Zambia's Agricultural Input Subsidy Program: Estimating the impact of e-voucher delivery system on crop diversification*

Abstract

This paper employs a treatment effect approach to evaluate the impact of the electronic-voucher reforms to Zambia's Farmer Input Support Programme on household-level crop diversification and rotation. The paper combines a two-wave panel of rural household survey data, high-resolution satellite rainfall data, and primary qualitative data from in-depth interviews with key informants to provide answers to questions around the effectiveness of the reforms in promoting climate adaptation through crop diversification and the practice of crop rotation. The results however do not show any positive impact of the reforms on outcome variables. Instead, the reform is seemingly associated with a negative change in outcome variables. Our key informant evidence point to rigidities in private sector markets and cultural barriers as major hindrances to the effectiveness of the electronic-voucher reforms in enhancing crop diversification and rotation. This raises important policy implications on the need for broader reforms including the promotion of markets for alternative crops and enhanced extension services.

Keywords: crop diversification, crop rotation, impact evaluation, reforms.

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 is projected to decrease by about 3% by mid-century (Hamududu and Ngoma, 2019). The declining rainfall threaten the viability of Zambia's smallholder dominated, maize-centric agricultural sector and the livelihood of the vulnerable rural population (Hamududu and Ngoma, 2019; Smit and Pilifosova, 2001). In response, stakeholders have been promoting crop diversification t in order to help minimise

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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).

Alongside many efforts, the government has continued to reform the country's agricultural subsidy programme, dubbed Farmer Input Support Programme (FISP).[1] FISP provides highly subsidized 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). When selected, a farmer is shortlisted to receive one pack of inputs, which, before the reforms, comprised 10kg of hybrid maize seed and 200kg of fertilizer (MoA, 2012, 2016). To be eligible, a farmer had to belong to a cooperative/farmer organisation and be cultivating between half and two hectares of maize (MoA, 2012, 2013a, 2016).

The reforms included the expansion of the programme to include inputs for multiple crops (MoA, 2012) and the introduction of the electronic voucher input delivery system in selected districts (MoA, 2013b). In the multicrop districts, benefiting farmers received inputs of either groundnuts or cotton in addition to either maize or sorghum. In the e-voucher districts, the government provides participating farmers with electronic vouchers[2] which they redeem with farming inputs of their choice from participating agro-dealers. The e-voucher system expanded the choice of crops for farmers in the selected districts so as to include not only a variety of crops, but livestock feed and medicines, fish feed and fingerlings (ibid.). This paper will focus on the e-voucher reform.

The e-voucher system was initially piloted in 16 districts out of the 104 existing at the time. These are Chibombo, Chisamba, Kabwe, Kapiri-Mposhi, Mumbwa, Ngabwe, and Shibuyunji in the Central province; Ndola in the Copperbelt province; Chongwe in Lusaka province; and Chikankata, Choma, Kalomo, Mazabuka, Monze, Pemba, and Zimba in the Southern province (MoA, 2013b; Siame et al., 2017). Districts were selected for the e-voucher partly because of their proximity to transport lines in order to take advantage of existing communication and transport infrastructure that is conducive to private sector participation in the input distribution and supply under the e-voucher system (MoA, 2013b). See figure 1, where e-voucher districts are shown in blue while the traditional fisp is red. Districts on the multicrop treatment, which is outside the scope of this paper, remain in white.

The introduction of the e-voucher system was intended to achieve a number of broad objectives including: (1) reducing public expenditure, especially on the delivery of inputs; (2) encouraging private sector participation in the agro-input market; and (3) providing farmers with the freedom to choose crops, and promoting diversification both in terms of crop mix and a shift to other farm enterprises, such as livestock or aquaculture (Kuteya and Chapoto, 2017). It is envisaged that, with the inputs of many crops redeemable, farmers will start to move towards crops suitable to their respective microclimates and hence improve their resilience to extreme weather events. In addition, the system is also expected to improve the degree of CD at the household level.

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[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).

[2] In the 2013/2014 farming season, each voucher had a face value of K950 ($US\$1 \approx K5.39$ then). Farmers were required to top up this amount by K190 (20%) up front. In the 2019/2020 farming season, e-vouchers had a redeemable value of K2, 000. Farmers contributed K300 and government contributes K1, 700 ($US\$1 \approx K13.40$ then).

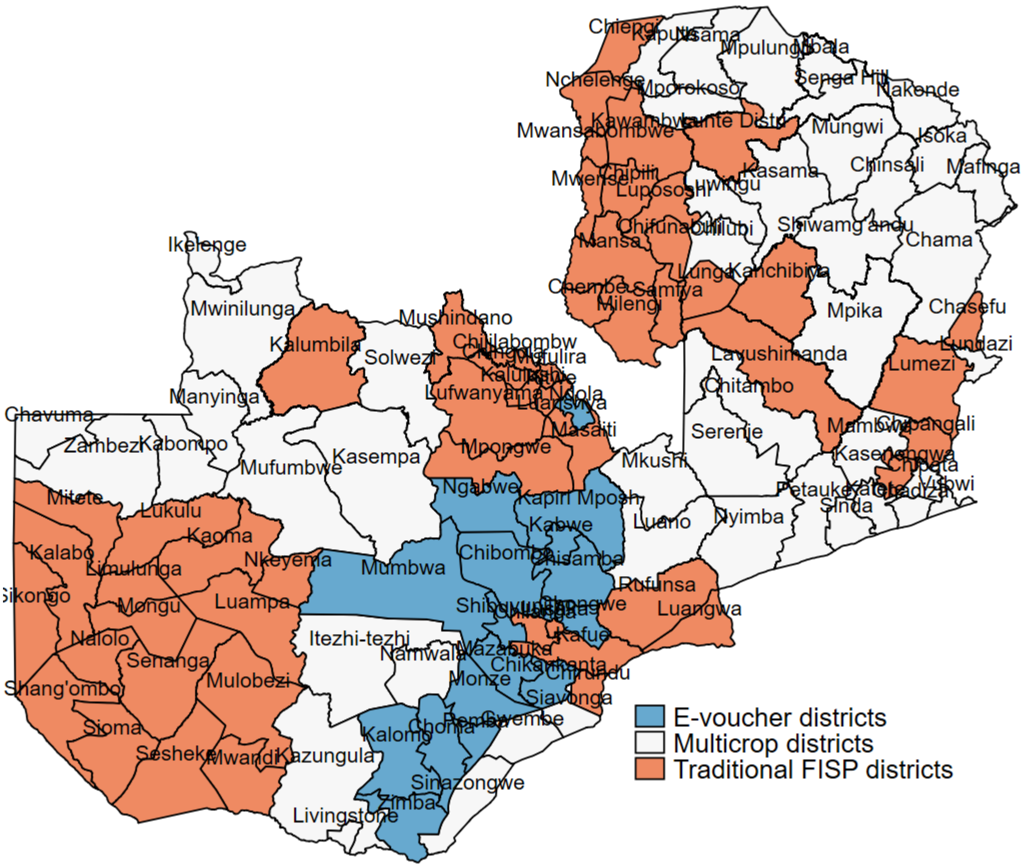

Figure 1: Districts classified by FISP type in the 2013/14 agricultural season.
Source: Author generated based on the FISP implementation manuals (MoA, 2013a)

The e-voucher system was ultimately rolled out to all the districts in the 2017/2018 farming season. However, due to communication network limitations in some districts, and competence limitations in the usage of ICT, among other challenges, some districts were returned to the direct input supply mode (MoA, 2018).

In theory, the reform must lead to increased diversification as farmers use the inputs on other crops or ventures besides maize. However, it is also possible that farmers may fail to diversify due to other binding constraints such as the availability of complementing inputs, cultural rigidities and the imperfections of output markets for alternative crops (Khonje et al., 2022a). Although secondary effects of reforms are important, available literature tend to focus on primary objectives such as input delivery efficiency, household level input use, output and productivity. Not many studies (Kankwamba et al., 2018; Khonje et al., 2022b; Koppmair et al., 2017; Matita et al., 2022) have looked at the impact of subsidy programme reforms on secondary objectives such as crop diversification and climate adaptation even though such reforms have the potential to accelerate adoption of new technologies.

For instance, Koppmair et al. (2017) noted that a subsidy programme is a good avenue for promotion of conservation farming practices, Kankwamba et al. (2018) found the subsidy programme to have a positive effect on the degree of crop diversification among farmers in Malawi, while and Khonje et al. (2022b) found that subsidies of legumes were associated with increased hectarage of legumes in Malawi. On the other hand, Matita et al. (2022) have argued that the impact of access to subsidised inputs of legumes on crop diversification is context specific and the impact varied within Malawi. Other studies, such as Jayne et al. (2018), argue that subsidy programs 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 programs 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 localized empirical studies that take into account prevailing agro-climates, farming systems and other key variables.

Evaluation of agricultural input subsidy programs also presents endogeneity problems due to self or criteria-based selection to treatment. Potential remedies include instrumental variables (Chibwana et al., 2014), the fixed effects approach (Koppmair et al., 2017) or the difference-in-differences method (Kankwamba et al., 2018). However, these may not be sufficient to cure endogeneity problems in observational studies. Instrumental variables or fixed effects, for instance, do not cure unobserved effects, while the efficacy of the difference-in-differences hinges on the assumption of a common trend, which may not always hold (Fredriksson and Oliveira, 2019; Stuart et al., 2014).

This paper contributes to the literature on impact evaluation and climate adaptation by investigating the impact of the introduction of the e-voucher system on household level crop diversification. We focus on crop diversification for a number of reasons. First, crop diversification is being promoted to help farmers build resilience to climate variability. Second, the reforms broadly sought to enhance smallholder farmers' access to inputs for other crops so as to increase crop diversification. Third, the low levels of crop diversity and the culture of maize mono-cropping among smallholder farmers, have been blamed on the limited access to inputs for alternative crops.

The paper will provide empirical evidence and inform policy on how the reforms of FISP, which aims, *inter alia*, to create resilience to climate variability, has impacted the degree of crop diversification in the context of climate adaptation. As government plans to roll-out the e-voucher system, this paper has potential to provide insight on how this is likely to impact crop diversification and climate adaptation in general.

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 programs 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 programs 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 not appropriately incorporated. 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 in a household and education based on the highest level of education in a household as opposed to demographics of the head only.

Third, the paper used a rich and unique data set comprising a nationally representative household survey, detailed district level FISP allocation data, high resolution satellite rainfall data and qualitative data from key informant interviews. 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 lack of positive impact of the reform on the household-level degree of crop diversification and the intensity of crop rotation. The results actually suggest a negative impact of the reforms on the intensity of crop rotation. These results are supported by key informant evidence, which point to existing barriers to crop diversification and practice of crop rotation. The results also show that crop diversification is a major determinant of the intensity of crop rotation. Key informant evidence suggest 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 organized 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).

The e-voucher reform was piloted in the 2013/2014 farming season in selected districts. 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 $6,113$ rural households from e-voucher and traditional FISP districts. This is further reduced to $2,907$ rural households because some households have missing information on critical variables, such as fertilizer usage. The data has modules on demographic characteristics of households, farming asset ownership, acquisition and usage of fertilizer, and farming practices that permit the computation of measures of crop diversification and crop rotation, among others. We consider FISP recipients from e-voucher districts to have received treatment while recipients from traditional FISP districts serve as control households.

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. Social capital is defined as at least one member of 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 respective assets 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	47.06	46.64	48.12	-1.48*	-0.51
gender (Proportion)	0.47	0.47	0.47	0	0.02
education	8.16	7.99	8.59	-0.60***	0.40**
household size	3.24	3.15	3.47	-0.32***	0.21
trained	0.6	0.51	0.82	-0.31***	-0.03
remoteness	18.91	19.3	17.95	1.35	-3.23***
land cultivated (hectares)	2.23	1.85	3.19	-1.33***	-0.21
number of cattle	3.53	2.38	6.43	-4.05***	-0.52
number of ploughs	0.36	0.17	0.83	-0.66***	-0.01
number of sprayers	0.18	0.08	0.45	-0.38***	0.00
social capital	0.47	0.39	0.67	-0.28***	0.02*
total fertiliser	550.58	478.71	650.05	-171.34***	71.65
fisp fertiliser	325.1	335.46	310.76	24.7	15.10
seasonal rainfall	1056.38	1142.17	840.74	301.43***	44.10**
Observations	2839	2031	808	2839	2839

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

From the table, the level of education and household size was significantly higher among the treated. The proportion of trained farmers was also higher in the treated districts, suggesting that more farmer orientation was done in these districts than the control districts. In addition, farmers in the treated districts cultivate more land than farmers in the control group, own more cattle and other complementing implements, and have more membership in farmer associations. 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).

The total quantity of fertilizer used in significantly higher in the treated districts but the quantity acquired from FISP are statistically not different. The quantity sourced from FISP was more than 300kg in both the 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 amount of seasonal rainfall was significantly lower in the treated districts.

Column (5) on the other hand show that for most of the variables, the weighted differences are not significantly different between the treated and control districts. It is worth noting that remoteness becomes significantly different after weighting where as with rainfall, the difference has reduced but remains significant at 5% level of significance.

The RALS also allow for the computation of outcome variables as defined here. Crop diversifi-

[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.

cation (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 using either hectarage or output. If hectarage, the index reveals farmers' actions or efforts towards diversification. When computed using output, it shows the level of diversification in output, which might differ from the measurement using hectarage if crop failure is not independent of crop type. In this paper, we follow Kankwamba et al. (2018) and compute the index at household level using hectarage, given by

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

where A_i is the total household-level area of land allocated to the i'th crop. The index is bounded $[0, 1)$. 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 espoused in FAO's (2019) definition. 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,

$$PCR_{ij} = \frac{H_{it}^{CR}}{H_{it}}, \text{ where } H_{it}^{CR} = \sum_{j=1}^{m} p_{ijt} h_{ijt} \text{ and } H_{it} = \sum_{j=1}^{m} h_{ijt}, \tag{2}$$

where H_{it}^{CR} is the total hectarage under crop rotation and H_{it} is the total hectarage of all the fields. The proportion 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 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 approach, the weighted differences in column (5) of table 1 show that the treated and control sub-samples 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 studies 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. A regression based test for attrition bias, as described in Wooldridge (2010, p.837) was performed and the abridged results shown in table 2. The full table is in the appendix as table 5.

The attrition results show that the dependent variables, as well as assignment to treatment, were independent of attrition. The observed attrition is not expected to bias the results, and therefore, does not require any remedial measures.

We supplement the data 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. We then compute two measures of rainfall performance.

Table 2: Full table of table 2: Auxiliary regression for test of attrition bias.

VARIABLES	(1) SID	(2) CR	(3) treated
attrition	0.007 (0.027)	0.038 (0.028)	-0.031 (0.040)
Observations	3,665	3,665	3,696

SEA clustered robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The fitst is the rainfall shock computed as the sum of standardised negative deviations of each month's rainfall from the long-term average for that month $\bar{r}_{im}$ in a season (eqn. 3a). In the regressions, this is lagged because farmer decisions are mainly driven by rainfall forecast, which under naive expectations, is dependent on the previous season. The second is the measure of standardised rainfall for the months of November and December only (eqn. 3b) in order to capture impact on early season decision making on crop mix.[4]

$$R_{it}^{-} = \sum_{m=1}^{12} \frac{r_{itm} - \bar{r}_{im}}{\sigma_{im}}, \tag{3a}$$

$$R_{it}^{nd} = \sum_{m=1}^{2} \frac{r_{itm} - \bar{r}_{im}}{\sigma_{im}}, \text{ for November and December} \tag{3b}$$

where r_{itm} is the monthly rainfall at household i, in month m of agricultural season t and $\bar{r}_{im}$ and σ_{im} are the mean and standard deviations respectively for month m at household i. Rainfall has the potential to affect farmers' attitudes towards climate adaptation measures, as well as to favour or hinder the cultivation of certain crops. This is used in the regressions to control for variations in rainfall. Rainfall has the potential to affect farmers' attitudes towards climate adaptation measures, as well as to favour or hinder the cultivation of certain crops.

In addition, in-depth primary key informant interviews were conducted with Agricultural Extension Officers (AEOs). These interviews solicited detailed information on the frameworks that are available to support climate adaptation, as well as the challenges and opportunities that each adaptation strategy presents. A multi-stage sampling approach was utilized to choose AEOs to interview. First, two farming districts were selected purposely, 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. A semi-structured key information interview guide in appendix B was used to collect information on climate adaptation support available, observed levels of adaptation, key challenges, among others. Qualitative data is analysed thematically in Nvivo. Qualitative data is important to provide context to some quantitative findings.

[4] In Zambia, the agricultural season runs from 1st October of one year to 30th September of the following year (CSO, 2016; Mason et al., 2013).

3 Estimating the impact of the reform

Our identification strategy 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 e-voucher FISP. The assignment of districts to treatment was informed by their respective microclimates among other factors (MoA, 2013b), which also have the potential to impact outcome variables. The criteria-based assignment brings two central problems: 1) the post-treatment differences may also 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 has the potential to defeat the parallel trends hypothesis.

A number of methods have been suggested to deal with the resulting potential endogeneity: the inverse probability weighting with regression adjustment (IPWRA), instrumental variables (IV), difference-in-differences (DiD), regression discontinuity (RD), endogenous switching regressions (ESR) and matching methods, including propensity score matching (PSM). The IPWRA computes a weighted difference in addition to the inclusion of potential control variables in the model, where weights are based on each observation's probability of belonging to the treated (or control) group (Dehejia and Wahba, 2002; Imai and Dyk, 2004; Imbens and Wooldridge, 2009; Lopez and Gutman, 2017). The instrumental variables method relies on an additional layer of treatment which have to satisfy specific exogeneity restrictions (Frolich, 2004; Imbens and Wooldridge, 2009) and requires identification of an instrument that has no direct influence on outcome variables, except through its influence on selection for treatment.

In this paper, we identify the impact of e-voucher 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), endogenous switching regressions (ESR) and the propensity score matching using the nearest neighbour matching. 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.

The endogenous switching regression (ESR) model, based on Lee (1978, 1982), is made of two stages or parts: the selection to treatment and the impact of treatment as in eqn. 4.

$$Y_{iT} = X_{iT}^{'}\beta_T + u_{iT}, \tag{4a}$$

$$Y_{iC} = X_{iC}^{'}\beta_C + u_{iC}, \tag{4b}$$

$$T_i^{*} = Z_i^{'}\gamma + v_i. \tag{4c}$$

Equations (4a) and (4b) regress the dependent variable (Y) on a vector of covariates X for farmers in the treated and control groups, respectively. The dependent variables Y_{iT} and Y_{iC} are said to be censored since only one can be observed on the same farmer (Lee, 1982). The third (eqn. 4c) is the *decision equation*. The latent variable, T_i^*, can be thought of as the net benefit gained from self-assigning to treatment. The model runs a simultaneous estimation of the binary adoption model and the continuous outcome models. This is analogous to the two-stage least squares in the Heckman (1979) methodology.

Matching methods generally use the Mundlak (1978) and Rosenbaum and Rubin (1983) approaches, utilizing *propensity score* matching (Sekhon, 2010). Propensity score nearest neighbour matching involves matching each treated unit with the nearest control unit on the basis of a propensity score, a unidimensional metric (ibid.).

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

$$\Delta Y_{ijt} = \tau T_{ijt} + \varepsilon_{ijt}, \tag{5}$$

where T_{ijt} is one if the farmer is from an e-voucher district and zero if from traditional FISP districts, and Y_{ijt} represents measures of crop diversification and crop rotation.

The OLS estimation in eqn. 5 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 a combination of DiD and IPWRA. We then apply the ESR and propensity matching for robustness check. The PSM is run with replacement, allowing observations in the control group to be matched with multiple observations in the treated groups. Matching with replacement has been argued to produce matches of higher average quality and yield lower bias compared to matching without replacement (Abadie and Imbens, 2006; Caliendo and Kopeinig, 2008; Dehejia and Wahba, 2002; Imbens and Wooldridge, 2009; Lopez and Gutman, 2017). On the downside, matching with replacement may lead to an unbalanced sample, having fewer observations in the control than are in the treated group.

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 curing unobserved time invariants and improving the balance between comparison groups.

Therefore, the following expanded model is estimated

$$Y_{ijt} = \gamma G_{it} + \pi P_{ij} + \tau T_{ijt} + X'_{ijt}\beta + \varepsilon_{ijt}, \tag{6}$$

where G represents group (treated or control) while P represents period (pre- and post-treatment), X is a vector of household characteristics including education, family size, land size, ownership of cattle, subsidy or FISP dependence in eqn. (7), remoteness (measured as average distance to an agro-shop, tarred road and communication network), and seasonal rainfall amount measured from the nearest satellite measurement point.[5] Although assignment to treatment

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

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 brings 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.

Therefore, the FD is defined on the basis of fertilizer as

$$FD = \frac{Q_F}{Q_T}, \tag{7}$$

where Q_F is the quantity of fertilizer 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 fertilizer and 0 if the farmer did not receive fertilizer from FISP in the particular farming season. We are motivated to use fertilizer only for three reasons. First, fertilizer is used in a reasonably fixed ratio with improved seed and other inputs. Second, fertilizer is mostly supplied in standardized quality and packaging of $50kg$ bags which makes it easy for farmers to account and recall. Third, although farmers can use any type of fertilizer, 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.

In order to account for clustered sample selection in line with Abadie et al. (2017), the standard errors are clustered. Abadie et al. (ibid.) have 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 reform on crop diversification

We measure the ATET of multi-crop FISP reform on the degree of crop diversification using the model developed from the general model in eqn. (6), where the dependent variable is the Simpson index of diversification in eqn. (1), measured at household level. The difference-in-differences estimation results are presented in table 3. Column (1) has the OLS while column (2) employs the IPWRA, which forms the main estimation. We conduct a robustness check using the ESR, columns (3) and the PSM, column (4) methods. The estimations control for household characteristics such as demographic, asset ownership and experience of rainfall but these are not shown in the table.

Table 3: Impact of E-voucher reform on degree of crop diversification

VARIABLES	(1)	(2)	(3)	(4)
	OLS	IPWRA	ESR	PSM
Dependent variable[1]	SID	SID	SID	SID
period	0.076 (0.046)	-0.041 (0.067)	0.121** (0.050)	
group	-0.175*** (0.061)	-0.297*** (0.070)	-0.347*** (0.070)	
treatment	0.026 (0.074)	0.212** (0.089)	0.023 (0.075)	-0.112 (0.074)
Observations	2,431	2,431	2,431	1,151

SEA clustered robust standard errors in parentheses[2] *** p<0.01, ** p<0.05, * p<0.1

[1] SID is Simpson (1949) index of diversification. *See* eqn. (1).
[2] PSM use robust Abadie-Imbens standard errors (Abadie and Imbens, 2006).

The results do not show any significant improvement in the degree of crop diversification as a result of treatment. Although the coefficient is suggestively positive under the IPWRA, it is largely insignificant under other estimation methods. Instead, the results show a significant negative coefficient on *group*. This may be suggesting that the differences in the outcome variable between the treated and control are existing pre-treatment differences which may emanate from criteria based assignment to treatment. Figure 1 presented early may also suggest that the assignment of districts to treatment was regional. This may have resulted in districts sharing similar characteristics such as micro-climates, farming systems and cultures assigned to one group or the other.

Our results are also supported by key informant evidence, which suggest that the e-voucher programme may not have induced any increase in crop diversification due to existing rigidities. For instance, key informants mention a number of hindrance to crop diversification. First is the absence of certified seed for alternative crops as is the case for maize. While the e-voucher systems allows farmers to redeem inputs of their choice, key informant evidence suggests that there are still some rigidities in the supply of inputs for alternative crops. We cite a few here.

''the challenge there is the issue to do with the availability of legume seeds. I can't walk into an agro-shop and buy either beans or groundnut usually they are in short supply. They are not readily available. So what the farmer has to relay on is recycled seed.
(Chisamba, male)

Some legume technologies are also being encouraged but it is difficult to get certified seeds.''
(Chisamba, male)

''Farmer are free to pick whatever seed they want but like last year, cowpeas ran out. Farmers wanted to get cowpeas, it ran out, they wanted groundnuts, it was not available. Even soybeans, not much was stocked.''
(Monze, female)

''cowpeas in most cases farmers use recycled seed. It's not that it is their wish. Even when you go on the market, there is a shortage of certified seed for legumes. Even just soybeans, it's not there. So those are some of the challenges. Whilst you are preaching diversification, also the availability of seed is also another thing. You find that these seed companies, their concentration is maize, maize, maize. So these are the issues hampering diversification, market issues and availability of seed.''

(Monze, female)

This evidence suggest that the private sectors input suppliers have not diversified as expected in order to complement the e-voucher reforms. Therefore, input availability has remained a hindrance, preventing farmers from fully exploiting the flexibility of the e-voucher programme.

In addition to rigidities in the input markets, there is also evidence that structural differences between the public sector driven market for maize and private sector led market for alternative crops is pulling farmers towards maize. The country's food reserve agency provides an assured market for maize across the country but there is no equivalent for many alternative crops.

''Then the farmer will not grow things for the sake of growing, they will also look at, what is the monetary value at the end of it. The cereal already has a structured market but for the legumes its different, I may grow beans and I may not have already market to sell that beans, I may grow groundnuts, I will not have ready market for that. So why should I grow it at a large scale despite being told the benefits?''
(Chisamba, male)

''WFP [World Food Programme] had promoted cowpeas and that time we saw farmers grow large areas of cowpeas. So crop rotation at that time worked very well but they [WFP] stopped buying. The problem is markets for the legumes, that is why they don't grow a lot of them.''
(Monze, female)

''But the other thing on crop rotation, they always talk about available markets for other crops. They know that maize, they can sell to FRA or briefcase buyers. But if one wants to maybe grow maybe a 4 ha of groundnuts, where would they find the market for groundnuts? Those are the issues coming out from the field.''
(Monze, male)

''Farmer in Monze can grow anything as long as they have an assured market. Because of issues of markets, you find them involuntarily going back to maize production.''
(Monze, female)

This evidence speaks to market uncertainty for other crops, suggesting an additional sources of risk. This indeed has the potential to hinder smallholders from venturing into other crops.

Besides market limitations, there are also historical cultural issues. There is an entrenched culture of maize monocropping among many smallholders.

''There is so much concentration on maize, maybe it is our staple crop and others it is because that is what parents were growing.
(Chisamba, male)

Majority are still glued to maize but there is a number that is accessing things like chicks, things like feed, planting tools.''
(Chisamba, male)

''There's a challenge with behavioural or attitude change towards growing maize. ... We've been doing nutritional demonstrations/training to show the farmers the other alternative they can have from even just ordinary foods they grow to shift major concentration from maize.''

(Chisamba, female)

"Even after the introduction of the E—voucher system, monoculture still remains higher. Even when you go into town, you would find that,.. Because if you look at the E-voucher, farmers are able to redeem what they want. For example, they can get wire fencing, they can get drugs, they can get anything related to agriculture. But it is like our farmers here, maize, that is what is in them."
(Monze, female)

This is a cultural barrier which may emanate from lack of knowledge or experience with other crops. The inadequacy of social safety nets and absence of insurance in the sector could also coerce farmers into safe crops but at the expense of productivity (Alem and Broussard, 2017; Teklewold et al., 2013).

4.2 The impact of reform on crop rotation

To measure the impact of the reform on the adoption of crop rotation, we estimate the model in eqn. (6) using the proportion of land under crop rotation, as defined in eqn. (2), as the dependent variable. The difference-in-difference regression results are presented in table 4. Column (1) has the OLS results while (2) has the IPWRA which form the main estimation results. We use the ESR (column 3) and PSM (column 4) for robustness check. Again, the estimations control for household characteristics such as demographic, asset ownership and experience of rainfall but not shown in the table.

Table 4: Impact of E-voucher reform on degree of crop diversification

VARIABLES	(1) OLS	(2) IPWRA	(3) ESR	(4) PSM
Dependent variable	SID	SID	SID	SID
period	-0.023 (0.033)	-0.046 (0.041)	0.011 (0.035)	
group	0.136*** (0.043)	0.119*** (0.045)	0.001 (0.050)	
treatment	-0.097** (0.049)	-0.005 (0.050)	-0.099** (0.048)	0.070 (0.059)
SID	0.186*** (0.021)	0.138*** (0.025)	0.172*** (0.023)	
Observations	2,431	2,431	2,431	1,151

SEA clustered robust standard errors in parentheses[2] *** p<0.01, ** p<0.05, * p<0.1

[2] PSM use robust Abadie-Imbens standard errors (Abadie and Imbens, 2006).

The results show that the e-voucher treatment was actually associated with a negative change in the intensity of crop rotation. Farmers in treated districts ended up with a lower intensity compared to farmers in control districts, *ceteris paribus*. This is at odds with expectation. We also note that the intensity of crop rotation is mainly driven by the level of crop diversification. Therefore, the hindrances of crop diversification discussed earlier, would indirectly hinder improvements in the intensity of crop rotation. This is 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."
(Chisamba, male)

"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."

(Chisamba, male)

''Then crop rotation also, monoculture 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?''
(Monze, female)

Therefore, efforts to promote crop diversification at household level would also ease limitations on crop rotation.

5 Conclusion

The paper estimated the impact of the introduction of the electronic voucher FISP delivery system on the practice of crop diversification and rotation at household level. The paper employed a mixed methods approach, combining econometric methods and qualitative methods in a complementary manner. The quantitative data comprised two waves of nationally representative rural agricultural livelihood surveys, one wave before the reforms and another post-reform. This provides a unique quasi-experimental structure which we exploit to identify the impact of reform. We also complement this quantitative data with qualitative data from key informant interviews which helps provide context and intuition to the findings.

The results show that the e-voucher reform did not produce the expected positive impact on crop diversification and rotation. In fact, the results point to a potential negative association, which we allude to regional selection of districts to treatment. Qualitative evidence point to a number of barriers to diversification that remain even after the e-voucher flexibility. These include the inertia of the private sector to provide inputs of alternative crops. The evidence here shows that the supply of inputs for crops besides maize is inadequate to match demand. The absence of assured markets for these crops, compared to maize which enjoys a public sector led markets, results is huge fluctuations and a risk that smallholder cannot take with ease. There are also cultural hindrances which entrench maize monoculture, likely due to limited knowledge and experience with other crops.

These findings provide important implications on the need for broader reforms to complement the e-voucher reform. There is need to promote sector wide reforms in order to provide secured markets for alternative crops. In addition, the extension services remain important in order to promote knowledge and skills sharing, which is critical to reversing entrenched cultural barriers to diversification.

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A Additional tables

Table 5: Full table of table 2: Auxiliary regression for test of attrition bias.

VARIABLES	(1) SID	(2) CR	(3) treated
attrition	0.007 (0.027)	0.038 (0.028)	-0.031 (0.040)
age	0.001 (0.001)	-0.001*** (0.000)	-0.001 (0.001)
gender	0.013 (0.050)	0.036 (0.034)	-0.043 (0.073)
education	0.006 (0.004)	-0.002 (0.003)	0.001 (0.006)
household size	-0.012 (0.007)	0.002 (0.005)	-0.012 (0.011)
fisp dependency	0.134*** (0.032)	0.023 (0.022)	-0.212*** (0.047)
cattle (number)	-0.003*** (0.001)	-0.001* (0.001)	0.004*** (0.001)
land (hectarage used)	-0.028*** (0.005)	0.011*** (0.003)	0.091*** (0.007)
social network	-0.012 (0.028)	0.072*** (0.019)	0.340*** (0.041)
Constant	0.107** (0.049)	0.464*** (0.033)	0.521*** (0.071)
Observations	3,665	3,665	3,696

SEA clustered robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

B Interview guide

IN-DEPTH INTERVIEW GUIDE.

Research Title: **Assessing smallholder farmers' response to climate change**

Introduction

I want to get your views on a number of issues surrounding climate change, smallholder farmers and how you or other institutions are supporting farmers to adapt to climate change. I would greatly appreciate your input in this study.

May I now get your following particulars. These will be recorded separately from our discussion that follow. You **can skip any that you prefer not to provide**.

Name: ______________________ Age: _________ Gender: ___________ Level of education: ______________
Your position: ____ Years in this position: ______________
Locality: ____ Years in this locality: ______________

KQ 1: **Describe the weather and climate situation and how it is affecting the Agriculture sector**	
Probes	Describe the extent of change in climatic variables in this region. How do you describe the extent of effect on the smallholder farmers?
KQ 2: **What options do farmers have in responding to climate change effects?**	
Probes	What are farmers able to do in order to deal with increasingly unpredictable rains? What farming practices are working and how is the response? Are farmers adopting? What practices do you think are more appropriate for your catchment area? What are some of the challenges inhibiting full adaptation?
KQ 3: **Describe the support available to help farmers adapt to climate change.**	
Probes	What policy and strategies are in place to support smallholder farmers adapt to climate change? Describe institutions that are supporting climate change adaptation for smallholder farmers.
KQ 4: **Describe the adoption of Conservation Farming or Agriculture among smallholder farmers.**	
Probes	How effective is CF is achieving the intended objectives? To what extent is CF critical to climate change adaptation? Should focus be on CF? What are some of the barriers to adoption of CF among smallholders? How are these barriers being addressed?
KQ 5: **Describe the adoption of irrigation among smallholder farmers in your area.**	
Probes	To what extent has irrigation helped reduce the impact of climate change? What are some of the barriers to adoption of irrigation among smallholders? To what extent has water availability affected the adoption of irrigation? How are these barriers being addressed?
Any other comments.	
Probes	Are there other issues you may want to highlight around climate change adaptation among smallholder farmers