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The Impact of Farmer Input Support Programme Reform on Crop Diversification and Rotation in Zambia

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Abstract

This paper evaluates the impact of Zambia's Farmer Input Support Programme reform on the degree of crop diversification and crop rotation. The paper combines a rich two-wave panel of rural household survey data, high-resolution satellite rainfall data, and primary in-depth interviews with Agricultural Extension workers. The paper finds that expanding the number of crops supported beyond just maize positively impacted both the level of crop diversification and the intensity of crop rotation. These results show that reforms are effective in stimulating the adoption of climate-smart farming behaviour. However, the impact is undermined by the absence of functioning markets for alternative crops, the entrenched culture of mono-cropping maize, and the general lack of knowledge and resources necessary to adopt new technologies.

Keywords: subsidy, reform, impact evaluation, crop diversification, crop rotation.

JEL classification: O38, Q00, Q12, Q18

1 Introduction

Climate change has resulted in altered rainfall activities, with increased occurrence of precipitation extremes, which threatens the viability of agricultural sectors, especially in tropical zones of developing countries (Altieri and Koohafkan, 2008). In Zambia, for instance, the UNDP (McSweeney et al., 2012) estimates that the mean annual temperature has increased by 1.3◦C since the 1960s, while the annual rainfall has decreased both in duration and quantity. The declining rains pose a danger to the viability of the agricultural sector and the livelihood of the rural population dominated by smallholder farmers (AFAI, 2015). Smallholder farmers remain vulnerable to the effects of climate change because they lack the resources necessary to cope (Smit and Pilifosova, 2001).

In order to help farmers mitigate the effects of climate change, the government adopted conservation farming (CF) as an official government policy in Zambia. The government and its cooperating partners have since been promoting the adoption of different principles of CF among smallholder farmers, as a climate-change adaptation strategy. This paper will focus on crop diversification and the adoption of crop rotation principles. Crop diversification helps to minimise climate-related crop failure because different crops tolerate different weather conditions. It also enhances balanced human nutrition, especially in rural settings, where consumption is tied to own production (Arslan et al., 2014; Feliciano, 2019; Kankwamba et al., 2018). Crop rotation allows optimal use of soil nutrients, as different crops reach nutrients at different depths, while the inclusion of legumes in the rotation cycle allows farmers to benefit from the legumes' nitrogen fixing ability (Koppmair et al., 2017).

As part of this drive to promote the adoption of these principles, the government has reformed the Farmer Input Support Programme (FISP),[1] which provides highly subsidised agricultural inputs to eligible smallholder farmers. Beneficiaries are selected through farmer organisations, such as cooperatives and women's groups, and Camp Agricultural Committees (CACs) (Mason et al., 2013). CACs are comprised of both elected farmers' and traditional leaders' representatives, as well as a government-employed Agricultural Extension Officer (AEO). Anecdotal evidence suggests that farmer organisations recommend members on a first-come basis. When selected, a farmer is shortlisted to receive one pack of inputs, which, before the reforms, comprised 10kg of hybrid maize seed and 200kg

[1] For the period under review (2011-2015), the programme targeted 900,000 farmers out of an estimated 1.47 million smallholder farmers in the country (CSO, 2016).

of fertiliser (MoA, 2012, 2016). To be eligible, a farmer had to belong to a cooperative/farmer organisation and be cultivating between one half and two hectares of maize (MoA, 2012, 2013a, 2016, 2018).

The reforms included the expansion of the programme to include inputs for multiple crops and the introduction of the electronic voucher input delivery system in selected districts (MoA, 2013). Districts were selected for the multi-crop reform based on their suitability for the additional crops, while the e-voucher pilot was implemented in districts close to main highways and the 'line of rail' in order to take advantage of existing communication and transport infrastructure that is conducive to private sector participation in the input distribution and supply system (MoA, 2013).

However, the effectiveness of FISP reforms in enhancing the adoption of climate-smart agricultural principles has not been conclusively evaluated. Studies on farm subsidy programmes (Asfaw et al., 2017; Carter et al., 2014; Chibwana et al., 2014; Jayne and Rashid, 2013; Xu et al., 2009) are biased towards evaluating the impact of subsidies on crop yields, fertiliser use, and poverty in general, ignoring potential spill-over effects such as the impact on the adoption of climate-related farming practices. For instance, Chibwana et al. (2014) found a significant impact of Malawi's farm input subsidy programme on the intensity of fertiliser use, while Carter et al. (2014) found that subsidies have a persistent impact on fertiliser use.

Although secondary effects of reforms are important, few studies (Kankwamba et al., 2018; Koppmair et al., 2017) have looked at these. In particular, Koppmair et al. (2017) noted that a subsidy programme is a good avenue for promotion of conservation farming practices, while Kankwamba et al. (2018) found the subsidy programme to have a positive effect on the degree of crop diversification among farmers in Malawi. Others, such as Jayne et al. (2018), argue that subsidy programmes either have had no effect on climate-smart agricultural practices or have reduced their use. This suggests that there is no consensus in the literature on how subsidy programmes impact the adoption of climate-related farming practices. The mixed results may be due to spatial variations in key agricultural determinants, such as climate and farming cultures, which many studies fail to control for (Jayne et al., 2018). These mixed results underscore the need for more localised empirical studies that take into account prevailing agro-climate, farming systems and other key variables.

Evaluation of agricultural input subsidy programmes also presents endogeneity problems due to self-selection or criteria-based selection. Studies have dealt with this potential endogeneity problem by using instrumental variables (Chibwana et al., 2014), the fixed effects approach (Koppmair et al., 2017) or the difference-in-differences method (Kankwamba et al., 2018). This paper argues that the measures implemented in the literature may not be sufficient to cure endogeneity problems in observational studies. Instrumental variables or fixed effects, for instance, are blind to unobserved effects, while the efficacy of the difference-in-differences method hinges on the assumption of a common trend, which may not always hold.

This paper contributes to the literature on impact evaluation and climate adaptation among smallholder farmers by investigating the impact of the FISP reform on the intensification of crop diversification and rotation. We focus on these two outcomes for a number of reasons. First, crop diversification and crop rotation are being promoted to help farmers build resilience to climate change. Second, the reforms broadly sought to enhance smallholder farmers' access to inputs for other crops so as to increase crop diversification and encourage the adoption of conservation farming in general and crop rotation in particular. Third, the low levels of crop diversity and the culture of maize mono-cropping among smallholder farmers, which also hinders the adoption of conservation farming, have been blamed on the limited access to inputs for alternative crops.

The paper will provide empirical evidence and inform policy on how the reform of FISP, which aims *inter alia* to create resilience to climate change, has impacted the degree of crop diversification and adoption of crop rotation in the context of climate change adaptation. As FISP continues to be reformed, this paper will provide insight on how further reforms are likely to impact adoption of crop rotation and other conservation farming principles as the country strives to build a climate-resilient agricultural system.

The paper is relevant to the literature in a number of aspects. First, as noted above, there is no consensus on the impact of input support programmes such as FISP on the adoption of climate-related farming practices. In particular, there are not many studies that have looked at secondary benefits of input subsidy programmes such as FISP.

Second, this paper accounts for variables that influence farmer response to subsidy stimuli. In particular, this paper introduces the measurement of subsidy dependence and objective measures of farm-level exposure to rainfall shocks, which past studies have failed to incorporate. The degree of subsidy dependence has the potential to exacerbate or attenuate the responsiveness of farmers to FISP reforms. Similarly, rainfall outcomes or shocks have the potential to affect farm-level decision-making and response to FISP stimuli. Other areas of novelty include better measures of demographic information which take into account the role of other members of a household, as suggested by both Anderson et al. (2017) and Zepeda and Castillo (1997). In particular, we measure gender based on the proportion of males and education based on the highest level of education in a household.

Third, the paper is based on a rich and unique data set comprising a nationally representative household survey, detailed district level FISP allocation data, and high resolution satellite rainfall data. The household survey data has a rare property of pre- and post-reform observations, which allow for the isolation of the impact of FISP reforms on outcome variables.

Our results generally show a positive impact of the reform on the household-level degree of crop diversification and the intensity of crop rotation. However, we remain inconclusive on the interaction of treatment and the level of dependence on the subsidy. The results also show that crop diversification is a major determinant of the intensity of crop rotation. Key informant interviews demonstrate that the practice of crop rotation is often hindered by the low level of crop diversification, which is partly due to the culture of mono-cropping of the staple crop (maize) and absence of input and output markets for alternative crops.

The rest of the paper is organised as follows. Section 2 discusses the context and the data. Section 3 looks at the estimation strategy and the econometric model employed. Section 4 discusses results and findings, while section 5 draws conclusions.

2 Context and Data

The main data comes from the Rural Agricultural Livelihood Surveys (RALS), a two-wave panel of nationally representative rural households, conducted in 2012 and 2015 (IAPRI, 2016). In the first round in 2012, a total of 476 standard enumeration areas (SEAs) were sampled with probability proportional to their respective number of households, from the 25,207 SEAs used in the 2010 Census of Population and Housing (CSO, 2013). Then households were sampled using stratified random sampling methods, based on the category of farmers defined by the size of land cultivated. Three strata were defined as: A if less than 2 *ha*, B if 2 − 5 *ha* and C if 5 − 20 *ha* (CSO, 2015). Baseline data on crop yield, farm-level crop diversification and rotation was collected in 2010/2011 (and 2011/2012 for some variables).

Then the multi-crop FISP reform was introduced in the 2012/2013 farming season in selected districts. In addition to maize inputs, the selected districts also received inputs for sorghum, groundnuts and cotton.[2] The second round of RALS was then conducted in 2015 with the same households. An additional 680 households were added from 34 SEAs. After accounting for attrition and missing data, we obtained a balanced, two-wave panel of 6113 rural households from the traditional and multi-crop districts. This is further reduced to 2907 rural households because some households have missing information on critical variables, such as fertiliser usage. The data has modules on demographic characteristics of households, farming asset ownership, acquisition and usage of fertiliser, and farming practices that permit the computation of measures of crop diversification and crop rotation, among

[2] In the succeeding farming season, the e-voucher reform was also introduced on a pilot basis in another set of districts.

others. We consider households from multi-crop FISP districts to have received treatment while households from traditional FISP districts serve as control households.

The pre- and post-reform data presents an opportunity to evaluate the impact of the introduction of multi-crop support in the FISP. In this paper, age refers to the age of the head of household. Although traditionally the demographic information of the head is used (Kassie et al., 2013), there is growing evidence that other members of the household, such as a spouse and other adult members, do influence decision making (Anderson et al., 2017; Zepeda and Castillo, 1997) and therefore their demographic information is equally important. Therefore, we define gender as the proportion of males in the household and education as the highest level of education in the household, irrespective of whether it is attained by the head or another member. These measures have the advantage of capturing more detail about the human capital in a household. Household size is the number of members who are above 15 years of age. Membership in associations is defined as at least one member in a household belonging to an association, such as farmers' cooperatives or women's groups, and zero otherwise, while ownership of assets is measured by the number of cattle owned.

Table 1 provides pre-treatment demographic, social and economic information in the control and treated districts. Column 1 shows the means of the overall sample, while (2) and (3) show the means for the control and treated samples, respectively. Column (4) shows the simple differences in means between the control and treated groups. In column (5), we compute the same difference but based on group means that are weighted by a propensity score, discussed below. The asterisks in columns (4-5) indicate the statistical significance of the difference.

Table 1: Social, economic and demographic information

Variable	(1) all	(2) control	(3) treated	(4) diff (raw)	(5) diff (wgt)
age	46.25	48.05	45.68	2.37***	-0.34
gender (male=1)	0.50	0.50	0.50	-0.00	-0.01
education	8.59	9.55	8.28	1.28***	-0.31
hh size	3.45	3.62	3.40	0.22**	-0.28**
been trained	0.79	0.78	0.79	-0.00	-0.01
remoteness	26.47	18.77	29.15	-10.38***	-6.07
land cultivated	2.97	2.39	3.15	-0.76***	-0.60
cattle_number	2.87	1.83	3.20	-1.37***	-1.74
Plough_number	0.32	0.16	0.37	-0.21***	-0.12
Ripper_number	0.03	0.01	0.04	-0.03***	-0.01
Sprayer_number	0.26	0.22	0.27	-0.05	-0.01
cooperative	0.77	0.74	0.79	-0.05**	-0.04*
women group	0.31	0.30	0.32	-0.02	-0.03
Local saving and loans	0.05	0.04	0.05	-0.01	0.00

fertiliser FISP	452.50	452.34	452.55	0.21	-34.03**
fertiliser total	244.62	254.99	241.32	13.67	-13.19
seasonal rainfall	1035.61	1113.88	1010.74	103.14***	8.12
Observations	2907	701	2206	2907	2888

*** p<0.01, ** p<0.05, * p<0.1

From the table, the average age of heads of households is 45.7 years in treated districts and 48.0 in the control and the difference is significant at $\alpha = 0.01$. Similarly, the level of education is also significantly higher ($\alpha = 0.01$) in the control than it is in the treated. The proportion of males in a household is exactly half in both the control and treated. The average household size is just over three adult members in both groups.

Farmers in the treated group cultivate more land than farmers in the control group. The average number of cattle owned is over two, with a very high standard deviation, an indication that the average is pulled down by many zeros. Cattle are an integral asset among smallholders, serving both as a store of value and a source of draft power (Chompolola and Kaonga, 2016; Dibbits, 1999). In all key farming assets, there is no significant difference between the treated and control groups.

Membership in farmer cooperatives was 74% in control districts and 79% in the treated districts with a significant difference, while membership in women's groups was 30% and 32% in the control and treated districts, respectively. Membership in local savings and loan societies is low across all the districts, at just around 5% of farmers. It would seem from these statistics that farmers in the treated group are more likely than those in the control group to belong to at least one farmers' association.

The total quantity of fertiliser used as well as the quantity acquired from FISP are comparable in the two groups. The average quantity of fertiliser used was just above 450kg. The quantity sourced from FISP was more than 240kg in both control and treated groups, above the 200kg that was prescribed per recipient farmer (MoA, 2012, 2016).[3] The average seasonal rainfall was higher in the control than the treated districts.

The data shows that there are significant differences in some covariates between the treated and control groups. These differences are expected given that assignment to treatment was non-random. As a consequence, the simple estimates may yield biased results. This calls for identification strategies that will take into account the observed pre-treatment differences in covariates. This paper proposes, in the following section, the use of inverse probability weighting with regression adjustment. Based on that

[3] Households may acquire more than the stipulated quantity from FISP because some households may have more than one member registered to receive FISP inputs. In some cases, two or more farmers may, informally, share a pack.

approach, the weighted differences in column (5) of table 1 show that the treated and control subsamples are no longer statistically different in terms of the listed covariates.

Attrition in panel data sets has the potential to bias the results if factors driving attrition are also related to factors driving variables of interest. The two rounds of the RALS data have an attrition rate of about 18%. Similar surveys such as Xu et al. (2009) have also observed an attrition rate of around 18%, while Asfaw and Davis (2018) observed an attrition rate of 8.7% over two years. The paper performs a regression-based test for attrition bias, as described in Wooldridge (2010, p.837). Dependent variables are regressed on a binary indicator variable defined to categorise respondents into those that form the panel and those lost to attrition, as well as other regressors. The regression results are presented in table 2 with other variables suppressed. Columns 1 and (2) show regressions of crop diversification and crop rotation while (3) shows the regression of the treatment variable.

Table 2: Auxiliary regression for test of attrition bias

VARIABLES	(1) SID	(2) CR	(3) Treatment
attrition	0.006	-0.028	0.027
	(0.020)	(0.017)	(0.019)
Constant	0.597***	0.683***	0.966***
	(0.037)	(0.033)	(0.037)
Observations	3,511	3,511	3,512

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The attrition test results in table 2 show an insignificant attrition indicator in all three regressions. These results show that the dependent variables, as well as assignment to treatment, are independent of attrition. The observed attrition is not expected to bias the results, and therefore, does not require any remedial measures.

The data is supplemented with high resolution ($0.25^{\circ} \times 0.25^{\circ}$) satellite rainfall data, obtained from the Climate Hazards group Infrared Precipitation with Stations (CHIRPS). CHIRPS uses multi-satellite precipitation analysis to calibrate rainfall estimates (Funk et al., 2015). Each household is linked to the nearest satellite point. Using this data, we compute the amount of seasonal rainfall for each farmer. This is used in the regressions to control for variations in rainfall. Rainfall has the potential to affect farmers' response to climate change adaptation measures, as well as to favour or hinder the cultivation of certain crops.

In addition, in-depth primary interviews were conducted with Agricultural Extension Officers (AEOs). These interviews solicited detailed information on the frameworks that are available to support climate change adaptation, as well as the challenges and opportunities that each adaptation strategy presents. A multi-stage sampling approach was utilised to choose AEOs to interview. First, two farming districts were selected purposively, mainly to represent the two farming regions of the country: Monze in the low rainfall southern region and Chisamba in the medium rainfall central region. At the time of the interviews, Chisamba had 16 AEOs while Monze had 39. However, only 10 were available in Chisamba and were all interviewed. In Monze, a systematic sampling method was used to select 11 from amongst AEOs that had clocked five years in their positions. In addition, one officer was interviewed from the District Agricultural Office in each of the two districts. The qualitative data is important to provide context to some quantitative findings.

3 Estimating the Impact of Reform

The model in this paper is based on the *Neyman-Rubin model* of treatment effect (*see* Abbring and Heckman (2007), Rosenbaum and Rubin (1983), and Sekhon (2010)). Each farmer is assigned to either traditional or multi-crop FISP. The assignment of districts to treatment was informed by their respective microclimates, among other factors (MoA, 201), which also have the potential to impact outcome variables. The criteria-based assignment brings two central problems: 1) the post-treatment differences include pre-treatment difference in outcomes and 2) the treated and control would evolve with different trajectories (Fredriksson and Oliveira, 2019; Stuart et al., 2014). This defeats the parallel trend hypothesis, discussed below.

A number of methods have been suggested to deal with the resulting potential endogeneity: regression adjustment (RA), inverse probability weighting (IPW) with regression adjustment (IPWRA), instrumental variables (IV), Difference in Differences (DiD), regression discontinuity (RD) and matching methods, including propensity score matching (PSM) and nearest neighbour matching (NNM). The RA includes potential explanatory variables in the model in order to isolate a treatment-induced difference in outcomes, while the IPW computes a weighted difference, where weights are based on each observation’s probability of belonging to the treated (or control) group (Cattaneo, 2010; Imai and Dyk, 2004; Imbens and Wooldridge, 2009; Lopez and Gutman, 2017). The instrumental variables method relies on an additional layer of treatment that satisfies specific exogeneity restrictions (Frolich, 2004; Imbens and Wooldridge, 2009); it requires identification of an instrument that has no direct influence on outcome variables, except through its influence on selection for treatment, and is blind to unobserved determinants (White, 2013).

In this paper, we identify the impact of FISP reform on adoption of crop diversification and rotation practices using the difference-in-differences (DiD) approach in combination with the inverse probability weighting with regression adjustment (IPWRA) and matching methods. The DiD controls the post-estimation difference with the pre-treatment differences to isolate the effect of treatment, particularly with respect to time-invariant unobservable factors (Asfaw and Davis, 2018). The DiD provides a panel comparison of treated vs. control and before vs. after treatment and is able to isolate time-invariant unobservable determinants through differencing (Frolich, 2004; Imbens and Wooldridge, 2009).

Identification using DiD relies on the parallel trends assumption that, in the absence of treatment, the treated would have followed the same time trend as the control group (Fredriksson and Oliveira, 2019; Stuart et al., 2014). This assumption, however, cannot be tested in a DiD approach with only one time point on each side of treatment. Because of criteria-based assignment to treatment, the treated and the control groups are likely to differ in variables that also influence the time trends of outcome variables. This selection bias across groups is not cured by DiD alone. A regression discontinuity design is not applicable to solve this problem in the present circumstance because it requires many time points on at least one side of treatment (Imbens and Wooldridge, 2009)

Matching methods generally use the Mundlak (1978) and Rosenbaum and Rubin (1983) approaches. The approaches utilise *propensity score* and/or *nearest neighbour* matching (Sekhon, 2010). Propensity score matching (PSM) involves matching each treated unit with the nearest control unit on the basis of a propensity score, a unidimensional metric (ibid.). On the other hand, the nearest neighbour matching (NNM) approach imputes the unobserved potential outcomes for the control group using average outcomes of individuals with similar observed characteristics based on the *Mahalanobis distance* (Imbens and Wooldridge, 2009; Rosenbaum and Rubin, 1983; Sekhon, 2010).

Matching methods fail to cure the problem of unobservables; we will address this problem below.

The simple ordinary least squares estimation of the DiD is of the form

$$\Delta Y_{ijt} = \tau T_{ijt} + \varepsilon_{ijt}, \tag{1}$$

where T_{ijt} is one if the farmer is from a multi-crop district and zero if he or she is from traditional FISP districts, and Y_{ijt} represents measures of crop diversification and crop rotation. Crop diversification (CD) refers to the cultivation of multiple crops in each season, often driven by the desire to spread the risk of crop failure attributed to climate hazards (Feliciano, 2019; Kankwamba et al., 2018; Maggio et al., 2018). We measure crop diversification using the Simpson index of diversification (SID), based on Simpson (1949), which can be computed at either hectarage or output levels. At hectarage level, the index reveals farmers' actions or efforts towards diversification. When computed at output level, it shows the level of diversification in output, which might differ from the measurement at hectarage level if crop failure is not independent of crop type. In this paper, we follow Kankwamba et al. (2018) and compute the index at hectarage level, given by

$$SID = 1 - \sum \left(\frac{A_i}{\sum A_i}\right)^2 \quad (2)$$

where A_i is the area of land allocated to the ith crop. The index is bounded between 0 and 1. The SID has been applied in a number of studies such as Arslan et al. (2018) in Zambia, and Jones et al. (2014) and Kankwamba et al. (2018) in Malawi.

Crop rotation (CR) is defined as the alternation of crops cultivated on the same land during successive cultivation cycles (Kassam et al., 2019), without placing any emphasis on the use of legumes as required in the FAO's definition (2019). The intensity is then computed in line with Andersson and D'Souza (2014) as the proportion of land under crop rotation to total land cultivated,

$$PCR_{it} = \frac{H_{it}^{CR}}{H_{it}} \quad (3)$$

where H_{it}^{CR} is the total hectarage under crop rotation and H_{it} is the total hectarage of all the fields. It is bounded in [0,1]: zero if crop rotation was not practised at all and one if crop rotation was implemented on the entire cultivated land.

The OLS estimation in eqn. 1 is likely to yield biased results arising from selection bias. As demonstrated in table 1, there are systematic differences between the treated and control households which would violate the parallel trends assumption. Therefore, we identify the treatment effect using the IPWRA and propensity matching. Rosenbaum and Rubin (1983) have demonstrated that, when conditioned on a set of observable explanatory variables *X*, non-random assignment can be considered unconfounded. Therefore, the difference that is observed *ex post*, conditional on *X*, is attributed to the effect of the treatment. As noted by Abadie and Imbens (2006), matching estimators are consistent even under weak regularity conditions. The combination of DiD and propensity weighting/matching has been employed by Alem and Broussard (2017) and Gilligan and Hoddinott (2007) to evaluate the impact of Ethiopia's food aid programme and has the advantages of both curing unobserved time invariants and improving the balance between comparison groups.

The IPWRA also allows for the examination of other control variables which are difficult to evaluate under matching estimators. In particular, the model includes a measure of subsidy dependence, SD, and its interaction with treatment. Subsidy dependence can be defined as the extent to which a farmer depends on FISP for inputs. This ratio is calculated using the number of 50kg bags of fertiliser a farmer uses as a measure of inputs. Therefore, the following expanded model is estimated

$$Y_{it} = \tau T_{it} + \pi(T_{it} \cdot SD_{it}) + \theta SD_{it} + X'_{it}\beta + \varepsilon_{it}, \tag{4}$$

where X is a vector of household characteristics including education, family size, land size, ownership of cattle, wealth status, distance to main amenities (including Extension Officers and markets), and seasonal rainfall amount measured from the nearest satellite measurement point.[4] Although assignment to treatment and control was based on district characteristics, Arpino and Mealli (2011) have demonstrated that matching on district-level characteristics is not necessary. Following Arpino and Mealli (ibid.), the propensity score is specified as a function of household-level characteristics.

Subsidy dependence might be related to a farmer's economic status but may bring out other interesting aspects. For instance, issues of access to input markets and the role of inter-household transfers are well captured by looking at an index of dependence on FISP. A farmer may be well-to-do but lack market access, especially in remote areas, which has the potential to impact decision-making (Arslan et al., 2014; Jayne and Rashid, 2013). Others will be poor but enjoy inputs through inter-household transfers (Fink et al., 2014). In the two cases, the response to FISP reforms will differ from what would be predicted by economic status alone.

We are motivated to consider dependence on fertiliser for three reasons. First, fertiliser is used in a reasonably fixed ratio with improved seed and other inputs. Second, fertiliser is mostly supplied in standardised quality and packaging of 50kg bags, which makes it easy for farmers to account and recall. Third, although farmers can use any type of fertiliser, most use the Nitrogen, Phosphorous and Potassium (NPK) 10-20-10 for basal or 46-0-0 for top dressing, especially for maize (Burke et al., 2019). Using seed might be biased by use of recycled seed, which introduces different qualities (Thapa and Keyser, 2012). Wineman et al. (2020) have shown that, in Tanzania, it is common for farmers to misrepresent recycled seed as being improved seed. Therefore, the SD is defined on the basis of fertiliser as

$$SD = \frac{Q_F}{Q_T} \tag{5}$$

where Q_F is the quantity of fertiliser obtained from FISP and Q_T is the total quantity used. The index is bounded in [0,1]. In the extremes, it is 1 if a farmer is wholly dependent on FISP for fertiliser and 0 if the farmer did not receive fertiliser from FISP in the particular farming season.

[4] In Zambia, the agricultural season runs from 1st October of one year to 30th September of the following year (Mason et al., 2013).

In order to account for clustered sample selection in line with Abadie et al. (2017), the standard errors are clustered. Abadie et al. (2017) has argued for clustered standard errors whenever the sampling is clustered as is the case in this paper.

4 Results and Discussion

This section analyses the data and the discussion of the results in two parts. Section 4.1 looks at the impact of reforms on the degree of crop diversification, while section 4.2 looks at the impact on the intensity of crop rotation. We are motivated to discuss the two separately mainly because crop diversification is an outcome in the former but a determinant factor in the latter.

4.1 The Impact of FISP Reform on Crop Diversification

We measure the ATET of multi-crop FISP reforms on the degree of crop diversification using the model developed from the general model in eqn. (4),

$$SID_{it} = \tau T_{it} + \pi(T_{it} \cdot SD_{it}) + \theta SD_{it} + X_{it}'\beta + \varepsilon_{it}, \quad (6)$$

where SID_{it} is the Simpson index of diversification in eqn. 2, measured at household level. The index is bounded between 0 and 1 and the bounded *tobit* will be used for estimation. The tobit model combines a binary choice model in the censored portions and a linear regression model in the uncensored portion (Greene, 2012, p.764). It is similar to a two-stage decision process, where a farmer is assumed to make a binary adoption decision in the first step and then decides on the extent or degree of adoption in the second step. The estimation results are presented in table 3. Column (1) shows the DiD in isolation, while column (2) has control variables added. Columns (3) and (4) show the DiD combined with IPWRA and PSM, respectively.

Table 3: Impact of FISP Reform on Crop Diversification

VARIABLES	(1) OLS	(4) RA	(5) IPWRA	(7) PSM
_Itreat_1	0.1358***	0.1411***	0.1268***	0.0921***
	(0.0280)	(0.0271)	(0.0278)	(0.0190)
subsidy dependency (sd)	0.0867***	0.0798***	0.0816***	
	(0.0154)	(0.0162)	(0.0218)	
_ItreXsd_1	-0.0302	-0.0384*	-0.0333	
	(0.0185)	(0.0201)	(0.0254)	
educ_highest		-0.0139***	-0.0124***	
		(0.0019)	(0.0022)	
age		0.0039*	0.0027	
		(0.0021)	(0.0024)	
age2		-0.0000	-0.0000	

		(0.0000)	(0.0000)	
gender		-0.0046	0.0055	
		(0.0224)	(0.0267)	
remoteness		0.0007**	0.0012***	
		(0.0003)	(0.0003)	
adult_number		-0.0029	-0.0046*	
		(0.0025)	(0.0028)	
cattle_number		-0.0020***	-0.0012*	
		(0.0005)	(0.0007)	
any_trained		0.0437***	0.0382***	
		(0.0111)	(0.0121)	
land_used		0.0118***	0.0085	
		(0.0029)	(0.0058)	
_Ifarm_cate_2		0.0823***	0.0969***	
		(0.0132)	(0.0171)	
_Ifarm_cate_3		0.0422***	0.0493**	
		(0.0158)	(0.0205)	
soc_net_coop		0.0011	-0.0088	
		(0.0117)	(0.0142)	
rainfall_seasonal		0.0000	0.0001	
		(0.0000)	(0.0001)	
rainfall_seasonal_1		0.0002***	0.0001	
		(0.0001)	(0.0001)	
Constant	0.3928***	0.0420	0.0478	
	(0.0157)	(0.0715)	(0.0766)	
Observations	5,800	5,039	5,039	2,894

Standard errors clustered by standard enumeration area; *p<.05; **p<.01; ***p<.001

The results show a positive impact of the introduction of multiple crops in the FISP on the degree of crop diversification. The coefficient on multi-crop reform is positive and statistically significant across the four estimators. We note that there is a noticeable reduction of the coefficient in the PSM. Multi-crop treatment increases the degree of crop diversification by between 6.8 and 12.0 percentage points. These results are consistent with expectation and suggest that the additional inputs do not displace private investments in other crops. Farmers who benefit from inputs of ‘other’ crops end up growing more of the ‘other’ crops.

The index of subsidy dependency (SD) is highly significant, suggesting that farmers who are highly dependent on FISP tend to have high levels of diversification. Because of dependence on FISP for inputs, these farmers are more likely to grow limited quantities of many crops. On the other hand, farmers who are less dependent on FISP usually are economically advantaged and tend to grow large quantities of a few crops or to concentrate on cash crops. This would have the effect of reducing the level of crop diversification, as observed here. The interaction of treatment and subsidy dependence

(SD) is insignificant. We conclude that the impact of FISP reforms is uniform across different degrees of dependence on FISP.

The level of crop diversification seems positively associated with the age of the head of household, though at a declining rate. Age has a positive influence on the level of crop diversification, but, beyond a certain age, estimated around 40 years, farmers tend to concentrate on fewer crops. Age is associated with the accumulation of knowledge, experience, and physical and social capital (Kassie et al., 2013). This would lead to an increasing level of crop diversification. However, beyond a certain level, age is associated with a loss of energy and a shorter planning horizon (Kassie et al., 2013, 2015; Pedzisa et al., 2015), which might contribute to concentration on basic or staple crops. The coefficient on education is significantly negative, suggesting that a higher level of education in a household is associated with a reduced level of crop diversification. There are no differences in the level of crop diversification between female- and male-dominated households.

More remote households tend to have a higher degree of crop diversification. With longer distances to critical amenities such as roads, markets and extension services, households located in remote areas are less likely to concentrate on cash or high value crops, but instead tend to grow small quantities of many crops. This has the net effect of raising the degree of crop diversification as measured in this paper.

Large households and those owning more cattle tend to have low levels of crop diversification. With both human and physical capital at their disposal, this category of farmers is more likely to concentrate on cash crops. However, when a large portion of land is available, there is a high level of crop diversification. The same is true for category 2 and 3 farmers, who cultivate more land compared to category 1 farmers. This may suggest that inadequate land could be hindering the enhancement of crop diversification among smallholder farmers.

Similarly, receipt of training is associated with an increased level of crop diversification. Training of farmers takes different forms and is offered both by the government, through AEOs, and by cooperating partners. These trainings include orienting farmers on climate change and adaptation strategies, which explains why training leads to increased levels of crop diversification. There are also indications that membership in farmer groups, such as women's groups and local saving and loans societies, is associated with higher levels of crop diversification. Membership in farmer groups provides a platform for information sharing among farmers, receipt of extension services, and FISP inputs. Therefore, farmers who belong to these groups are expected to have more knowledge and appreciation of the importance of crop diversification.

Crop diversification can increase farmers' resilience to periods of low rainfall. However, the results here show the opposite behaviour: crop diversification is higher in periods of higher rainfall and lower in periods of lower rainfall. Crop diversification is actually reduced when there is a threat of a drought. This finding is also supported by a key informant who stated that,

> *''Our farmers have not grown a lot of crops right now, they still wanted to plant but the rains are gone. They just concentrated on maize immediately they received early rains. Most of them planted maize than other crops. Other crops, that is when they wanted to start.'' (MO, F)*

When there is enough rainfall, farmers are able to grow more alternative crops, enhancing the level of crop diversification. However, in periods of rainfall stress, there is usually little time to venture into many crops. Instead, most farmers concentrate on the staple crop. This finding also may reflect farmers' risk aversion, in that they are reluctant to try something new during a low-rainfall period that threatens their subsistence.

4.2 The Impact of FISP Reform on Adoption of Crop Rotation

To measure the impact of the reform on the adoption of crop rotation, we use a tobit regression method to estimate the model of the form:

$$PCR_{ij} = \tau T_{it} + \pi(T_{it} \cdot SD_{it}) + \theta SD_{it} + X_{it}'\beta + \varepsilon_{it} \qquad (7)$$

where P^{CR} is the proportion of land under crop rotation, as defined in eqn. (3), and other variables are as defined in eqn. (4). The regression results are presented in table 4. Column (1) shows the DiD in isolation while the other columns combine the DiD with regression adjustment (in column (2)), IPWRA (in column (3)) and PSM (in column (4)).

Table 4: Impact of FISP reforms on Crop Rotation

VARIABLES	(1) OLS	(4) RA	(5) IPWRA	(7) PSM
_Itreat_1	0.2624***	0.2073***	0.2335***	0.1880***
	(0.0419)	(0.0371)	(0.0456)	(0.0219)
subsidy dependency (sd)	-0.0378	-0.0491**	-0.0737**	
	(0.0263)	(0.0220)	(0.0345)	
_ItreXsd_1	-0.0114	-0.0181	-0.0288	
	(0.0378)	(0.0334)	(0.0441)	
SID		0.7568***	0.7706***	
		(0.0490)	(0.0568)	
educ_highest		-0.0017	-0.0026	
		(0.0029)	(0.0034)	
age		-0.0083**	-0.0090**	
		(0.0033)	(0.0041)	
age2		0.0000	0.0000	

		(0.0000)	(0.0000)	
gender		0.0023	-0.0295	
		(0.0370)	(0.0598)	
remoteness		-0.0014***	-0.0016***	
		(0.0003)	(0.0005)	
adult_number		0.0043	0.0084	
		(0.0041)	(0.0064)	
cattle_number		-0.0008	-0.0008	
		(0.0009)	(0.0013)	
any_trained		0.0425**	0.0429*	
		(0.0195)	(0.0228)	
land_used		-0.0045	-0.0133***	
		(0.0034)	(0.0047)	
_Ifarm_cate_2		0.0146	0.0291	
		(0.0174)	(0.0231)	
_Ifarm_cate_3		0.0350	0.0540*	
		(0.0236)	(0.0310)	
soc_net_coop		0.0051	0.0135	
		(0.0198)	(0.0286)	
rainfall_seasonal		-0.0008***	-0.0005***	
		(0.0001)	(0.0001)	
rainfall_seasonal_1		0.0007***	0.0005***	
		(0.0001)	(0.0001)	
Constant	0.6336***	0.5585***	0.5033***	
	(0.0266)	(0.1059)	(0.1419)	
Observations	5,812	5,765	5,762	2,897

Standard errors clustered by standard enumeration area; *p<.05; **p<.01; ***p<.001

The results show a statistically significant positive impact of multi-crop FISP on the intensity of crop rotation at the household level. The coefficients are significant across the four estimation methods. *Ceteris paribus*, multi-crop reform raises the intensity of crop rotation by more than 18 percentage points. This means the FISP reform of providing inputs for many crops is effective in promoting the intensification of crop rotation among smallholder farmers.

The coefficient on subsidy dependency is insignificant in the OLS estimation but significant in the adjusted regressions (RA and IPWRA). Conversely, the interaction of subsidy dependency and treatment is negative, although insignificant in all the regressions. Nonetheless, the results do suggest that the impact of the multi-crop reform decreases with subsidy dependency. Farmers highly dependent on FISP seem less responsive to FISP reforms compared to farmers who are less dependent on FISP. Obviously very poor farmers (1) are also highly risk averse (Pedzisa et al., 2015), (2) may be cultivating fields that are too small for a beneficial rotation, or (3) may be focused on staple crop cultivation (Maggio et al., 2018). Even with the reform, this kind of farmer has little of the flexibility necessary to implement crop rotation. Our results, however, are inconclusive on this.

The degree of crop diversification shows quite strongly as a driver of the intensity of crop rotation at household level. The coefficients are consistently significant in both the DiD and its combination with IPWRA. A change from mono-cropping to perfectly diversified farming would increase the intensity of crop rotation by more than 50 percentage points, *ceteris paribus*. This suggests that access to inputs for other crops and the level of crop diversification complement each other in the adoption of crop rotation. These results are also supported by qualitative findings, as demonstrated in the following excerpts.

> *''Usually, legumes they plant small areas compared to cereal crops. So now to rotate cereal crop where a legume was, it can't fit properly.'' (CH,M)*

> *''You find that the maize portion is very big and for groundnuts very small. So next year, you find it will not balance, ... They don't have equal portions of land to balance with maize. Farmers are concentrating much on maize'' (CH,M)*

> *''Then crop rotation also, mono-culture is also high ... because the farmers would say, this is the only field I rely on where I harvest maize. So why should I plant a legume?'' (MO,F)*

> *''Most of the farmers [here] are maize growers, they don't rotate their fields but we have explained to them the importance of crop rotation'' (MO,F)*

The above statements suggest that the adoption of crop rotation among smallholder farmers is hampered by the low levels of crop diversification. A detailed discussion of drivers of crop diversification is presented in the preceding section. Suffice to say that issues of markets and access to inputs for other crops remain the major factors.

The intensity of crop rotation declines with age and level of education, although the rate of decrease declines with age. It was argued earlier that increased age is associated with loss of energy and a shortened planning horizon (Kassie et al., 2013, 2015; Pedzisa et al., 2015). At the same time, age also comes with specialisation in cash and staple crops, which would have the effect of inhibiting the practice of crop rotation as farmers cultivate portions of staple/cash crops that are too large for rotation with legumes. The level of education in a household is hypothesised to improve knowledge and appreciation of new farming practices. At the same time, education may also be positively related to access to non-farm income (Kassie et al., 2013). This may have the effect of reduced attention to farm activities and concentration on a few crops.

Farmer training and extension services remain important in promoting the adoption of new farming technologies. Farmers who reported receiving training related to crop rotation tended to have higher intensity of CR. As expected, education or training helps farmers appreciate the importance of crop rotation and promotes its adoption. These results are in conformity with findings from a number of studies both in Zambia and elsewhere (Kassie et al., 2013; Mulwa et al., 2017).

Other important variables include the measures of remoteness, which include distance to a tarred road, a communication network and an agro-dealer. The results show that farmers who are located in remote areas tend to practice little or no crop rotation. This is consistent with findings from other studies such as Arslan et al. (2014) and Feliciano (2019), who found a negative association between distance to a tarred road and adoption of new farming technologies. Farmers in very remote areas are deprived of access to information and appropriate technologies such as tools and implements that would support the intensification of crop rotation. Access to markets for other crops also remains a challenge for these farmers, who tend to rely on the government-run Food Reserve Agency (FRA), mainly for the staple crop.

Rainfall may have two opposing effects on the adoption of climate-related farming practices such as CF in general and crop diversification and crop rotation in particular. First, low rainfall may cause farmers to diversify the crop base in order to spread the risk; in the process, they also practice crop rotation. This is expected to produce a negative coefficient of rainfall on adoption of CF. However, during a season of low rainfall, farmers concentrate on staple crops. This also has the effect of stifling the practice of crop rotation and is expected to produce a positive coefficient. The results show a negative *contemporaneous* effect and a positive coefficient on the *lag* of rainfall. This implies that farmers respond to previous episodes of low rainfall by adopting crop rotation in future seasons. A further examination shows that low rainfall in two consecutive periods is not likely to produce any effect, as the positive and negative effects counterbalance each other.

5 Conclusion

The paper looked at the impact of FISP reforms using a mixed methods approach. The paper finds that FISP reforms have been successful in altering the agricultural landscape among smallholder farmers. The reforms have allowed the cultivation of other crops as well as offering flexibility to farmers to respond to climate change.

The results on the impact of reforms on crop diversification are incongruous. The multi-crop reform is found to have a significantly positive impact on the level of crop diversification. These results support the expansion of the multi-crop FISP in order to promote crop diversification, which is necessary in climate change adaptation. The impact of reforms on the intensification of crop rotation is positive but is potentially underestimated by the indirect effect through crop diversification. Our model has controlled for crop diversification, allowing the estimation of the direct impact of reforms on crop rotation.

However, the effectiveness of these reforms is hampered by a number of other factors. These include the absence of well-functioning private sector-led markets for inputs and sale of alternative crops. Key informant evidence shows that farmers fail to respond to the stimuli of FISP reforms because they cannot find certified seeds for other crops on the market and because the output market is not as assured as is the case with maize. In addition, farmers respond to early dry spells not by diversifying their crop base, but by concentrating on maize production based on the safety first principle. Key informant evidence also shows that the culture of mono-cropping of maize is well entrenched among smallholder farmers. In the absence of well-functioning crop insurance and other social safety nets, the farmers' primary concern is securing the staple crop.

Promoting the adoption of climate-smart agricultural technologies among smallholder farmers through FISP reforms will require parallel reforms in other aspects of agriculture. In particular, there is a need for enhanced extension services and an improvement in markets for both inputs and output of alternative crops.

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