
=1 if Copperbelt Province	0.058				
=1 if Eastern Province	0.245				
=1 if Luapula Province	0.093				
=1 if Lusaka Province	0.024				
=1 if Northern Province	0.175				
=1 if Northwestern Province	0.070				
=1 if Southern Province	0.120				
=1 if Western Province	0.103				

Source: Authors' calculations based on the 2004 and 2008 CSO/MACO/FSRP Supplemental Surveys.
Note: N=8,522. SEA = standard enumeration area (SEAs contain roughly 150-200 households or 2-4 villages). HH = household. CV = coefficient of variation. The growing season is November-March. All ZMK values are in real 2011/12 terms.

Table A.4. Summary statistics: RALS explanatory variables (2011/12 marketing year)

Explanatory variables	Mean	Std. dev.	Percentile 25th	Percentile 50th	Percentile 75th
=1 if HH acquired Farmer Input Support Program fertilizer	0.300				
Kg of Farmer Input Support Program fertilizer acquired	77.708	168.393	0	0	100
District-level FRA maize purchases (t-1, kg/ag HH)	606.017	466.315	271	468	953
Farmgate FRA maize price (t-1, ZMK/kg)	1,223	46	1,200	1,240	1,250
Maize producer price (t-1, ZMK/kg)	1,087	100	1,111	1,130	1,130
Groundnut producer price (t-1, ZMK/kg)	2,555	782	2,188	2,404	3,000
Mixed beans producer price (t-1, ZMK/kg)	3,166	573	2,778	3,282	3,704
Sweet potato producer price (t-1, ZMK/kg)	463	109	383	435	478
Basal fertilizer price (ZMK/kg)	3,883	487	3,500	4,000	4,100
Top dressing fertilizer price (ZMK/kg)	3,782	474	3,460	3,800	4,020
Hybrid maize seed price (ZMK/kg)	8,472	1,742	6,897	7,759	10,345
Weeding wage per 0.25 ha (ZMK)	57,364	24,183	43,243	50,000	61,776
Land preparation wage per 0.25 ha (ZMK)	78,785	30,499	60,000	70,000	100,000
Landholding size (ha)	2.011	2.309	1	1	3
Value of farm equipment ('000 ZMK)	250	1,008	0	0	0
Value of livestock ('000 ZMK)	2,458	10,446	0	0	1,050
Number of children age 4 and under	0.790	0.791	0	1	1
Number of children age 5 to 14	1.671	1.445	0	2	3
Number of full-time equivalent prime age adults (age 15 to 59)	2.598	1.513	2	2	3
Number of full-time equivalent adults age 60 and above	0.275	0.573	0	0	0
Age of household head	44.544	15.517	32	41	54
=1 if female-headed HH	0.241				
=1 if HH head has no formal education	0.125				
=1 if HH head completed some lower primary education (grades 1-4)	0.216				
=1 if HH head completed some upper primary education (grades 5-7)	0.379				
=1 if HH head completed some secondary education (grades 8-12)	0.245				
=1 if HH head completed some post-secondary education	0.036				
Km from the homestead to the nearest district town	43.649	35.587	18	35	60
Km from the homestead to the nearest tarred/main road	34.866	42.654	5	20	50
Km from the homestead to the nearest feeder road	2.197	7.441	0	0	1
% HHs in dist. with income from non-farm salaried/wage employment	12.670	8.044	6.004	11.494	16.330
% HHs in dist. earning income from formal/informal business activities	45.162	14.108	36.543	42.809	51.785
% HHs in district earning income from work on others' farms	8.864	8.385	1.131	5.406	15.949
=1 if agro-ecological region I (< 800 mm rainfall)	0.075				
=1 if agro-ecological region IIa (800-1000 mm rainfall, clay soils)	0.398				
=1 if agro-ecological region IIb (800-1000 mm rainfall, sandy soils)	0.081				
=1 if agro-ecological region III (> 1000 mm rainfall)	0.446				
Number of moisture stress periods (20-day periods w/ <40 mm rainfall)	1.528	0.995	1	2	2
Growing season rainfall (t, mm)	854.398	100.840	770	854	920
Growing season rainfall (t-1, mm)	923.240	121.228	835	899	997
Growing season rainfall (t-2, mm)	946.810	83.356	880	944	1,003
Growing season rainfall (t-3, mm)	809.567	93.785	747	795	863
Long-run average # of moisture stress periods (1983/84-2009/10)	1.783	0.758	1.259	1.963	2.407
Long-run average growing season rainfall (mm, 1983/84-2009/10)	836.825	91.824	771.402	831.626	886.928
Long-run CV of growing season rainfall (%, 1983/84-2009/10)	14.370	2.781	12.033	14.070	16.372
=1 if Central Province	0.113				
=1 if Copperbelt Province	0.056				
=1 if Eastern Province	0.187				
=1 if Luapula Province	0.106				
=1 if Lusaka Province	0.031				
=1 if Muchinga Province	0.082				
=1 if Northern Province	0.121				
=1 if Northwestern Province	0.071				
=1 if Southern Province	0.131				
=1 if Western Province	0.102				

Source: Authors' calculations based on the 2012 CSO/MAL/IAPRI Rural Agricultural Livelihoods Survey.
Note: N=8,833. SEA = standard enumeration area (SEAs contain roughly 150-200 households or 2-4 villages). HH = household. CV = coefficient of variation. The growing season is November-March.

Table A.5. Econometric models used for each dependent variable

Dependent variables	Econometric model: SS panel data	Econometric model: RALS cross-sectional data
Maize kg harvested	CRE Tobit	Tobit
Total income ('000 ZMK) – gross, net, and per AE	Linear/FE	Linear/OLS
Log total income – gross, net, and per AE	Linear/FE	Linear/OLS
Crop income ('000 ZMK) – gross, net, and per AE	Linear/FE	Linear/OLS
Log crop income (non-zero crop income only) – gross, net, & per AE	Linear/FE	Linear/OLS
Other income ('000 ZMK) – gross and per AE	CRE Tobit[a]	Linear/OLS
Log other income (non-zero other income only) – gross and per AE	Linear/FE	Linear/OLS
Binary poverty – US$2/day, US$1.25/day, gross and net	CRE probit, logit	probit, logit
Poverty severity – US$2/day, US$1.25/day, gross and net	CRE fractional response logit[b]	fractional response logit[b]

Notes: CRE = correlated random effects. FE = fixed effects. OLS = ordinary least squares. [a] Tobit used due to significant number of observations with zero other income. [b] Fractional response *probit* models do not converge.