Do input subsidies crowd in or crowd out other soil fertility management practices? Panel survey evidence from Zambia

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ABSTRACT

In many countries in sub-Saharan Africa, low crop yield response to inorganic fertilizer contributes to low profitability of fertilizer use and reduces the positive effects of and returns to input subsidy programs (ISPs). A major reason for poor crop yield response to fertilizer is low soil quality. However, using other soil fertility management (SFM) practices in conjunction with fertilizer can improve its response rate. But do ISPs encourage ('crowd in') or discourage ('crowd out') the use of such SFM practices? Using nationally representative household panel survey data, we estimate the effects of subsidized fertilizer acquired through Zambia's ISP on the use of several SFM practices: (i) leaving land fallow, (ii) intercropping, and (iii) applying animal manure. For each practice, we estimate the household-level effects of an increase in the quantity of subsidized fertilizer acquired on the probability of SFM adoption, land area covered by SFM, and the share of land dedicated to SFM, using the ordinary least squares, fixed effects, and fixed effects-instrumental variable estimators. The results suggest that subsidized fertilizer has statistically significant crowding out effects on all fallow variables, for all measures of adoption, using all estimators. Additionally, we find some evidence that subsidized fertilizer crowds out intercropping. However, the weight of the evidence suggests that subsidized fertilizer has no significant effect on intercropping with legumes or the use of animal manure. By disincentivizing fallowing and intercropping, Zambia's ISP may be inadvertently reducing soil quality and the effectiveness and profitability of its main input, inorganic fertilizer.

1. INTRODUCTION

In an effort to catalyze an African Green Revolution, many governments in sub-Saharan Africa (SSA) currently devote a large share of their agricultural sector and national budgets to input subsidy programs (ISPs) (Jayne and Rashid, 2013). ISPs provide inorganic fertilizer, and in some countries, improved seed, to farmers at below-market prices. Despite heavy spending, ISP impacts on crop yields have been smaller than anticipated (ibid.). In Zambia and Malawi, maize output increases by an average of only 1.88 kg and 1.65 kg, respectively, per one-kg increase in subsidized fertilizer (Mason et al., 2013a; Ricker-Gilbert and Jayne, 2011). Low crop yield response reduces the profitability of fertilizer use and has contributed to relatively low economic returns to these programs: Zambia's ISP benefit-cost ratio (BCR) is below one at 0.92 while Malawi's ISP BCR is only 1.08 (Jayne et al., 2015). While higher yields would increase the impact and cost effectiveness of these programs, poor soil quality constrains improved yield response to fertilizer across SSA (Marenya and Barrett, 2009; Tittonell and Giller, 2013; Burke et al., 2015). In Zambia high soil acidity coupled with low soil organic matter reduces the effectiveness of inorganic fertilizer for many farmers.

In recognition of these challenges, there is a growing consensus that a holistic approach to soil fertility management (SFM) is needed to improve the effectiveness of ISPs and achieve sustainable intensification more broadly (Jayne and Rashid, 2013; Montpellier Panel, 2014; FAO, 2015). Cost-effective SFM practices (e.g., manure application, intercropping, composting, etc.) could increase the profitability of fertilizer use and ISPs by improving soil health. Moreover, by altering the relative prices of inputs, ISPs have the potential to influence farmer behavior, including their use of SFM practices – an area largely neglected in previous literature.

This study begins to fill that gap by answering the question: how does subsidized fertilizer affect the use of SFM practices that have the potential to increase crop yield response to inorganic fertilizer? When farmers receive inorganic fertilizer at a subsidized price, fertilizer becomes relatively cheaper than other inputs and demand increases, *ceteris paribus*. In this case, one might expect receipt of subsidized inorganic fertilizer to crowd in (encourage) the use of SFM practices if farmers view SFM practices as complementary to inorganic fertilizer. This is consistent with findings in Beaman et al. (2013) that Malian farmers receiving fertilizer grants re-optimize production, increasing levels of complementary inputs such as herbicide. On the other hand, subsidized fertilizer could crowd out (discourage) the use of SFM practices if farmers view inorganic fertilizer and SFM as substitutes or if the household is resource constrained and cannot pursue both fertilizer application and SFM. Crowding out of complementary SFM practices could reduce the returns to ISPs and render the soil less productive or non-responsive to future fertility management efforts (Tittonell and Giller, 2013). Ultimately, whether ISPs crowd in or crowd out these practices is an empirical question, and one that has important implications for agricultural policy, national budgets, regional food supply, household income, and soil health.

To answer this question, we use nationally representative panel survey data from smallholder farm households in Zambia to estimate the effect of receiving subsidized fertilizer on a household's decision to use some of the most promising soil fertility enhancing practices (Place et al., 2003): (i) leaving land fallow (including both natural and improved fallows), (ii) intercropping (in general and with legumes), and (iii) applying animal manure.[1] Panel data methods and IV techniques correct for the potential endogeneity of subsidized fertilizer to the SFM practices. Zambia is an appropriate case study due to the extensive history and reach of its input subsidy programs, the low maize yield response to inorganic fertilizer in the country (Burke, 2012), and the wide promotion of SFM practices.

The study builds on previous work and contributes to the literature in a number of ways. First, it provides a useful comparison to Holden and Lunduka (2012), who estimate the effects of Malawi's ISP on farmers' probability and intensity of organic manure use. Their results suggest that access to subsidized fertilizer crowds in organic manure but that the effects are small in magnitude and not statistically significant. Second, our work complements Vondolia et al. (2012), who estimate the effects of fertilizer subsidies on the number of days Ghanaian farmers invest in soil and water conservation. They find no statistically significant effects thereon. Third, unlike Holden and Lunduka and Vondolia et al., this study is based on nationally representative survey data, which should increase the external validity of the results. Fourth, we expand upon Mason et al.'s (2013a) analysis of the effects of Zambia's ISP on fallowing. They find that receipt of subsidized fertilizer incentivizes farmers to reduce their area of fallow land. We build on this work by estimating the impacts of subsidized fertilizer on improved fallows versus natural fallows. (Mason et al. only consider the effects on fallowing in general.) Fifth, in order to further unpack the effects of ISPs on SFM practices, we estimate separate models for three different measures of adoption: probability of adoption, area under the practice, and share of land under the practice.[2] Sixth and finally, this study estimates the effects of fertilizer subsidies on an SFM practice not previously examined: intercropping.

The remainder of the paper is organized as follows. Section 2 provides background information on Zambia's ISPs, on SFM practices, and on SFM in Zambia. Sections 3 and 4 describe the methods and data, respectively. Section 5 reports the results and Section 6 summarizes the conclusions and policy implications.

2. BACKGROUND

2.1 Agricultural Input Subsidies in Zambia

Building on a long history of market intervention through ISPs, in 2002 Zambia's Ministry of Agriculture and Co-operatives (MACO) established the large-scale, targeted Fertilizer Support Program (FSP). FSP's stated goals were "improving household and national food security, incomes, [and] accessibility to agricultural inputs by small-scale farmers through a subsidy" (MACO, 2008, p. 3). Running through the 2008/09 agricultural

[1] Natural fallowing refers to leaving previously cultivated land uncultivated in order to permit natural vegetation to grow. On improved fallow land, fast growing nitrogen-fixing plants are planted. When the biomass from the plants is incorporated into the soil, soil organic matter increases, achieving the same results as natural fallows but in a shorter period of time (Place et al. 2003; Juo and Lal 1977; Kwesiga and Coe 1994).

[2] In this paper, we use the term *adoption* to refer to the *use* of a practice (as opposed to the *first time use* of a practice).

year, FSP was to provide a uniform package of 400 kg of fertilizer and 20 kg of hybrid maize seed to selected beneficiary households. The beneficiaries paid 25-50% of the market price for the inputs while the government covered the rest of the cost. In the 2009/10 agricultural year, FSP was replaced with the present day Farmer Input Support Program (FISP), under which the input pack size was halved to 200 kg of fertilizer and 10 kg of seed. See Table 1 for further information on the fertilizer subsidy rate, metric tons of fertilizer, and number of intended beneficiaries for each year of Zambia's modern ISPs.

In this paper we focus on FSP, as we have panel data for smallholder famers in Zambia during the time of its operation. In order to be eligible for FSP, a household was to meet the following requirements: be a small-scale farmer (i.e., cultivate less than five hectares of land) actively involved in farming; have the capacity to grow at least one hectare of maize; have the ability to pay the farmers' share of the input costs; be a member of a cooperative; have not defaulted from an earlier input loan scheme (the Fertilizer Credit Program); and not be a current beneficiary of the Food Security Pack Program.[3]

The panel data used in this study cover the 2002/03 and 2006/07 agricultural years. In those years, subsidized fertilizer was provided to beneficiaries at roughly 50% and 60%, respectively, of the estimated district-level market price. In 2002/03, 120,000 farmers were to receive 48,000 MT of FSP fertilizer. The program grew by 2006/07, when 210,000 farmers were to receive 84,000 MT of FSP fertilizer (Table 1). FSP ultimately reached 11.6% of smallholder farmers that year, with each participating household receiving an average of 356 kg and a median of 300 kg of fertilizer.

2.2 SFM Practices and Their Use in Zambia

Fallowing, intercropping, and manure application have a key commonality that improves inorganic fertilizer use efficiency: they allow soil organic matter (SOM) to accumulate (Kumwenda et al., 1996). SOM is decomposing plant or animal matter in soil and is vital to maintaining soil fertility (Woomer et al., 1994). As the organic matter is mineralized over years, it makes crucial micronutrients available to plants, which has the potential to dramatically improve inorganic fertilizer use efficiency (Kumwenda et al., 1996). In Zambia, a significant share (28%) of smallholders' largest maize fields have SOM levels below 1.4%, which has been identified as a critical threshold below which maize yield response to fertilizer is significantly reduced (Burke et al., 2015). In addition to increasing SOM, applying animal manure also reduces soil acidity, positively impacting yield response to basal fertilizer in particular (Bationo et al., 1995; Whalen et al., 2000; Burke et al., 2015).[4]

Table 2 presents summary statistics on the use of SFM practices by Zambian smallholders during the period of analysis (the 2002/03 and 2006/07 agricultural years). Natural fallowing is the most commonly used SFM practice considered, with 37.0% of the sample fallowing some of their land in at least one of the survey waves. In contrast, only 1.1% of smallholders practiced improved fallowing. 15.4% of households practiced intercropping, while 8.0% intercropped with legumes. Approximately 6.8% of households applied animal manure.

[3] For further information on Zambia's ISPs, see Mason et al. (2013a).
[4] When soil is acidic, the phosphorus found in basal fertilizer converts into a phosphate that is insoluble and cannot be used by plants (Busman et al. 2002).

3. METHODS

3.1 Conceptual Model

To identify the independent effect of FSP on SFM practices, we begin by specifying an input demand function derived from a non-separable agricultural household model (Singh et al., 1986) relating smallholder use of SFM practices to receipt of FSP fertilizer and other factors that affect the use of those practices. This model is similar to the one used by Kamau et al. (2014) to model farmer demand for SFM practices in Kenya. A non-separable model is also appropriate in the Zambian context due to land, labor, credit, and other market failures.

Per Singh et al. (1986) and as adapted by Kamau et al. (2014), the reduced form input demand function for a given SFM practice is a function of the household's landholding size ($\boldsymbol{A}$), labor availability ($\boldsymbol{L}$), variable input prices (including the market price of fertilizer) and expected output prices ($\boldsymbol{p}$), household characteristics affecting production and/or consumption ($\boldsymbol{z}$), market characteristics and access to information ($\boldsymbol{m}$), and land quality and agro-ecological conditions ($\boldsymbol{g}$). To incorporate the potential effect of FSP on SFM practice adoption, we add to Kamau et al.'s model the quantity of FSP subsidized fertilizer acquired by the household (FSP), and the subsidy rate (s):

$$SFM = SFM(\boldsymbol{A}, \boldsymbol{L}, \boldsymbol{p}, \boldsymbol{z}, \boldsymbol{m}, \boldsymbol{g}, FSP, s) \quad (1)$$

3.2 Empirical Model

To bring equation (1) to the data, we specify a linear unobserved effects panel data model:

$$SFM_{it} = \beta_0 + \beta_1 FSP_{it} + \boldsymbol{A}_{it}\boldsymbol{\beta}_2 + \boldsymbol{L}_{it}\boldsymbol{\beta}_3 + \boldsymbol{p}_{it}\boldsymbol{\beta}_4 + \boldsymbol{z}_{it}\boldsymbol{\beta}_5 + \boldsymbol{m}_{it}\boldsymbol{\beta}_6 + \boldsymbol{g}_{it}\boldsymbol{\beta}_7 + d_t + c_i + u_{it} \quad (2)$$

where i indexes the household; t indexes the agricultural year (t=2002/03 and 2006/07); c_i and u_{it} are the time constant and time varying error terms, respectively; d_t is a year fixed effect; and the $\beta's$ are parameters to be estimated.[5] SFM_{it} is a variable capturing the use of a given SFM practice. Separate equations are estimated for each of the SFM practices: (i) leaving land fallow (general, natural, and improved), (ii) intercropping (general and with legumes), and (iii) applying animal manure. The use of a given SFM practice is modeled in three ways: first, as a binary variable equal to one if the household used the practice on any of its fields, and equal to zero otherwise; second, as the hectares of the household's land under the practice; and third, as the share of land devoted to the practice.

FSP_{it}, the key explanatory variable of interest, is the kilograms of FSP fertilizer acquired by the household. We use this rather than an indicator variable for having received FSP fertilizer due to many households receiving substantially more or less than the intended 400 kilograms (Mason et al., 2013a). The subsidy rate variable in our conceptual model, s,

[5] Note that equation (2) is a household level model, and not a plot level model. Given the paucity of plot-level information available in the survey data, the econometric models are specified and estimated at the household level.

does not appear in the empirical model because it is pan-territorial and thus perfectly collinear with the year fixed effect.

$\boldsymbol{A_{it}}$ is landholding size and landholding size squared in hectares. $\boldsymbol{L_{it}}$ is labor availability represented by the number of household members in four age categories: under 5, 5-14, 15-59, and 60 and above. $\boldsymbol{p_{it}}$ is a vector of variable input prices and expected output prices, proxied by lagged output prices. $\boldsymbol{z_{it}}$ is a vector of household characteristics as well as province- and province-by-year fixed effects to control for year-specific province level unobservables. $\boldsymbol{m_{it}}$ is a vector of market characteristics and access to information. $\boldsymbol{g_{it}}$ is a vector of land quality and agro-ecological conditions. See Table 3 for a list of the specific variables included in the fixed effects regressions. Additional, time constant variables are included in the ordinary least squares regressions (e.g., soil type, estimates of soil quality, slope, distances to the nearest district town, tarred road, and feeder road).[6]

3.3 Hypotheses and Identification Strategy

Our goal is to estimate the effect of a one-kilogram increase in the quantity of FSP fertilizer acquired by the household on the household's use of the various SFM practices. For each practice, we test the null hypothesis that there is no effect of FSP on use of SFM (i.e., the coefficient of FSP_{it}, $\beta_1 = 0$) against the alternative hypothesis that FSP affects use of SFM (i.e., $\beta_1 \neq 0$). If the coefficient on FSP_{it} is positive (negative) and statistically significant for a given SFM practice, this would suggest that FSP fertilizer crowds in (out) the SFM practice.

Equation (2) is estimated for each SFM practice and each specification of the dependent variable (probability of adoption, area, and share) using three different estimators: ordinary least squares (OLS), fixed effects (FE), and fixed effects-instrumental variables (FE-IV). Our main threat to identification is selection bias since farmers choose to enroll in FSP. There could also be time-constant and time-varying unobserved factors that are correlated with FSP fertilizer receipt and affect the use of SFM practices that are not controlled for in equation (2). Hence, we use OLS as a baseline, but we must use other methods to correct for endogeneity.

Fixed effects allows us to control for time-constant unobserved heterogeneity, the c_i in equation (2) that could be correlated with FSP receipt. However, the expected value of the time-varying error term (u_{it}) given the explanatory variables from all time periods and given the time-constant error term must be equal to zero (strict exogeneity) in order for the FE estimator to be unbiased and consistent. Because this is unlikely to be the case due to unobserved factors that vary with time (e.g., social learning), we correct for time-constant and time-varying endogeneity using the FE-IV estimator (Wooldridge, 2010).

Following Mason and Jayne (2013), we use an IV for FSP fertilizer that is equal to zero for constituencies lost by the ruling party in the last presidential election, and equal to the percentage point margin of victory between the ruling party and lead opposition otherwise. To test that the IV is sufficiently strong, we estimate the reduced form using FE and then compute the F-statistic for the IV. The reduced form results are reported in Table 3

[6] Summary statistics and a complete list of variables are available at
http://web2.msue.msu.edu/afreTheses/fulltext/N.%20Kendra%20Levine-%20Final%20Plan%20B%20Paper.pdf

for general and legume intercropping, which are similar to the reduced form results for the fallow variables and applying animal manure.[7] These results suggest that a one-percentage point increase in the IV raises the quantity of FSP fertilizer received by households in the constituency by an average of 0.52 kg, *ceteris paribus* (p=0.001).[8] The F-statistic for the IV is greater than 10 in the reduced form for each practice, indicating that the IV is sufficiently strong.

We build a case to support the validity of this IV by drawing on an additional (though weaker) candidate IV and testing the over-identifying restrictions using Hansen J tests. Under the assumption that at least one of the IVs is valid, the joint null hypothesis of the Hansen J test is that the IVs are not correlated with the error term and that they are correctly excluded from the structural equation (Hayashi, 2000); the alternative hypothesis is that the IVs are correlated with the error term or should be included in the structural equation. The additional IV we use is the percentage of other households in the household's SEA with landholdings of 1-4.99 hectares. This variable is intended to proxy for the FSP eligibility requirements that participants be small-scale farmers and 'have the capacity' to cultivate at least one hectare of maize. We fail to reject at the 10% level the joint null hypothesis for 16 of the 18 Hansen J tests (one test for each of the 18 SFM dependent variables), but we reject the null hypothesis at the 1% level for the general fallow area and natural fallow area variables, indicating that at least one of the IVs is invalid for those two outcome variables. Given that the Hansen J test results support the validity of our main IV for the vast majority of the outcome variables, we proceed to use it in the FE-IV regressions for all outcome variables; however, we do not rely heavily on the FE-IV results for general fallow area and natural fallow area due to concerns about the validity of the IV for those practices.

In addition to these tests, we also test for the statistical endogeneity of FSP_{it} to each dependent variable via a Hausman test as described in Baum et al. (2003). The null hypothesis for these tests is that FSP_{it} is exogenous; the alternative hypothesis is that it is endogenous. As shown in Table 4, the results for the endogeneity tests are mixed. They suggest that FSP_{it} is endogenous to all fallow dependent variables except area of natural fallow, to two of the three general intercropping dependent variables (the probability of adoption and the share of cropped area), to none of the legume intercropping variables, and to one of the three animal manure dependent variables (the hectares to which manure is applied).

[7] The reduced form results for leaving land fallow, intercropping, and manure usage vary slightly (but not substantively) due to missing data for a few households for each these practices.

[8] See Mason et al. (2013b) for a discussion of the political economy of FSP.

4. DATA

We principally draw on panel data from the second and third waves of the Supplemental Survey (SS) to the 1999/00 Post-Harvest Survey, a nationally representative survey of rural, smallholder households in Zambia.[9] The SSs were conducted by the Zambia Central Statistical Office (CSO) and MACO in collaboration with the Food Security Research Project. The SS captures detailed information on household demographics, agricultural activities (crops and livestock), off-farm activities, asset holdings, services offered by farmer organizations, household participation in FSP, and farmer use of the SFM practices studied here.

The first wave of the survey covered the 1999/00 agricultural year and was conducted in May 2001. A total of 6,922 households were interviewed. We exclude this first wave in our analysis because the questions asked do not cover the SFM practices of interest in this study. The second wave of the SS was conducted in May 2004, covered the 2002/03 agricultural year, and successfully re-interviewed 5,358 (77.4%) of the first wave households. The third wave was conducted in June 2008, covered the 2006/07 agricultural year, and successfully re-interviewed 4,286 (80.0%) of the second wave households. There are thus 4,286 households in the balanced panel.

Given that a sizable percentage of households were not successfully re-interviewed in the second and third waves of the panel survey, attrition bias is a potential concern. Using regression-based tests described by Wooldridge (2010) we determine if there are still systematic differences in the SFM dependent variables between attritors and non-attritors after we control for the observed covariates. We fail to reject the null hypothesis of no attrition bias in all cases. Results of these tests are available from the author upon request.

Several explanatory variables included in our models were not collected in the SS and are drawn from other datasets. Lagged producer prices are from the 2001/02 and 2005/06 CSO/MACO Post-Harvest Surveys. Rainfall data are from Tropical Applications of Meteorology using SATellite data (TAMSAT) (Tarnavsky et al., 2014; Maidment et al., 2014; Grimes et al., 1999; Milford and Dugdale, 1990). Slope data are from the Shuttle Radar Topography Mission and processed by CGIAR's Consortium for Spatial Information (Jarvis et al., 2008). Soil nutrient availability and soil nutrient retention capacity data are from the Harmonized World Soil Database v1.2 (FAO, 2012), while the soil type data are from the Zambia Agriculture Research Institute. Lastly, our main IV is based on constituency-level data from the Electoral Commission of Zambia.

5. RESULTS

Table 4 summarizes the key results from the econometric analysis of the effects of FSP on the use of SFM practices in Zambia. (The full regression results are available from the authors upon request.) Although OLS results are reported in Table 4, in the discussion below we focus mainly on the FE and FE-IV results due to the likelihood that receipt of FSP fertilizer is correlated with time-constant and/or time-varying factors that also affect the use

[9] In Zambia, smallholder household are defined as those cultivating less than 20 hectares of land.

of SFM. When interpreting the magnitude of the results, we focus on the average partial effect and/or effect size of a 200-kg increase in FSP fertilizer; this is the median quantity acquired by FSP beneficiaries during the study period and the quantity included in the present day FISP. It is important to note at the onset that we observe large differences in magnitude between the FE and FE-IV results. While some change in magnitude is to be expected, many of the FE-IV magnitudes are implausibly large. We suspect this could be due to the IV being somewhat weak; while it passes the F>10 threshold, it does so by only a small magnitude (F=10.8). The true magnitude of the FSP effects is likely somewhere in between the FE and FE-IV estimates, and likely closer to the FE effect.

5.1 Fallowing

The results suggest statistically significant (p<0.10) crowding out effects of FSP fertilizer on farmers' use of fallowing in general, and on both natural and improved fallowing.[10] These results are robust to the measure of fallowing (probability of adoption, area, and share of land) and to the estimator used (OLS, FE, and FE-IV) (Table 4). We generally reject the exogeneity of FSP fertilizer in these regressions. Based on the FE-IV results for general fallowing, receiving an additional 200 kg of FSP fertilizer decreases the probability that a household leaves any of its land fallow by 50 percentage points on average, decreases the area of land left fallow by an average of 0.83 ha (which is 39.5% of the average landholding size), and decreases the share of the household's total landholdings left fallow by 25 percentage points on average, *ceteris paribus.* These changes are equivalent to effect sizes of approximately one standard deviation (SD) for the probability of adoption and share of land, and equivalent to about 0.5 SD for area under general fallow, indicating that the changes are very large in magnitude. The effect sizes of the FE estimates are much smaller in magnitude: about 0.1 SD or less. By reducing the relative price of fertilizer, it appears that FSP significantly alters Zambian farmers' fallow-cultivation decision (on average). This is consistent with earlier findings in Mason et al. (2013a) and with the predictions of Willassen's (2004) model of the fallow-cultivation decision.

5.2 Intercropping

All regressions for the three dependent general intercropping variables suggest negative FSP effects on intercropping, but only a subset of the results is statistically significant (Table 4). The FE-IV estimates for both the probability of adoption and share of land with general intercropping are statistically significant, and suggest negative FSP fertilizer effect sizes of 1.15 and 1.45 SD, respectively, for an additional 200 kg of FSP fertilizer. Again, these effect sizes seem improbably large, especially compared to the (statistically insignificant) FE effect sizes of 0.02 SD for probability of adoption and 0.01 SD for share of cultivated land. The negative effect of FSP on the area of land intercropped is only statistically significant when using OLS.

Although the general intercropping results are not as robust as the fallowing results, they do provide some evidence that FSP fertilizer crowds out general intercropping (i.e.,

[10] Throughout this section, we use the 10% level as our cutoff for statistical significance.

crowds in monocropping). This could be due to a number of factors. For example, if farmers consider intercropping and inorganic fertilizer to be substitutable ways to improve soil fertility, when the price of inorganic fertilizer decreases, the returns to intercropping may decrease relative to the returns of monocropping (with fertilizer), others factors constant. If the returns to monocropping with FSP fertilizer exceed those of intercropping, then farmers may choose to monocrop. Another potential factor that may cause FSP to crowd out general intercropping may be labor constraints – i.e., if FSP raises fertilizer use, receipt of FSP fertilizer would increase the labor required for fertilizer application and for harvesting of the additional maize production (among other potential tasks). This would reduce the amount of labor available for planting and maintaining intercrops. Lastly, FSP crowding out general intercropping may be due to implicit messaging delivered by the program: a government program that provides inputs for only one crop (like FSP did for maize during the period of analysis) could implicitly encourage farmers to focus solely on the production of that one crop, resulting in monocropping. While there is some evidence that FSP crowds out general intercropping, the weight of the evidence in Table 4 suggests that FSP has no statistically significant effects on intercropping with legumes.

5.3 Animal Manure

We find virtually no evidence of statistically significant FSP effects on Zambian smallholder's use of animal manure (Table 4). The lack of significant FSP effects on animal manure application could be due to the small percentage of households (6.8%) in our sample that use animal manure, resulting in lower statistical power, or the results could reflect that there is indeed no FSP effect on manure use as measured here. One explanation for this finding is that inorganic fertilizer can be considered a substitute or a complement to animal manure. Thus, FSP making inorganic fertilizer relatively cheaper could crowd out (in) the use of manure in the case that the household considers it a substitute (complement). If both effects occur in different households, the average effect across all households could be close to zero.

6. CONCLUSIONS AND POLICY IMPLICATIONS

African governments spend more than US$1 billion per year on ISPs, yet the returns to these programs have been disappointingly low in several countries due in large part to low crop yield response to inorganic fertilizer (Jayne and Rashid, 2013). There is an emerging consensus that, in many cases, SFM practices should be used in conjunction with inorganic fertilizer to improve soil quality so that it is above the minimum thresholds necessary for fertilizer to be effective (Jayne and Rashid, 2013; Montpellier Panel 2014; FAO, 2015). Among other impacts, SFM practices can build SOM, prevent erosion, increase soil nutrients, and/or reduce soil acidity, all of which are crucial for raising agricultural productivity and work synergistically with the inorganic fertilizer that ISPs promote and distribute (Weight and Kelly, 1999).

Our results suggest that receiving subsidized fertilizer through Zambia's ISP, known as FSP, has a crowding out effect on general, natural, and improved fallowing. These results are robust to the measure of fallowing used (probability of adoption, area, and share of total landholding) and to the estimator used (OLS, FE, and FE-IV). There is also some evidence that FSP crowds out (discourages) general intercropping or, in other words, encourages monocropping, a known driver of soil degradation and decreased crop yields if practiced continuously over multiple seasons (Bennett et al., 2012). We find little evidence of FSP effects on intercropping with legumes in particular or on smallholders' use of animal manure.

Policy implications of the results on farmer welfare in the short-run are not easy to draw due to smallholder households' multiple objectives, including, amongst others, increasing household income, maintaining the soil health in their fields over multiple seasons, and including necessary nutrients in the household diet. More research is needed to understand the impacts of decreasing fallow lands and intercropped fields in Zambia and whether the benefits to the farmer from the subsidized fertilizer and possible increased maize output outweigh the potential costs of cultivating in previously fallow land or monocropping in previously intercropped fields.

Where it can cost-effectively improve farmer welfare or raise the BCRs of ISPs, the following policies could be carefully explored and analyzed as potential means of promoting ISP crowding in effects on SFM practices: incorporating SFM practices into ISPs via extension efforts; requiring use of one or more of a menu of SFM practices as a precondition for receiving the subsidies; distributing desired goods to those who incorporate SFM practices as an incentive mechanism; and encouraging intercropping by, in addition to maize, adding significant amounts of inputs for other crops to the ISP pack (Dorward and Chirwa, 2011). Policies designed to crowd in complementary SFM practices could boost governments' returns on their inorganic fertilizer investments and aid in the transformation of low productivity farms to those that can be profitably farmed for many seasons to come.

TABLES

Table 1. Key features of Zambia's main fertilizer subsidy programs, 1997/98-2014/15

Input subsidy program	Agricultural year	Fertilizer subsidy rate	MT of fertilizer	Intended beneficiaries
FRA Fertilizer Credit Program	1997/98	Loan	15,495	--
	1998/99	Loan	50,001	--
	1999/00	Loan	34,999	--
	2000/01	Loan	23,227	--
	2001/02	Loan	28,985	--
Fertilizer Support Program	2002/03	50%	48,000	120,000
	2003/04	50%	60,000	150,000
	2004/05	50%	46,000	115,000
	2005/06	50%	50,000	125,000
	2006/07	60%	84,000	210,000
	2007/08	60%	50,000	125,000
	2008/09	75%	80,000	200,000
Farmer Input Support Program	2009/10	75%	100,000	500,000
	2010/11	76%	178,000	891,500
	2011/12	79%	182,454	914,670
	2012/13	--	183,634	900,000
	2013/14	50%	188,312	900,000
	2014/15	--	208,236	1,000,000

Notes: -- Information not available.
Source: Mason et al. (2013a) and MAL (2014).

Table 2. Summary statistics for SFM practices

SFM Practice	Mean	Standard Deviation
General Fallow (Improved and/or Natural) (N=9245) [a]		
=1 if used practice	0.380	0.485
Area (ha)	0.466	1.482
Share	0.149	0.235
Improved Fallow (N=9245)		
=1 if used practice	0.011	0.104
Area (ha)	0.010	0.148
Share	0.004	0.041
Natural Fallow (N=9245)		
=1 if used practice	0.370	0.483
Area (ha)	0.456	1.475
Share	0.146	0.234
General Intercropping (N=9391)		
=1 if used practice	0.154	0.361
Area (ha)	0.102	0.481
Share	0.062	0.183
Legume Intercropping (N=9391)		
=1 if used practice	0.080	0.271
Area (ha)	0.055	0.426
Share	0.029	0.130
Animal Manure (N=9097)		
=1 if used practice	0.068	0.251
Area (ha)	0.095	0.594
Share	0.041	0.169

Note: HH=Households. [a]The difference sample sizes (*N*) across SFM practices is due to missing data for the practices.
Source: **Authors' calculations.**

Table 3. Reduced form FE regression results: Factors affecting the kg of FSP fertilizer received by the HH

Explanatory Variables	Coef.	Sig.	p-value
IV			
=0 if ruling party lost in constituency; %-pt. margin of victory o.w.	0.517	***	0.001
Size of landholding			
Landholding (ha)	9.736	***	0.001
Landholding squared (ha)	0.003		0.968
Labor availability/Household composition: # of HH members age			
< 5 yrs	-6.680	**	0.049
5 to 14 yrs	-6.284		0.271
15 to 59 yrs	-1.537		0.508
> 59 yrs	-8.585		0.287
Variable input and expected output prices			
Fertilizer price (ZMK/kg)	0.005		0.756
Weeding wage (ZMK/0.25 ha)	-0.214		0.490
Maize producer price (ZMK/kg)	-0.005		0.891
Sweet potato producer price (ZMK/kg)	-0.062		0.263
Mixed bean producer price (ZMK/kg)	-0.024		0.448
Groundnut producer price (ZMK/kg)	-0.006		0.743
Household characteristics			
=1 if female headed HH	-8.845		0.265
Age of HH head	0.334		0.207
HH head's education			
=1 if lower primary	-9.874		0.106
=1 if upper primary	-4.525		0.480
=1 if secondary	-7.483		0.517
=1 if post-secondary	-21.520		0.432
# of cattle	-0.390		0.542
Tropical Livestock Units	0.722		0.908
% of HH land owned	-0.108		0.506
Market characteristics and access to information			
=1 if HH owns cell phone	24.783	**	0.034
=1 if HH owns radio	-0.001		1.000
Km from HH to vehicular transport	-0.044		0.672
=1 if received minimum tillage extension advice	17.475	**	0.013
=1 if received crop residue extension advice	12.096	*	0.066
=1 if received crop rotation extension advice	-18.835	***	0.009
Land quality and agro-ecological conditions			
16- yr mean growing season rainfall	-0.404		0.326
16- yr CV of growing season rain (%)	2.372		0.395
16- yr mean moisture stress	-3.693		0.897
=1 if survey year is 2008	32.229		0.227
Constant	369.534		0.234
Province x year dummy	Yes		
F-stat. for IV	10.830	***	0.001
Observations	8188		

Note: ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. p-values based on robust standard errors clustered at the household level. HH=Households. ZMK=Zambian Kwacha. CV=Coefficient of variation. Moisture stress = number of 20-day periods during the growing season with less than 40 mm rain.
Source: Authors' calculations.

Table 4. Summary of results: Effect of kg of FSP fertilizer on SFM practices

Variable	(A) Estimator	(B) Coef.	(C) Sig.	(D) p-value	(E) Coef.* 200	(F) Std. dev. for 2004 SS	(G) Effect size for 200 kg increase in FSP (E/F)[a]	(H) Endogeneity test p-value	(I) Endogeneity test Sig.
General Fallow (Improved and/or Natural)									
=1 if used practice	OLS	-2.27E-04	***	0.000	-0.045	0.498	-0.091		
	FE	-1.46E-04	***	0.002	-0.029	0.498	-0.059		
	FE-IV	-2.48E-03	**	0.035	-0.496	0.498	-0.997	0.012	**
Area (ha)	OLS	-1.05E-03	***	0.000	-0.209	1.528	-0.137		
	FE	-7.80E-04	***	0.001	-0.156	1.528	-0.102		
	FE-IV	-4.16E-03	**	0.048	-0.831	1.528	-0.544	0.060	*
Share	OLS	-1.40E-04	***	0.000	-0.028	0.240	-0.117		
	FE	-8.94E-05	***	0.000	-0.018	0.240	-0.074		
	FE-IV	-1.24E-03	**	0.029	-0.248	0.240	-1.033	0.009	*
Improved Fallow									
=1 if used practice	OLS	-1.65E-05	***	0.01	-0.003	0.062	-0.053		
	FE	-3.96E-05	***	0.007	-0.008	0.062	-0.128		
	FE-IV	-5.64E-04	**	0.037	-0.113	0.062	-1.817	0.017	**
Area (ha)	OLS	-3.12E-05	***	0.001	-0.006	0.057	-0.109		
	FE	-3.39E-05	***	0.008	-0.007	0.057	-0.119		
	FE-IV	-5.87E-04	*	0.057	-0.117	0.057	-2.054	0.032	**
Share	OLS	-6.70E-06	***	0.001	-0.001	0.011	-0.123		
	FE	-8.88E-06	***	0.005	-0.002	0.011	-0.163		
	FE-IV	-1.88E-04	*	0.055	-0.038	0.011	-3.461	0.029	**
Natural Fallow									
=1 if used practice	OLS	-2.14E-04	***	0.000	-0.043	0.497	-0.086		
	FE	-1.12E-04	**	0.014	-0.022	0.497	-0.045		
	FE-IV	-1.96E-03	*	0.073	-0.391	0.497	-0.786	0.048	**
Area (ha)	OLS	-1.02E-03	***	0.000	-0.203	1.523	-0.133		
	FE	-7.46E-04	***	0.001	-0.149	1.523	-0.098		
	FE-IV	-3.57E-03	*	0.077	-0.714	1.523	-0.469	0.116	
Share	OLS	-1.34E-04	***	0.000	-0.027	0.240	-0.111		
	FE	-8.05E-05	***	0.000	-0.016	0.240	-0.067		
	FE-IV	-1.05E-03	**	0.049	-0.210	0.240	-0.876	0.026	**
General Intercropping									
=1 if used practice	OLS	-8.77E-05	*	0.000	-0.018	0.394	-0.045		
	FE	-3.62E-05		0.128	-0.007	0.394	-0.018		
	FE-IV	-2.26E-03	**	0.024	-0.451	0.394	-1.147	0.003	***
Area (ha)	OLS	-1.93E-04	*	0.058	-0.039	0.575	-0.067		
	FE	-5.90E-05		0.204	-0.012	0.575	-0.021		
	FE-IV	-1.24E-03		0.149	-0.248	0.575	-0.431	0.129	
Share	OLS	-3.64E-05	***	0.001	-0.007	0.179	-0.041		
	FE	-1.23E-05		0.328	-0.002	0.179	-0.014		
	FE-IV	-1.29E-03	**	0.013	-0.259	0.179	-1.448	0.000	***

Variable	Estimator	Coef.	Sig.	p-value	Coef.* 200	Std. dev. for 2004 SS	Effect size for 200 kg increase in FSP (E/F)[a]	Endogeneity test p-value	Endogeneity test Sig.
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
Legume Intercropping									
=1 if used practice	OLS	-4.96E-05	***	0.000	-0.010	0.394	-0.025		
	FE	-1.89E-05		0.308	-0.004	0.394	-0.010		
	FE-IV	9.19E-05		0.878	0.018	0.394	0.047	0.853	
Area (ha)	OLS	-1.38E-04		0.174	-0.028	0.575	-0.048		
	FE	-2.28E-05		0.576	-0.005	0.575	-0.008		
	FE-IV	-1.78E-04		0.781	-0.036	0.575	-0.062	0.810	
Share	OLS	-2.19E-05	***	0.010	-0.004	0.179	-0.025		
	FE	-7.34E-06		0.455	-0.001	0.179	-0.008		
	FE-IV	-2.54E-04		0.364	-0.051	0.179	-0.285	0.360	
Animal Manure									
=1 if used practice	OLS	1.36E-05		0.515	0.003	0.256	0.011		
	FE	1.75E-06		0.948	0.000	0.256	0.001		
	FE-IV	2.05E-04		0.634	0.041	0.256	0.160	0.632	
Area (ha)	OLS	-4.83E-05		0.585	-0.010	0.669	-0.014		
	FE	-2.04E-04		0.137	-0.041	0.669	-0.061		
	FE-IV	1.23E-03	*	0.100	0.246	0.669	0.368	0.024	**
Share	OLS	1.85E-06		0.882	0.000	0.170	0.002		
	FE	-2.08E-05		0.324	-0.004	0.170	-0.024		
	FE-IV	1.27E-04		0.648	0.025	0.170	0.149	0.593	

Note: ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. p-values based on robust standard errors clustered at the household level. p-values for endogeneity test refer to H_o: suspected endogenous explanatory variable is exogenous, H_a: the variable is endogenous.
Source: Authors' calculations.

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