Do Input Subsidy Programs Raise Incomes and Reduce Poverty among Smallholder Farm Households? Evidence from Zambia

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Working Paper 92

February 2015

Indaba Agricultural Policy Research Institute (IAPRI)

Lusaka, Zambia

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ACKNOWLEDGEMENTS

The Indaba Agricultural Policy Research Institute is a non-profit company limited by guarantee and collaboratively works with public and private stakeholders. IAPRI exists to carry out agricultural policy research and outreach, serving the agricultural sector in Zambia so as to contribute to sustainable pro-poor agricultural development.

The authors are grateful to Antony Chapoto, Nicholas Sitko, and Saweda Liverpool-Tasie for their feedback on an earlier draft of the paper. They also wish to thank Margaret Beaver for technical assistance with the survey data used in the study and Patricia Johannes for formatting and editorial assistance.

The authors acknowledge financial support from the United States Agency for International Development Zambia Mission.

Any views expressed or remaining errors are solely the responsibility of the authors.

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EXECUTIVE SUMMARY

Many of the agricultural input subsidy programs (ISPs) currently being implemented in Sub-Saharan Africa include among their objectives raising farm incomes and reducing rural poverty. However, there is a dearth of empirical evidence on the extent to which ISPs are achieving these objectives. Moreover, results from previous studies on ISPs in Zambia and Malawi, and stubbornly high rural poverty rates in both countries despite many years of large-scale ISPs, have raised doubts that ISPs are effectively reducing poverty. For example, previous studies have shown that: (1) subsidized fertilizer is disproportionately allocated to wealthier households; (2) crowding out of commercial fertilizer purchases by ISP fertilizer and diversion and resale of fertilizer intended for ISPs before it reaches intended beneficiaries has dramatically reduced the impacts of ISPs on total fertilizer use; (3) crop yield response to ISP fertilizer has been low; (4) ISPs have only minimally reduced retail maize prices; and (5) spending on ISPs comes at the expense of other public investments that have been shown to have higher returns to agricultural growth and poverty reduction than ISPs. Nonetheless, to our knowledge, no previous studies have directly estimated the effects of fertilizer distributed through Zambia's Farmer Input Support Program (FISP) on smallholder incomes and poverty.

This paper attempts to fill that gap. We use nationally-representative panel survey data from smallholder farm households in Zambia to estimate the effects of an increase in FISP fertilizer on household incomes, poverty incidence (the probability that household income falls below the US$2 and US$1.25/capita/day poverty lines), and poverty severity (the squared percentage difference between household income and these poverty lines).

Results from our econometric analysis suggest that although FISP fertilizer raises incomes and reduces the severity of poverty, the program has no statistically significant effect on poverty incidence among smallholder farm households in Zambia. More specifically, a 200-kg increase in FISP fertilizer raises total household income by approximately 7.7% and reduces poverty severity (relative to the US$1.25/capita/day poverty line) by 3.6 percentage points, but these effects are not large enough or widely distributed enough to reduce the probability of household income falling below the poverty line.

To increase the poverty reduction impacts of FISP, government should consider: (i) removing the cooperative/farmer group membership requirement to increase participation among the poorer households; (ii) capping the area cultivated requirement for FISP participation at 2 hectares, as eligible households in the 2-5 hectare cultivated range currently capture a disproportionately large share of FISP fertilizer and many may be able to afford fertilizer at commercial prices; and (iii) recapitalizing the Food Security Pack Program as a complementary program for poverty reduction that targets the poorest of the poor. Moreover, to increase the production and income impacts of FISP, government should: (iv) prioritize timely delivery of FISP fertilizer; (v) engage and build the capacity of private sector input distribution systems; and (vi) provide extension support to farmers (and support research) on best agronomic and soil fertility management practices to promote sustainable intensification and improve crop yield response to fertilizer. Since rural poverty reduction is a priority and FISP has not proven to be an effective poverty reduction program, the government should consider more cost-effective approaches to poverty reduction such as social cash-transfer programs and increasing investments in rural infrastructure, agricultural research and development, health, and education.

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ACRONYMS AND ABBREVIATIONS

2SLS	two-stage least squares
AE	adult equivalent
APE	average partial effect
CFA	control function approach
CPI	Consumer Price Index
CRE	correlated random effects
CSO	Central Statistical Office
CV	coefficient of variation
FE	fixed effects
FGT	Foster-Greer-Thorbecke
FISP	Farmer Input Support Program
FRA	Food Reserve Agency
FSRP	Food Security Research Project
ha	hectare
HH	household
IAPRI	Indaba Agricultural Policy Research Institute
ISP	input subsidy program
IV	instrumental variable
kg	kilogram
LCMS	Living Conditions Monitoring Survey
MACO	Ministry of Agriculture and Cooperatives
MAL	Ministry of Agriculture and Livestock
mm	millimeter
MT	metric tons
pp	percentage points
PPP	Purchasing Power Parity
RALS	Rural Agricultural Livelihoods Survey
SEA	standard enumeration area
SS	Supplemental Survey
SSA	Sub-Saharan Africa
SVS	seed voucher system
TAMSAT	Tropical Applications of Meteorology Satellite
ZMK	Zambian Kwacha

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 and Rashid 2013; Lunduka, Ricker-Gilbert, and Fisher 2013; Mason, Jayne, and Mofya-Mukuka 2013). Although there is a growing body of empirical evidence on the effects of ISPs in SSA on the first two objectives (increasing access to inputs, crop yields, and production), much less is known about the effects of the programs on the latter two objectives (improving food security and incomes, and reducing poverty).[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, yields, and production but this may not be sufficient to improve their economic well-being and food security. Indeed, 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 the countries' rural poverty rates remain essentially unchanged despite the ISPs having been in place for many years (Jayne et al. 2011; Lunduka, Ricker-Gilbert, and Fisher 2013; Mason, Jayne, and Mofya-Mukuka 2013). However, 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 remained close to 80% for more than a decade in spite of continuous and expanding government subsidies for hybrid maize seed and inorganic fertilizer through the Farmer Input Support Program (FISP) (see Figure 1; CSO 2009 2011; Jayne et al. 2011; Mason, Jayne, and Mofya-Mukuka 2013).[2] In recent years, FISP has accounted for approximately 50% of the Zambian government's spending on agricultural sector Poverty Reduction Programs, and increasing smallholder incomes is an explicit objective of FISP (MAL various years). Yet, little is known about the effects of the program on smallholder incomes and poverty. The goal of this paper is to explicitly consider the counterfactual and estimate the causal effects of FISP subsidized fertilizer on incomes and poverty among smallholder farm households in Zambia.[3] This is achieved through the use of nationally representative panel survey data from smallholder households and econometric methods to hold constant other factors that affect poverty and incomes. We consider the impacts of an increase in FISP fertilizer received on smallholders' total household income, and decompose the total effect into effects on crop income versus other (non-crop) income. We also consider the impacts of FISP on poverty incidence (the probability that total household income falls below the US$1.25 and US$2 per day poverty lines) and poverty severity (the squared percentage difference between household income and these poverty lines). The study adds to the thin evidence base (for Zambia and SSA more broadly) on the impacts of ISPs on the economic well-being of smallholder farmers.

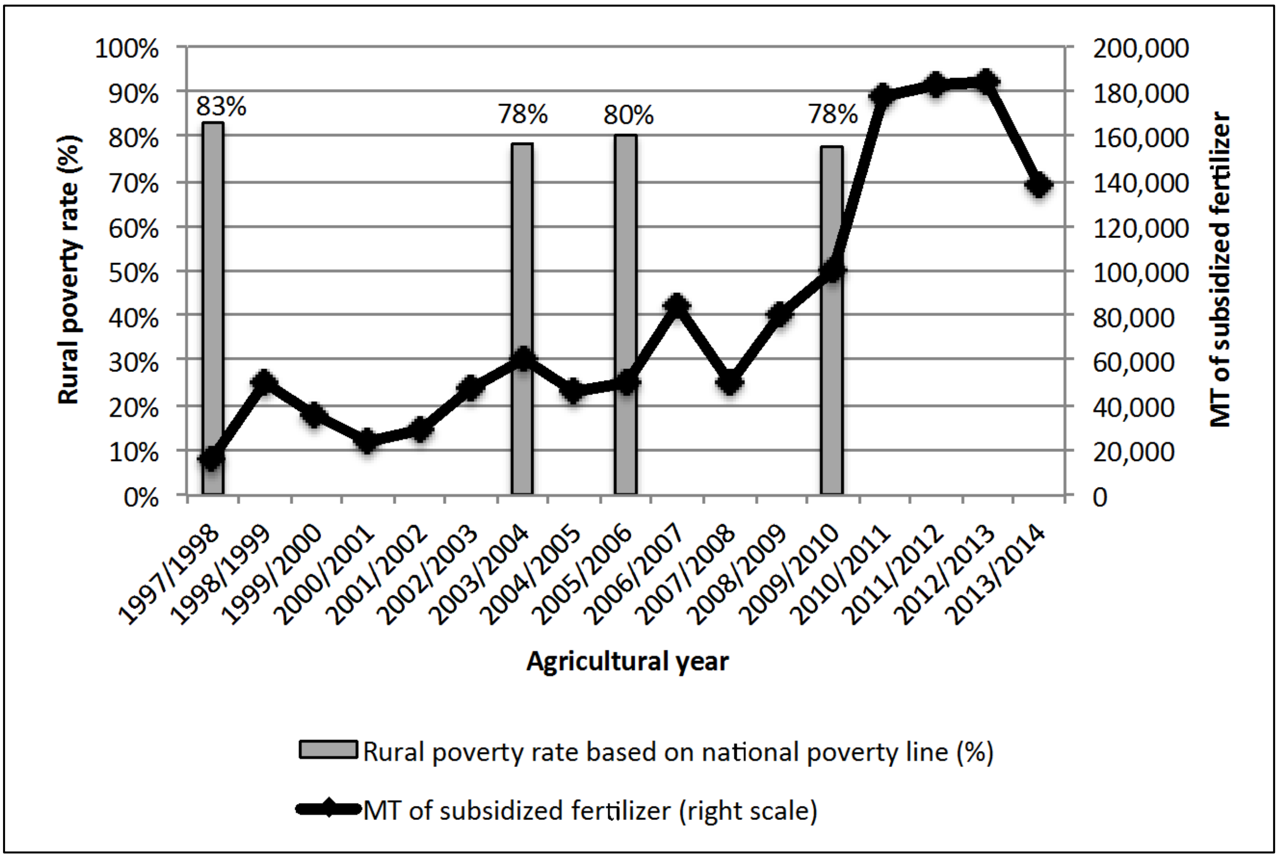
As a preview of our results, we find that FISP fertilizer raises smallholder households' total incomes through its effects on their crop incomes (there are no spillover effects on other,

[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 program was called the Fertilizer Support Program from its establishment in 2002/03 through 2008/09, then renamed the Farmer Input Support Program in 2009/10. Throughout the paper, we use FISP to refer to both of these programs, the details of which are described in section 4.
[3] Subsequent work will investigate the impacts of the program on food security.

non-crop income), and reduces poverty severity. However, FISP fertilizer has no statistically significant effect on poverty incidence; that is, the income effects of the program are not large enough or widely distributed enough to reduce households' probability of falling below the poverty line.

The remainder of the paper is organized is follows. Section 2 situates this study in the context of previous work on the impacts of ISPs on incomes and poverty in SSA. Section 3 describes the data used in the analysis. Section 4 provides an overview of FISP and the activities of the Food Reserve Agency (FRA), Zambia's strategic grain reserve/maize marketing board.[4] Sections 5, 6, and 7 present the methodology, results, and conclusions and policy implications, respectively.

Figure 1. Trends in the Official Rural Poverty Rate and the Quantity of Subsidized Fertilizer Distributed Through Government Programs, 1997/98-0213/14 Agricultural Years



Sources: CSO (2009, 2011); MACO (various years); MAL (various years).
Notes: 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 metric tons (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.

[4] In order to isolate the effects of FISP on incomes and poverty, we have to control for the effects of the FRA, Zambia's other major agricultural sector poverty reduction program.

2. PREVIOUS STUDIES ON ISP IMPACTS ON POVERTY AND INCOMES IN SSA

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 the *fertilizer* component of FISP on smallholder incomes and poverty in Zambia. Mason and Smale (2013) estimate the effects of the *seed* subsidy component of FISP on these outcomes but do not consider the fertilizer component of the program. They find that an additional 10 kilograms (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, Jayne, and Mofya-Mukuka (2013) present descriptive statistics showing that FISP fertilizer goes disproportionately to households that cultivate more land and are less likely to fall below the US$1.25 per day poverty line. Although this is expected to reduce FISP's effects on poverty, such descriptive statistics do not tell us the *causal* effects of FISP. In order to rigorously evaluate the impacts of FISP on poverty and incomes, we need to hold other factors constant as we do in the current paper.

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. (See Lunduka, Ricker-Gilbert, and Fisher (2013) for an overview of Malawi's ISP, which provides 100 kg of inorganic fertilizer, 2-5 kg of improved maize seed, and other inputs to farmers at subsidized prices.) Early estimates from Chirwa (2010) suggest that receipt of coupons for 100 kg of subsidized fertilizer increases Malawian beneficiary households' annual per capita expenditures by US$11.19 (8.2%). 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) 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 it has no statistically significant effect at the 10th percentile. Lunduka, Ricker-Gilbert, and Fisher (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 [Malawi Farm Input Subsidy Program] has made any substantive contribution toward reducing poverty", and "call for a rigorous investigation that directly measures the causal impacts of the [Malawi Farm Input Subsidy 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 using 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. The study does not, however, attempt to quantify the contribution of Malawi's ISP to this decline in rural poverty rates.

Although not focused directly on the income and poverty effects of ISPs, Jayne et al. (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 0.58 kg in Zambia, 0.55 kg in Malawi, and 0.57 kg or less in Kenya. These less than one-to-one effects are due to displacement or '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), and the maize production impacts of *subsidized* inorganic fertilizer are even lower (e.g., current year impacts are only about 2 kg of maize per kg of subsidized fertilizer in Zambia and Malawi) (Mason, Jayne, and Mofya-Mukuka 2013; Lunduka, Ricker-Gilbert, and Fisher 2013).[5] The effects of fertilizer subsidies on retail maize prices in Malawi and Zambia (Ricker-Gilbert et al. 2013), and on wage rates in Malawi (Ricker-Gilbert 2014) have also been very small, indicating that the spillover effects of the programs on non-beneficiary households are likely to be minimal. Together, these results suggest that the impacts of fertilizer subsidies on rural poverty are likely to be muted in Zambia, Malawi, and Kenya because: (i) the subsidized fertilizer goes disproportionately to better off households, and not the poor; (ii) it raises total fertilizer use by much less than 1 kg per kg distributed through the ISP due to crowding out and diversion; (iii) the impacts on maize production and yields are small; and (iv) there is little evidence of spillover effects through impacts on maize prices or wages.

Outside of Zambia, Malawi, and Kenya, Awotide et al. (2013) evaluate a certified improved rice seed voucher system (SVS) in Nigeria 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, and lead to erroneous conclusions and policy implications.

In summary, the evidence base on the impacts of ISPs in SSA on smallholder poverty and incomes is thin. Most previous studies have focused on the case of Malawi and have not controlled for the potentially confounding effects of grain marketing board / strategic grain reserve activities. The few existing studies for Zambia present only descriptive results of the relationship between FISP and poverty/incomes, or consider only the seed subsidy component of FISP. Finally, earlier results from Zambia on the targeting of FISP fertilizer, and its effects on total fertilizer use and maize production suggest that the program's impacts on incomes and poverty are likely to be small.[6]

[5] We briefly discuss some of the reasons for the disappointing production impacts of ISPs in the policy implications section of the paper. See Mason, Jayne, and Mofya-Mukuka (2013) for a more detailed discussion.
[6] For a comprehensive review of the empirical evidence through mid-2013 on the targeting and impacts of Zambia's FISP, see Mason, Jayne, and Mofya-Mukuka (2013). See Lunduka, Ricker-Gilbert, and Fisher (2013) for a similar review for Malawi.

3. DATA

The data used in this paper come mainly from the Supplemental Survey (SS), a three-wave, nationally-representative survey of smallholder farm households in Zambia conducted in June/July of 2001, 2004, and 2008.[7] These data cover the 1999/2000, 2002/03, and 2006/07 (October-September) agricultural years, and the subsequent (May-April) crop marketing years. We also draw on data from the Rural Agricultural Livelihoods Survey (RALS), a nationally-representative cross-sectional survey that covers the 2010/11 agricultural year and the 2011/12 crop marketing year.[8] The Zambia Central Statistical Office (CSO), the Ministry of Agriculture and Livestock (MAL, formerly the Ministry of Agriculture and Cooperatives (MACO)), and the Food Security Research Project (now the Indaba Agricultural Policy Research Institute) jointly carried out these surveys. See Megill (2005) for details on the sampling design of the SS. 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.[9] Given household attrition between rounds of the SS, attrition bias is a potential concern. However, regression-based tests per Wooldridge (2010) 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.

Other data used in the analysis are: lagged crop prices from the 1998/99, 2001/02, and 2005/06 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, and Bonifacio 1999; Milford and Dugdale 1990); constituency-level results from the 1996, 2001, and 2006 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).

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

[8] We use the SS panel data for the econometric and descriptive analysis but the RALS cross-sectional data only for descriptive analysis. This is because the RALS is a cross-sectional survey and thus we cannot adequately control for time constant unobserved factors when analyzing these data. See Mason, Jayne, and Mofya-Mukuka (2013) and IAPRI (2012) for details on the RALS.

[9] 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), zero gross income responses are not valid.

4. 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, Jayne, and Mofya-Mukuka 2013; Mason, Jayne, and Myers 2014), we focus here on the features of the programs that are most relevant to the current study. FISP 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).

4.1. 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 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, and was not a voucher-based ISP. That is, participants did not receive vouchers (coupons) to redeem for subsidized inputs at private sector agrodealers' and stockists' shops. Rather, the Zambian government contracted a small number of private sector firms to import and transport the inputs to participating farmer cooperatives. Participating farmers then collected the inputs from their cooperative. Approximately 9% and 11% of Zambian smallholder households received subsidized fertilizer through the Fertilizer Support Program in 2002/03 and 2006/07, respectively (Mason, Jayne, and Mofya-Mukuka 2013).

Although in theory all Fertilizer Support Program beneficiaries were to 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, Jayne, and Mofya-Mukuka 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, Jayne, and Mofya-Mukuka 2013).

According to the former 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). See Mason, Jayne, and Mofya-Mukuka (2013) for further details on the Fertilizer Support Program.

4.2. 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 FISP 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 FISP to reach more households than its predecessor. For example, in 2010/11 (the agricultural year captured in the RALS), approximately 30% of Zambian smallholders received subsidized fertilizer through the FISP. 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's input distribution system, 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, Jayne, and Mofya-Mukuka (2013) for further details on the FISP.

4.3. 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, Jayne, and Myers 2014).[10] 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 (the marketing years captured in the 2004 SS, 2008 SS, and 2012 RALS) (Mason, Jayne, and Myers 2014; CSO/MAL/IAPRI 2012). 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, Jayne, and Myers (2014) for further details on the Food Reserve Agency.

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[10] 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, Jayne, and Myers 2014).

5. 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 causal effects of subsidized fertilizer on these indicators of economic well-being.

5.1. Income and Poverty Measures Analyzed

Our main research question is do fertilizer subsidies raise incomes and reduce poverty among smallholder farm households in Zambia? We consider several measures of income and poverty. The income measures include total, crop, and other (non-crop) income net of fertilizer costs at the household level and in per adult equivalent household member terms.[11] 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 by the household from commercial retailers multiplied by the market fertilizer price paid. Crop income is defined as the gross value of crop production minus fertilizer costs. Total income is 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. Other income is total income minus crop income. 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).

The poverty measures considered are the Foster-Greer-Thorbecke (FGT) poverty incidence (a binary variable equal to one if total household income falls below the poverty line, and equal to zero otherwise), and FGT poverty severity (equal to the squared percentage difference between total household income and the poverty line if total household income falls below the poverty line, and equal to zero otherwise) (Foster, Greer, and Thorbecke 1984). Poverty incidence and severity are computed for the US$2/capita/day poverty line and the US$1.25/capita/day extreme poverty line.[12] We follow US Agency for International Development Feed the Future Indicators guidelines and convert household income from Zambian Kwacha to US$ based on the 2005 PPP conversion factor for private consumption, adjusted for inflation using the CPI.[13] 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. Summary statistics for maize kg harvested and all of the income and poverty measures are reported in Table 1 below.

[11] The surveys did not collect data on other crop input costs.

[12] 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.

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

Table 1. Summary Statistics: Dependent and Related Variables (2003/04 and 2007/08 Marketing Years)

Dependent & related variables	Mean	Std. dev.	Percentile 25th	50th	75th
=1 if HH harvested maize	0.823				
Kg of maize harvested	1,259	2,897	173	575	1,380
=1 if HH had crop income	0.973				
=1 if HH had other (non-crop) income	0.876				
Total income ('000 ZMK)	7,052	29,841	1,427	2,892	6,210
Crop income ('000 ZMK)	2,355	3,994	647	1,459	2,754
Other (non-crop) income ('000 ZMK)	4,697	29,190	120	717	3,066
Total income/AE ('000 ZMK)	1,448	4,206	329	665	1,382
Crop income/AE ('000 ZMK)	540	905	145	315	628
Other (non-crop) income/AE ('000 ZMK)	909	4,045	28	170	662
Poverty incidence (US$2/day)	0.956				
Poverty gap (US$2/day)	0.771	0.250	0.717	0.865	0.934
Poverty severity (US$2/day)	0.657	0.281	0.515	0.749	0.873
Extreme poverty incidence (US$1.25/day)	0.907				
Extreme poverty gap (US$1.25/day)	0.672	0.299	0.548	0.785	0.895
Extreme poverty severity (US$1.25/day)	0.541	0.309	0.300	0.616	0.801

Sources: Authors' calculations based on the 2004 and 2008 CSO/MACO/FSRP Supplemental Surveys.
Notes: N=8,522. HH=Household. All Zambian Kwacha (ZMK) values are in real 2011/12 terms. AE = full-time adult equivalent. Poverty incidence =1 if total household income/capita/day is below the poverty line, and =0 otherwise.

5.2. Conceptual Framework

Our conceptual framework is grounded in the work of Otsuka, Cordova, and David (1992), 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 ($\boldsymbol{z}$):

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

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 FISP (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, poverty, and maize kg harvested outcomes variables described in section 5.1.

5.3. Empirical Models

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

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

where *i* indexes the household and *t* indexes the year; c_i captures time-constant unobserved effects; $u_{i,t}$ 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 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 parameter that we seek to estimate in this study is 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, ***w*** includes an agricultural wage rate and the market price of inorganic fertilizer. (Seed prices were not captured in the SS data.) ***p*** includes lagged producer prices for maize, mixed beans, groundnuts, and sweet potatoes, the most common crops marketed by smallholders for which spatially-varying prices are available. ***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). ***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. ***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 Table 2 for details); agro-ecological region dummies; provincial dummies; a year dummy equal to one for the 2008 SS, and zero otherwise; and provincial dummy-year dummy interaction terms.[14]

Note that *FISP* is the kg of subsidized fertilizer acquired during the 2002/03 or 2006/07 agricultural year, 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 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 Table 2 for summary statistics for the explanatory variables.

[14] There were 72 districts and nine provinces in Zambia during the SS years.

Table 2. Summary Statistics: Explanatory Variables (2003/04 and 2007/08 Marketing Years)

Explanatory variables	Mean	Std. dev.	Percentile 25th	Percentile 50th	Percentile 75th
=1 if HH acquired FISP fertilizer	0.101				
Kg of FISP fertilizer acquired	33.353	155.982	0	0	0
District-level FRA maize purchases (t-1, kg/agricultural 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	0.746	0.935	0	0	1
Number of children age 5 to 14	2.013	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	50.519	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 avg. # of moisture stress periods (16-year moving avg.)	1.998	0.789	1.500	2.188	2.563
Long-run avg. growing season rainfall (mm, 16-year moving avg.)	820	93.437	768	815	866
Long-run CV of growing season rainfall (%, 16-year moving avg.)	15.074	3.347	12.433	14.803	17.434
=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				

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

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. 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).

5.4. Estimation and Identification Strategy

Although linear fixed effects (FE) models were the starting point for estimation of equation (2) for all dependent variables, we also estimate Tobit models for other (non-crop) income, which is equal to zero for roughly 12% of the SS sample, creating a pile-up of observations at zero. Poverty incidence is a binary variable and poverty severity is a proportion bound between zero and one, so we ultimately use binary response models (probit or logit) and fractional response models, respectively, for these dependent variables (Papke and Wooldridge 1996, 2008). The results are robust to our choice of estimator. Unobserved time invariant heterogeneity that may be correlated with the observed explanatory variables is controlled for in these nonlinear-in-parameters models (Tobit, probit, logit, and fractional response) using the correlated random effects (CRE) approach (also known as the Mundlak-Chamberlain device) (Mundlak 1978; Chamberlain 1984; Wooldridge 2010).

Even after controlling for time invariant heterogeneity via FE or CRE, concerns remain over the potential endogeneity of *FISP* in equation (2). Subsidized fertilizer distributed through FISP 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, Jayne, and Mofya-Mukuka 2013). Bivariate statistics also confirm that FISP recipients have systematically higher incomes and lower poverty rates than non-recipients. Thus, the *FISP* variable may be endogenous in equation (2), 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).

We test and control for the potential endogeneity of *FISP* in equation (2) using the control function approach (CFA). We prefer the CFA to the instrumental variables (IV) or two-stage least squares approaches (2SLS) here because several of our dependent variables are discontinuous, our potentially endogenous explanatory variable, *FISP*, is a corner solution (i.e., many households receive zero kg of FISP fertilizer), and we use both linear- and nonlinear-in-parameters models. 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 and Ricker-Gilbert 2013; Mason and Jayne 2013; Mason, Jayne, and Myers 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).[15]

Table A1 in the Appendix shows that 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. Holding other factors constant, households in constituencies won by the ruling party in the last election receive an average of 18.8 kg more FISP fertilizer than households in constituencies lost by the ruling party (p-value = 0.001). Moreover, 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 more FISP fertilizer (p-value = 0.024).[16] 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 time-invariant unobserved effects via FE or CRE. Tests for over-identifying restrictions generally support the validity of the IVs.

[15] Applying the CFA entails estimating a CRE 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).

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

6. RESULTS

In this section, we begin by discussing trends in rural and smallholder poverty rates vis-à-vis FISP. We 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 smallholder 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.

6.1. Descriptive Results

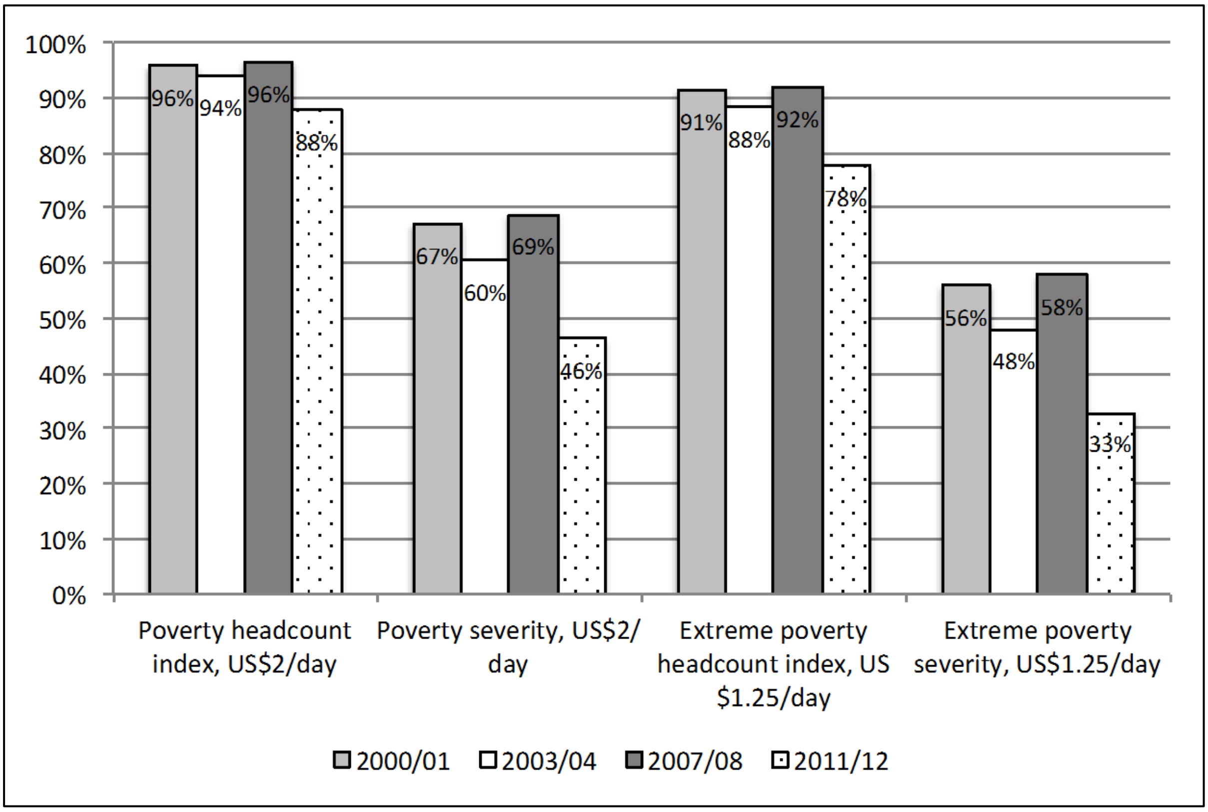
As noted earlier, the official rural poverty rate in Zambia changed little between 1998 and 2010 despite sustained government subsidies for inorganic fertilizer and hybrid maize seed (Figure 1). Between 2006 and 2010, for example, the scale of FISP doubled from 50,000 MT of subsidized fertilizer to 100,000 MT but the rural poverty rate dropped by only two percentage points (from 80% in 2006 to 78% in 2010). The scale of FISP has been even larger since 2010 (Figure 1). A Living Conditions Monitoring Survey (LCMS) was conducted 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 only smallholder farm households based on the SS and RALS data. Note that these poverty measures are based on total household income (not consumption expenditure) and 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.

The poverty rates in Figure 2 are therefore not directly comparable to the LCMS-based poverty rates in Figure 1. There are, however, some similar 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 FISP. Smallholder poverty rates are significantly lower in 2011/12 than in previous years, though still very high in absolute terms (Figure 2). In general, the *prima facie* evidence seems to suggest that FISP 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. (Again, we need to consider the counterfactual.) Smallholder poverty rates dropped significantly between 2007/08 and 2011/12. This decline may have been driven by FISP or other factors.

These results beg the question, to what extent are poor smallholder households participating in FISP? Table 3 disaggregates households into quintiles based on total 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 (Table 3, section C).

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: 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.

In the 2002/03 and 2006/07 agricultural years, for example, fewer 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 (Table 3, 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 of Table 3 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 limited FISP impacts on poverty would not be surprising. Although not strictly enforced (Mason, Jayne, and Mofya-Mukuka 2013), Burke, Jayne, and Sitko (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.

Table 3. Distribution of FISP Fertilizer among Smallholder Households by Total Income per Adult Equivalent Quintiles, 2002/03, 2006/07, and 2010/11 Agricultural Years (2003/04, 2007/08, and 2011/12 Marketing Years)

		Total income per adult equivalent quintile					
Extreme poverty or FISP fertilizer receipt	**Agricultural year (Crop marketing year)**	**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 (columns sum to 100%)	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 (within the quintile)	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 received (columns sum to 100%)	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 and 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. Comparisons of Mean Values of Income and Poverty Outcomes between FISP Recipient and Non-recipient Households (Based on SS Data for 2003/04 and 2007/08 Marketing Years)

Outcome variables	All HHs	Received FISP fertilizer? Yes	No	Difference (Yes – No)	p-value
Maize kg harvested	1,259	3,381	1,021	2,360	0.000
Total income ('000 ZMK)	7,052	12,841	6,404	6,437	0.000
Crop income ('000 ZMK)	2,355	4,539	2,110	2,428	0.000
Other (non-crop) income ('000 ZMK)	4,697	8,302	4,293	4,009	0.000
Total income/AE ('000 ZMK)	1,448	2,432	1,338	1,094	0.000
Crop income/AE ('000 ZMK)	540	868	503	365	0.000
Other (non-crop) income/AE ('000 ZMK)	909	1,564	835	729	0.000
Poverty incidence (US$2/day)	0.956	0.896	0.963	-0.067	0.000
Poverty gap (US$2/day)	0.771	0.651	0.784	-0.133	0.000
Poverty severity (US$2/day)	0.657	0.518	0.672	-0.154	0.000
Extreme poverty incidence (US$1.25/day)	0.907	0.807	0.919	-0.112	0.000
Extreme poverty gap (US$1.25/day)	0.672	0.529	0.688	-0.159	0.000
Extreme poverty severity (US$1.25/day)	0.541	0.390	0.558	-0.168	0.000

Sources: Authors' calculations based on the 2004 and 2008 CSO/MACO/FSRP Supplemental Surveys.
Notes: AE = full-time adult equivalent. Poverty incidence =1 if total household income/capita/day is below the poverty line, and =0 otherwise. All ZMK values are in 2011/12 terms. 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.

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 4. 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. 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.

6.2. Econometric Results

The econometric results are summarized in Table 5 and suggest modest impacts of FISP fertilizer on smallholder incomes, but negligible effects on poverty.[17] At 2.00 kg, our estimate of the average partial effect (APE) of a 1-kg increase in FISP fertilizer on

[17] The full regression results for eight of the 21 regressions summarized in Table 5 are presented in Tables A2 and A3 in the Appendix. (The included results are for total income, crop income, total income/AE, and crop income/AE, in both levels and logs.) The full regression results for the other 13 regressions in Table 5 are excluded due to space considerations 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).

households' maize quantity harvested is very similar to Mason, Jayne, and Mofya-Mukuka's (2013) estimate of 1.88 kg/kg.[18] We find evidence of statistically significant, positive effects of FISP fertilizer on total income and crop income (per household and per adult equivalent household member) but not on other income. That is, 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, a 200-kg increase in FISP fertilizer raises real total household income by K1,140,000 (US$233) or 7.7%, on average, other factors constant (Table 5, rows B and C).[19] As a second example, an additional 200 kg of FISP fertilizer raises total income per adult equivalent by K223,800 (US$46) or 6.9% (Table 5, rows I and J).

Although FISP fertilizer impacts on incomes are fairly large in *percentage* terms, they are not very large in *absolute* terms, and they do not translate into substantial reductions in poverty. Rather, the results suggest that FISP fertilizer has no statistically significant effect on smallholders' probability of falling below the US$2/day poverty line or US$1.25/day extreme poverty line (Table 5, rows P, Q, S, and T). FISP fertilizer does reduce the *severity* of poverty and extreme poverty but the effects are relatively small in magnitude (Table 5, rows R and U). On average, receiving 200 kg more subsidized fertilizer reduces poverty severity by 2.7 percentage points and extreme poverty severity by 3.6 percentage points. These are quite small declines relative to the high rates of poverty severity (median of 74.9%) and extreme poverty severity (median of 61.6%) in in our sample.

These disappointingly small effects on poverty are likely due in large part to the fact that relatively little FISP fertilizer reaches the poorest households (Table 3). Moreover, at just US$46 per adult equivalent per year (less than $0.13 per adult equivalent per day), the income-raising effects of 200 kg of FISP fertilizer are not large enough to lift many poor smallholders' incomes above the US$1.25 or US$2 per day poverty lines.

[18] Mason, Jayne, and Mofya-Mukuka's (2013) 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.

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

Table 5. Summary of Econometric Results: Average Partial Effects (APEs) of a 1-kg Increase in FISP Fertilizer on Smallholder Maize Production, Incomes, and Poverty

	Dependent variable (econometric model)	APE	Sig.	p-value	FISP fertilizer endo-genous?[a]	Tobit residuals p-value[b]	Estimated Δ per 200 kg FISP fertilizer (stat. sig. only)
(A)	Maize kg harvested (CRE Tobit)	2.004	***	0.000	No	0.433	400.8 kg
(B)	Total income, '000 ZMK (Linear/FE)	5.700	+	0.127	No	0.207	K1,140,000
(C)	Log total income (Linear/FE)	0.000387	***	0.000	No	0.549	7.74%
(D)	Crop income, '000 ZMK (Linear/FE)	3.310	***	0.004	No	0.186	K662,000
(E)	Log crop income (Linear/FE)	0.000506	***	0.000	No	0.398	10.12%
(F)	Other (non-crop) income, '000 ZMK (Linear/FE)	2.382		0.463	No	0.231	
(G)	Other (non-crop) income, '000 ZMK (CRE Tobit)	1.097		0.540	No	0.812	
(H)	Log other (non-crop) income (Linear/FE)	0.0000892		0.577	No	0.773	
(I)	Total income/AE, '000 ZMK (Linear/FE)	1.119	*	0.065	No	0.571	K223,800
(J)	Log total income/AE (Linear/FE)	0.000347	***	0.005	No	0.617	6.94%
(K)	Crop income/AE, '000 ZMK (Linear/FE)	0.571	***	0.003	No	0.884	K114,200
(L)	Log crop income/AE, (Linear/FE)	0.000476	***	0.000	No	0.320	9.52%
(M)	Other (non-crop) income/AE, '000 ZMK (Linear/FE)	0.545		0.313	No	0.513	
(N)	Other (non-crop) income/AE, '000 ZMK (CRE Tobit)	0.275		0.370	No	0.956	
(O)	Log other (non-crop) income/AE (Linear/FE)	0.0000502		0.756	No	0.723	
(P)	Poverty incidence, US$2/day (CRE probit)	-1.33E-06		0.920	Yes	0.023	
(Q)	Poverty incidence, US$2/day (CRE logit)	2.67E-07		0.988	Yes	0.031	
(R)	Poverty severity, US$2/day (CRE fractional response)	-0.000135	***	0.000	No	0.117	-2.70 pp
(S)	Extreme poverty incidence, US$1.25/day (CRE probit)	-0.0000112		0.591	Yes	0.002	
(T)	Extreme poverty incidence, US$1.25/day (CRE logit)	-7.13E-06		0.804	Yes	0.004	
(U)	Extreme poverty severity, US$1.25/day (CRE fractional response)	-0.000181	***	0.000	No	0.179	-3.62 pp

Source: Authors' calculations. Notes: CRE=correlated random effects. FE=fixed effects. AE=full-time adult equivalent. Poverty incidence =1 if total household income/capita/day is below the poverty line, and =0 otherwise. 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. Fractional response results reported are for logit specifications. Fractional response probits did not converge. [a]That is, do we reject the null hypothesis that FISP fertilizer is exogenous in favor of the alternative that it is endogenous? [b]p-value associated with a t-test of the null hypothesis that FISP fertilizer is exogenous against the alternative that it is endogenous.

7. 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 among smallholder farmers in Zambia? Using data from a nationally-representative panel survey of smallholder households, we estimate the average partial effects of increases in subsidized fertilizer acquired through Zambia's Farmer Input Support Program on numerous indicators of economic well-being. The results suggest that while FISP fertilizer raises smallholder incomes (by raising maize production and crop incomes) and reduces the severity of poverty (the squared percentage difference between household income and the poverty line), it has no statistically significant effect on poverty incidence (the probability that household income falls below the poverty line). More specifically, a 200-kg increase in FISP fertilizer (the current input pack size) raises total household income net of fertilizer costs by approximately K1,140,000 (un-rebased, US$233) or 7.7%, and raises household income per adult equivalent by roughly K223,800 (US$46) or 6.9%. A 200-kg increase in FISP fertilizer only reduces the severity of poverty (relative to the US$2/day poverty line) by 2.7 percentage points, and the severity of extreme poverty (relative to the US$1.25/day poverty line) by 3.6 percentage points. These are relatively small reductions given the median poverty severity and extreme poverty severity levels of 75% and 62%, 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. While the income effects of FISP fertilizer appear to be sizeable in *percentage* terms, the increases are modest in *absolute* terms – e.g., an increase of US$46 per adult equivalent *per year* is less than US$0.13 per adult equivalent *per day* – only a fraction of the US$2/day and US$1.25/day poverty lines. Another major explanation for lack of impact on FISP on poverty incidence among smallholders and the small impacts of FISP on poverty severity is that very little FISP fertilizer is allocated to 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, Jayne, and Mofya-Mukuka 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, Jayne, and Sitko 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, Jayne, and Mofya-Mukuka 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 per-kg 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, Jayne, and Mofya-Mukuka 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 by program implementers, this should increase the impacts of the program on total fertilizer use and maize production; it would also put greater downward pressure on market prices for maize to the benefit of poor maize net buyers (Ricker-Gilbert, Jayne, and Chirwa 2011; Mason and 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, Jayne, and Mofya-Mukuka 2013).

Finally, approximately 50% of Zambia's agricultural sector Poverty Reduction Program funds are spent on FISP each year, 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, and Thorat 2008; EIU 2008).

APPENDIX

Table A1. Reduced Form Tobit Regressions for the KG of FISP Fertilizer Received

Explanatory variables	APE	Sig.	p-value
IV: =1 if ruling party won constituency in last election	18.760	***	0.001
IV: | %-pt. spread b/w ruling party & lead opposition |	0.0592		0.650
IV: Interaction effect – ruling party won × %-pt. spread	0.451	**	0.024
District-level FRA maize purchases (t-1, kg/ag HH)	0.00879		0.140
Farmgate FRA maize price (t-1, ZMK/kg)	4.866		0.756
Maize producer price (t-1, ZMK/kg)	6.365		0.714
Groundnut producer price (t-1, ZMK/kg)	-352.552	***	0.002
Mixed beans producer price (t-1, ZMK/kg)	161.368	***	0.004
Sweet potato producer price (t-1, ZMK/kg)	146.305	***	0.000
Inorganic fertilizer price (ZMK/kg)	14.952		0.409
Weeding wage per 0.25 ha (ZMK)	0.922		0.861
Landholding size (ha)	1.046		0.395
Value of farm equipment ('000 ZMK)	-0.000755		0.745
Value of livestock ('000 ZMK)	0.000494		0.181
Number of children age 4 and under	-2.549		0.110
Number of children age 5 to 14	-0.458		0.766
Number of prime age adults (age 15 to 59)	0.00450		0.997
Number of adults age 60 and above	1.271		0.750
Age of the HH head	0.487	*	0.072
=1 if female-headed HH	-3.096		0.656
Highest level of education completed by the HH head (no formal education is base):			
=1 if some lower primary education (grades 1-4)	-6.163		0.338
=1 if some upper primary education (grades 5-7)	-4.033		0.622
=1 if some secondary education (grades 8-12)	4.928		0.609
=1 if some post-secondary education	-11.646		0.223
Km to the nearest district town	0.0693		0.618
Km to the nearest tarred/main road	-0.205	***	0.001
Km to the nearest feeder road	-2.397	***	0.004
% of HHs in district with income from:			
Non-farm salaried/wage employment	-0.349		0.344
Formal/informal business activities	0.216		0.389
Work on others' farms	-0.123		0.607
Moisture stress (# of 20-day periods w/ <40 mm rain)	-11.136	***	0.000
Growing season rainfall (t, mm)	-0.135	***	0.002
Growing season rainfall (t-1, mm)	-0.0430		0.272
Growing season rainfall (t-2, mm)	0.00029		0.994
Growing season rainfall (t-3, mm)	0.0910	*	0.096
Long-run average number of moisture stress periods	-36.517	*	0.052
Long-run average growing season rainfall (mm)	-1.267	***	0.007
Long-run CV of growing season rainfall (%)	11.600	***	0.001
Agro-ecological regions dummies?	Yes		
Provincial dummies?	Yes		
2006/07 agricultural year dummy?	Yes		
2006/07 agricultural year dummy × provincial dummies?	Yes		
Overall model F-statistic	4.22	***	0.000
Observations	8,522		

Source: Authors' calculations.

Notes: APE = Average Partial Effect. 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 A2. Fixed Effects Regression Results: Total and Crop Income (Levels and Logs)

Dependent variable:	Total income ('000 ZMK)			Crop income ('000 ZMK)			Log total income			Log crop income		
Explanatory variables	Coef.	Sig.	p-val.	Coef.	Sig.	p-val.	Coef.	Sig.	p-val.	Coef.	Sig.	p-val.
Kg of FSP fertilizer acquired	5.700		0.127	0.000387	***	0.000	3.310	***	0.004	0.000506	***	0.000
District-level FRA maize purchases (t-1, kg/ag HH)	-0.324		0.877	-0.000119		0.131	-0.145		0.592	-0.0000819		0.235
Log farmgate FRA maize price (t-1, 2011/12=100)	-6,283.140		0.312	0.0636		0.688	335.636		0.317	0.0819		0.538
Log maize producer price (t-1, 2011/12=100)	4,014.459		0.408	0.0378		0.785	743.701	**	0.039	0.126		0.341
Log groundnut producer price (t-1, 2011/12=100)						*Dropped due to collinearity*						
Log mixed beans producer price (t-1, 2011/12=100)						*Dropped due to collinearity*						
Log sweet potato producer price (t-1, 2011/12=100)	-10,507.700	***	0.008	-0.351	*	0.076	-500.887		0.295	-0.174		0.293
Log inorganic fertilizer price (2011/12=100)	-2,262.030		0.504	-0.162		0.368	633.987		0.373	-0.369	*	0.065
Log maize weeding wage (2011/12=100)	-4,376.120		0.233	0.105		0.135	233.732		0.320	-0.0172		0.780
Landholding size (ha, cultivated + fallow land)	1,056.533	***	0.000	0.115	***	0.000	596.219	***	0.000	0.157	***	0.000
Landholding size, squared	-9.592	*	0.065	-0.00150	***	0.000	-3.564	**	0.012	-0.00208	***	0.002
Value of farm equipment ('000 ZMK, 2011/12=100)	3.004		0.191	0.0000792	***	0.004	0.343	**	0.026	0.0000893	***	0.000
Value of farm equipment, squared				-2.85E-09	**	0.025	2.99E-06		0.770	-2.57E-09	***	0.003
Value of livestock ('000 ZMK, 2011/12=100)	-0.0914		0.680	0.0000188	***	0.000	0.0343	***	0.002	5.94E-06	***	0.005
Value of livestock, squared				-1.80E-11	***	0.000	-3.17E-08	***	0.005	-7.34E-12	***	0.001
Number of children age 4 and under	225.889		0.714	-0.00585		0.781	-15.191		0.822	-0.0193		0.249
Number of children age 5 to 14	441.494		0.126	0.0454	***	0.002	27.565		0.642	0.00852		0.519
Number of FTE prime age adults (age 15 to 59)	366.440		0.223	0.0833	***	0.000	6.856		0.878	0.0480	***	0.000
Number of FTE adults age 60 and above	1,386.462	***	0.006	0.149	***	0.002	60.030		0.571	0.0738	*	0.096
Age of household head	-99.609	**	0.038	-0.00854		0.616	-6.216		0.388	-0.00475		0.193
Age of household head, squared				-0.0000108		0.945						
=1 if female-headed HH	-997.224		0.243	-0.222	***	0.004	-39.734		0.779	-0.105		0.125
=1 if HH head completed some lower primary education (grades 1-4)	-212.907		0.661	0.126	**	0.047	224.907	*	0.097	0.159	***	0.002
=1 if HH head completed some upper primary education (grades 5-7)	1,578.460		0.178	0.220	***	0.001	113.190		0.476	0.134	**	0.015

Table A2. Fixed Effects Regression Results: Total and Crop Income (Levels and Logs) – cont'd

Dependent variable:	Total income ('000 ZMK)			Crop income ('000 ZMK)			Log total income			Log crop income		
Explanatory variables:	Coef.	Sig.	p-val.	Coef.	Sig.	p-val.	Coef.	Sig.	p-val.	Coef.	Sig.	p-val.
=1 if HH head completed some secondary education (grades 8-12)	-3,746.560		0.341	0.216	**	0.010	295.655		0.314	0.156	**	0.024
=1 if HH head completed some post-secondary education	8,664.931	*	0.088	0.766	***	0.000	-1.179		0.998	0.200		0.283
% of HHs in district earning income from non-farm salaried/wage employment	-12.969		0.874	0.00564		0.162	15.161		0.209	0.0112	***	0.001
% of HHs in district earning income from formal/informal business activities	147.820	***	0.007	0.00678	***	0.009	-10.758		0.192	-0.00456	**	0.045
% of HHs in district earning income from work on others' farms	-120.972		0.317	0.00271		0.272	7.694		0.390	0.00538	**	0.020
Number of moisture stress periods (20-day periods w/ <40 mm rainfall)	-1,633.830		0.333	0.0121		0.713	87.702		0.342	-0.0166		0.572
Growing season rainfall (t, mm)	-18.253		0.371	-0.0000475		0.907	-0.739		0.467	-0.000386		0.293
Growing season rainfall (t-1, mm)	-4.322		0.501	0.000196		0.564	-0.404		0.711	-0.000105		0.716
Growing season rainfall (t-2, mm)	1.209		0.781	0.000780	***	0.010	2.339	***	0.001	0.00115	***	0.000
Growing season rainfall (t-3, mm)	-4.285		0.717	0.00104	**	0.020	0.235		0.831	0.000405		0.287
Long-run average number of moisture stress periods (16-year moving average)	-2,568.660		0.498	0.00171		0.994	-569.262		0.567	-0.0829		0.689
Long-run average growing season rainfall (mm, 16-year moving average)	61.851		0.382	-0.00822	**	0.027	2.420		0.799	-0.00938	***	0.005
Long-run CV of growing season rainfall (%, 16-year moving average)	-416.710		0.234	-0.0102		0.683	-55.664		0.293	0.00275		0.901
=1 if agricultural year is 2006/2007	-946.503		0.724	0.258		0.160	980.523	*	0.053	0.287	*	0.093
Constant	1.08E+05		0.229	21.757	***	0.000	-1.13E+04		0.383	23.313	***	0.000
=1 if agricultural year is 2006/2007 × provincial dummies	Yes			Yes			Yes			Yes		
Observations	8,522			8,506			8,522			8,199		
Within R-squared	0.031			0.127			0.175			0.238		

Source: Authors' calculations.
Notes: ***p < 0.01, **p < 0.05, *p <0.10. Standard errors are clustered at the household level.

Table A3. Fixed Effects Regression Results: Total and Crop Income per Adult Equivalent (Levels and Logs)

Dependent variable:	Total income/AE ('000 ZMK)			Crop income/AE ('000 ZMK)			Log total income/AE			Log crop income/AE		
Explanatory variables	Coef.	Sig.	p-val.	Coef.	Sig.	p-val.	Coef.	Sig.	p-val.	Coef.	Sig.	p-val.
Kg of FSP fertilizer acquired	1.119	*	0.065	0.000347	***	0.005	0.571	***	0.003	0.000476	***	0.000
District-level FRA maize purchases (t-1, kg/ag HH)	-0.111		0.677	-0.0000908		0.262	-0.0119		0.865	-0.0000803		0.256
Log farmgate FRA maize price (t-1, 2011/12=100)	-914.900		0.241	0.0726		0.652	75.735		0.453	0.104		0.446
Log maize producer price (t-1, 2011/12=100)	470.878		0.370	0.0431		0.761	177.613	**	0.036	0.107		0.429
Log groundnut producer price (t-1, 2011/12=100)	*Dropped due to collinearity*											
Log mixed beans producer price (t-1, 2011/12=100)	*Dropped due to collinearity*											
Log sweet potato producer price (t-1, 2011/12=100)	-1,310.000	**	0.031	-0.334	*	0.089	-107.722		0.402	-0.190		0.256
Log inorganic fertilizer price (2011/12=100)	-66.424		0.939	-0.180		0.323	152.593		0.416	-0.439	**	0.028
Log maize weeding wage (2011/12=100)	-524.748		0.161	0.0795		0.258	0.514		0.994	-0.0228		0.714
Landholding size (ha, cultivated+fallow land)	176.193	***	0.001	0.115	***	0.000	103.874	***	0.000	0.156	***	0.000
Landholding size, squared	-1.355		0.333	-0.00153	***	0.000	-0.741	**	0.011	-0.00209	***	0.002
Value of farm equipment ('000 ZMK, 2011/12=100)	0.242		0.301	7.74E-05	***	0.005	0.0769	*	0.064	8.62E-05	***	0.000
Value of farm equipment, squared				-2.54E-09	**	0.038	-1.32E-06		0.384	-2.24E-09	***	0.010
Value of livestock ('000 ZMK, 2011/12=100)	0.00196		0.922	1.94E-05	***	0.000	0.00539	**	0.013	6.30E-06	***	0.003
Value of livestock, squared				-1.80E-11	***	0.000	-4.02E-09	*	0.082	-7.19E-12	***	0.001
Number of children age 4 and under	-231.582	***	0.006	-0.127	***	0.000	-100.271	***	0.000	-0.138	***	0.000
Number of children age 5 to 14	-145.697	***	0.001	-0.114	***	0.000	-98.905	***	0.000	-0.153	***	0.000
Number of FTE prime age adults (age 15 to 59)	-168.711	***	0.000	-0.117	***	0.000	-101.589	***	0.000	-0.150	***	0.000
Number of FTE adults age 60 and above	-62.493		0.478	-0.0626		0.207	-93.263	***	0.004	-0.125	***	0.007
Age of household head	-54.362		0.173	-0.0190		0.265	-2.316		0.205	-0.00333		0.357
Age of household head, squared	0.344		0.325	0.000102		0.514						
=1 if female-headed HH	-66.360		0.631	-0.117		0.138	69.784		0.130	-0.0164		0.817
=1 if HH head completed some lower primary education (grades 1-4)	68.335		0.495	0.121	*	0.058	95.685	**	0.025	0.149	***	0.004
=1 if HH head completed some upper primary education (grades 5-7)	329.800	**	0.039	0.213	***	0.002	47.055		0.328	0.129	**	0.023

Table A3. Fixed Effects Regression Results: Total and Crop Income per Adult Equivalent (Levels and Logs) – cont'd

Dependent variable:	Total income/AE ('000 ZMK)			Crop income/AE ('000 ZMK)			Log total income/AE			Log crop income/AE		
Explanatory variables:	Coef.	Sig.	p-val.	Coef.	Sig.	p-val.	Coef.	Sig.	p-val.	Coef.	Sig.	p-val.
=1 if HH head completed some secondary education (grades 8-12)	-275.867		0.492	0.192	**	0.023	48.479		0.436	0.127	*	0.073
=1 if HH head completed some post-secondary education	2,183.316	**	0.011	0.718	***	0.000	33.312		0.743	0.129		0.488
% of HHs in district earning income from non-farm salaried/wage employment	-4.776		0.694	0.00472		0.250	3.459		0.162	0.0120	***	0.001
% of HHs in district earning income from formal/informal business activities	20.221	**	0.016	0.00577	**	0.025	-3.765	**	0.040	-0.00537	**	0.020
% of HHs in district earning income from work on others' farms	-6.758		0.583	0.00267		0.298	2.184		0.335	0.00618	***	0.008
Number of moisture stress periods (20-day periods w/ <40 mm rainfall)	-211.135		0.231	0.00431		0.896	9.043		0.694	-0.0163		0.581
Growing season rainfall (t, mm)	-1.549		0.446	-0.00779	**	0.019	-2.762		0.131	-0.000422		0.255
Growing season rainfall, squared				4.30E-06	**	0.018	0.00121		0.219			
Growing season rainfall (t-1, mm)	-0.285		0.775	-0.000142		0.688	-0.153		0.569	-0.000139		0.638
Growing season rainfall (t-2, mm)	0.520		0.488	0.000886	***	0.004	0.737	***	0.000	0.00116	***	0.000
Growing season rainfall (t-3, mm)	-0.779		0.590	0.00129	***	0.005	-0.215		0.488	0.000501		0.197
Long-run average number of moisture stress periods (16-year moving average)	-963.163		0.126	-0.0528		0.808	-267.159		0.253	-0.108		0.610
Long-run average growing season rainfall (mm, 16-year moving average)	16.061		0.162	-0.00709	*	0.065	1.215		0.624	-0.0097	***	0.004
Long-run CV of growing season rainfall (%, 16-year moving average)	-108.883	*	0.089	0.00529		0.840	-18.792		0.204	-0.00189		0.933
=1 if agricultural year is 2006/2007	-272.511		0.631	0.327	*	0.082	271.246	**	0.036	0.309	*	0.076
Constant	9,907.062		0.467	23.994	***	0.000	-516.248		0.867	23.862	***	0.000
=1 if agricultural year is 2006/2007 × provincial dummies	Yes			Yes			Yes			Yes		
Observations	8,522			8,506			8,522			8,199		
Within R-squared	0.034			0.136			0.147			0.269		

Source: Authors' calculations.
Notes: ***p < 0.01, **p < 0.05, *p <0.10. Standard errors are clustered at the household level.

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