Selected Presentation at the 2020 Agricultural & Applied Economics Association Annual Meeting, Kansas City, Missouri, July 26-28

Identifying appropriate incentive mechanisms for smallholder farmers to exploit inter-temporal arbitrage opportunities for grain legumes: Experimental evidence from Malawi.

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Abstract

We administer a randomized control trial (RCT) among 1739 legume farmers in Central Malawi after the 2018 harvest and evaluate the causal impacts of an improved storage technology along with two storage commitment devices in the form of group storage arrangements on smallholders' storage and sales behavior. We compare our outcome variables including households' quantity stored at harvest and inventories, number of weeks stored before largest sale, net sales quantity and net sales revenue among three treatment groups and a control group. These treated groups received (i) an improved storage technology, a hermetic bag (T1:The technology only); (ii) the improved storage technology under the condition that they store collectively with their farmer club in their village, (T2:The village storage program) and (iii) the improved storage technology and financial management information under the condition that they store collectively at a centralized warehouse (T3: The warehouse storage program). Our aggregate results suggest that all three storage interventions significantly helped farmers to store more legumes at harvest (27 to 54 kgs), as well as store longer (1 to 2 weeks) compared to control households. We also find that treated households were able to significantly make more revenue from legume sales than control households (MK21,000 to MK30,000; US$1=MK730). However, for the two storage commitment devices in the form of group storage, we observe significant marginal effects of village group storage arrangements on quantity stored and storage length but not for the warehouse group storage arrangements. Some possible explanations for this could be the low take-up rate for the warehouse storage program which may have resulted from the transportation costs incurred and the clubs' limited commitment to store with other clubs in a larger group at the warehouse outside their village. This suggest that the village storage program is likely more effective at incentivizing farmers to store more legumes as well as store longer compared to the other two storage interventions. These results provide insights on the viability of warehouse programs for smallholders as we learn that incentivizing smallholders to store together locally within their villages may be more effective than a warehouse storage program. Although our aggregate treatment effects help to show how each intervention performed on average, our estimates of quarterly treatment effects highlight the inter-year effects of the interventions on farmers' behavior.

Keywords: RCT, PICS bags, Sell-low and buy-high, Group storage, Legumes, Malawi.

Introduction

In Sub-Saharan Africa (SSA), agricultural commodities such as groundnuts and soybeans often exhibit large seasonal price fluctuations. It is actually common for lean season grain prices to increase by as much as 50–100% from the peak harvest-season prices on average Burke et al. 2019; Gilbert et al. 2017; Kaminski and Christiaensen 2014). Although these price fluctuations potentially offer farmers inter-temporal price arbitrage opportunities to increase their sales returns, smallholders in most of SSA often do not exploit these opportunities to the fullest extent possible: many farmers sell a substantial amount of their grains immediately after harvest at low harvest prices, sometimes even at the expense of buying it at a higher price later in the year when their own stocks have been drawn down (Burke et al. 2019; Stephens and Barrett 2011). Baseline data from our study in Malawi supports this *"selling low and buying high"* phenomena with close to 50 percent of farmers in our sample reporting that they had their largest grain sales at harvest and close to 40 percent of the respondents reported to have made the most grain purchases for food in the lean season (See Figure 1).

Considering that smallholders in SSA are generally characterized as low-incomes earners, their inability to exploit these potential price arbitrage opportunities further reduces their income as well as undermines their lean season food security. As such, understanding the underlying factors influencing smallholder farmers' "*selling low and buying high*" behavior has been the subject of several studies in the recent past (Channa et al. 2020; Burke et al. 2019; Aggarwal et al. 2018; Dillon 2017; Basu and Wong 2015; Kaminski and Christiaensen 2014; Stephens and Barrett 2011; Tefera et al. 2011). Some of the possible explainations for the "*selling low and buying high"* behavior from literature include post-harvest challenges such as: (i) lack of effective storage technologies (Channa et al. 2020; Aggarwal et al. 2018; Kadjo et al. 2016); (ii) harvest period cash and liquidity constraints which push farmers to forgo profitable opportunities from grain storage due to the need to address their urgent cash constraints (Kadjo et al. 2018; Dillon 2017; Sun et al. 2013); (iii) limited access to credit markets (Channa et al. 2020; Burke et al. 2019; Basu and Wong 2015; Stephens and Barrett 2011); (iv) limited access to better output markets due to high transaction costs (Bernard et al. 2017) as well as (v) the social and behavioral challenges that households face when it comes to savings including impatience, self-control and social pressure to share are also considered to influence households' storage choices (Brune et al. 2011; Baland et al. 2011; Ashraf et al. 2006).

While several studies have looked a how credit and liquidity influence farmers storage behavior, not much has been done to understand the social and behavioral issues behind farmers' "*sell low and buy hign"* phenomena. When grain is stored at home where stocks are readily available for liquidation whenever there is need, farmers are likely to be pressured to sell their grain earlier than planned as they may be unable to deny their (extended) family's current needs in favor of storage or higher future returns. This may be especially challenging for the farmer if the grain is stored in plain sight for their social network (or "other"-control) including household members, relatives or friends in need to see. In addition, households may tend to be wasteful and consume more than planned when grain stocks are stored in plain sight due to lack of mental accounting (Aggarwal et al. 2018). Similarly, when farmers store their grain individually, they are likely to be tempted to liquidate their grain stocks earlier due to limited of self-control. This is a common behavioral challenge that households face even when trying to save cash (Dupas and Robinson 2013; Bryan, et al. 2010; Thaler and Shefrin 1981). As such, grain storage commitment devices to help farmers deal with self- control and "other'-contol problems are important.

In this paper, therefore, we focus on understanding how addressing these storage commitment constraints may influence farmers' behavior. We implement two grain storage commitment programs varying in terms of storage location and arrangements (T2, the village storage program and T3, the warehouse storage program). The village storage program involves grain storage within a farmers' village with fellow club member while the warehouse storage program involves storage at a centralized warehouse outside the village with multiple farmer clubs. We implement these commitment devices to evaluate the viability of Village Grain Banking programs (VGB) and Warehouse Receipt Systems (WRS) which are promoted in most developing countries.

VGBs are farmer groups which were originally promoted to help farmers who reside in same village to store seed together with a goal of ensuring increased access to improved seeds within their villages. However, these groups' objectives have evolved over time to also include grain aggregation for sale to increase bargaining and access to better markets (Odhong 2018). WRS are centralized system for recording warehouse receipts issued by a group of certified or registered warehouses. The receipt is a document which guarantees the quantity and quality of commodity stored within an approved facility and can be used as collateral for commodity finance. Since agricultural production in SSA is dominated by farmers who are generally small and widely spread in rural areas, commodity marketing is characterized by high transaction costs due to the high cost of aggregation and the quality and quantity uncertainty. WRS are designed to facilitate commodity trade by enabling aggregation of known commodity quality and quantities. This helps to eliminate information asymmetry while also reducing transaction costs for the buyers. The storage facilities through these WRS programs also help to minimize storage losses and ensure security of commodities. In addition, WRS can also be used as commitment devices allowing farmers to separate and store portions of their harvest for sell later when prices rise. Such programs have been promoted in several developing countries including Zambia, Tanzania, Ghana and Malawi. However, participation for smallholder farmers has been low. Some of possible reasons for low participation include the high transaction costs (Coulter and Onumah 2002; Baulch et al. 2018). However, the viability and impacts of such programs on smallholder farmers' grain storage behavior remains unclear.

In this paper, therefore, we use an experiment to evaluate the viability of village storage and warehouse storage programs for smallholder farmers. Although our warehouse storage intervention does not include commodity finance or credit, it aligns with most warehouse programs in that it allows farmers from different clubs to aggregate their produce in centralized warehouses increasing the farmers' access to better markets. In addition, the program also provides farmers with a commitment device allowing them to mentally and physically allocate part of their harvest for selling letter the year. The key research questions that we address in this article are: what storage intervention mechanisms would effectively incentivize smallholder farmers to store more legumes at harvest for exploitation of intra-seasonal price arbitrage opportunities? What are the causal impacts of (i) providing an improved storage technology, the hermetic (airtight) Purdue Improved Crop Storage (PICS) bag; increasing access to a storage commitment device in the form of (ii) village group storage arrangements and (iii) centralized warehouse group storage arrangements. We address these questions by implementing a clustered randomized controlled trial (RCT) in central Malawi with a control and three storage interventions. The treatment interventions included receipt of (i) the improved storage technology only (T1:The PICS technology only); (ii) the improved storage technology plus commitment to participate in village group storage arrangements with their club, (T2:The village storage program); and (iii) the improved storage technology plus commitment to participate in warehouse group storage arrangements which included financial management information (T3: The warehouse storage program).

Empirical evidence from (Kadjo et al. 2016) suggest that crop damage by pests[1] and molds significantly reduces grain market value. Considering that farmers who lack effective storage technologies are likely to have a high expectation of storage losses, it is possible that selling early may be an optimal strategy for such farmers to avoid storage losses and damages. Evaluating the causal impacts of an effective storage technology intervention such as PICS bags on smallholders' storage behavior is important. While previous studies including (Channa et al. 2020; Omotilewa, et al. 2019; Omotilewa et al. 2018) have evaluated the impacts of storage technologies such as the PICS bags on farmers' adoption behavior including for example, adoption of the bags themselves and adoption of improve maize varieties, this paper extends this literature by estimating the causal impacts of the PICS bags along with group storage interventions on farmers' post-harvest storage and marketing behavior.

Our study advances the literature on commitment devices for grain storage by estimating the causal impacts of two variations of group storage arrangements on smallholder farmers' storage behavior. To our knowledge, the only study that evaluates the impacts of group storage on farmers' demand for grain storage in SSA includes Aggarwal et al. 2018. They find that increasing farmers' access to appropriate storage arrangements may increase the amount of grain stored at harvest by smallholders as well as their cash income from sales. Their study tests the impact of "a combined technology" which is the combination of (i) some physical storage

[1] Weevils and large grain borer, rodents.

technology (the PICS bags and a stand); (ii) grain labeling, to enable farmers to mentally separate and allocate some portion of their stock to the purpose of selling later; and (iii) the collective grain storage. While their study estimates the joint impacts of the PICS bags, labelling and group storage, our paper advances their work by explicitly teasing out the the causal impacts of an improved storage technology (the PICS bags), and the two grain storage commitment devices in form of (i) village group storage arrangements and (ii) centralized warehouse group storage arrangements separately.

Our aggregate results suggest that all three storage interventions significantly helped farmers to store more legumes at harvest (27 to 54 kgs), as well as store longer (1 to 2 weeks) compared to control households. We also find that treated households were able to significantly make more revenue from legume sales than control households (MK21,000 to MK30,000; US$1=MK730). However, we find that Treatment 2, the village storage program, is more effective at incentivizing farmers to store more legumes as well as store longer compared to the other two treatment interventions mechanisms, Treatment 1, the PICS only and Treatment 3, the warehouse storage program. In order to tease out the marginal impacts of the two variations of group storage arrangements above the PICS technology, we use the F-test to compare Treatment 1 to Treatment 2 and 3. Our results shows significant marginal effects on quantity stored (24 to 27 kgs) and storage length (1 week) for the village group storage arrangements but not for the warehouse group storage arrangements. This is likely because of the low take-up rate which may have resulted from the transportation costs incurred and the clubs' limited commitment to store with other clubs in a larger group at the centralized warehouse outside their village. This is in line with literature on social interventions which shows that social interventions like group storages, tend to be more effective within smaller social circles where the peer effects tend to be stronger (Dahl et al. 2014; Gonzalez-

Mulé et al. 2014; Kandel and Lazear 1992; Bowles and Gintis 2002; Armendáriz de Aghion 1999). To our knowledge, this paper is the first to empirically estimate the impact of grain storage commitment tools at village and warehouse level. Our paper suggests that given the prevailing grain storage commitment problems due to self-control and "other"-control, encouraging farmers to store together in their villages may be more effective at helping smallholders to exploit inter-seasonal price arbitrage opportunities than warehouse storage programs. This paper provides some insights regarding the prevailing low smallholders' participation in the Warehouse Receipt Programs and Community grain banks that are widely promoted in SSA.

The rest of the paper is organized as follows: Section 2 presents the study setting and experimental design, Section 3 provides the details of the data collection process and estimation methods, Section 4 presents the study results and discussions while Section 5 presents the study conclusions.

Setting and Experimental Design

We utilized a multi-level sampling approach to select a representative sample of legume producers in Malawi. Malawi is divided into 18 livelihood zones, which are locations of similarities in terms of livelihood activities. The Kasungu-Lilongwe Livelihood zone is considered to exhibit higher potential for crop production compared to other zones. We purposively selected two districts from this zone namely Lilongwe and Mchinji (see Study Area in Figure 2), which are predominantly also major producers of legumes in the country. Our targeted districts have a total of 26 Agricultural Extension Planning Areas (EPA) and 423 Sections or communities below them[2]. We

[2]An EPA is local administrative unit for the Ministry of Agriculture and EPAs have Sections below them as the lowest administrative level.

chose this region because it was more likely to have farmers who produce legume surplus that could potentially be sold and/or stored at harvest for sell later in the year.

Since we administered a clustered RCT to evaluate treatment effects of three storage intervention mechanisms, we employed cluster sampling where 377 clusters were randomly selected for the study comprising 1739 legume farmers. These farmers are members of the National Smallholder Farmers' Association of Malawi (NASFAM), a farmer-based organization with membership throughout the country. NASFAM has 43 Associations across Malawi and an average NASFAM Association covers an entire EPA which typically comprise multiple communities. Below the Associations, NASFAM has what are considered Group Action Centers (GACs) which are generally at community level[3]. An average community in Malawi has about 10 to 35 villages and communities may typically be about 10 to 35 kilometers apart on average. A single NASFAM Associations has an average of about 21 GACs (or communities) with each GACs having an average of about 15 farmer clubs. A club is made of an average of about 10 farmers who reside within the same village and these village are typically about 1 to 5 kilometers apart. Although villages that fall within the same community are very similar, they are generally far apart enough to limit possible treatment contamination. Our sampling clusters were farmer clubs which are at the village level. Among the sampled clubs, 274 clubs (1199 farmers) were treated with the three interventions, and 103 clubs (540 farmers) were in the control group (See Figure 3: Study Consort diagram).

The choice to have at least 85 clusters per study group and at least 5 households within each cluster or club was based on power calculations to arrive at a minimum detectable effect (MDE) of 0.33 standard deviations in outcomes comparison between treated and control

[3] Communities or Sections are at Group Village Head level or sometimes comprise two or three Group Village Heads

households. In practice, this is below what is generally considered Medium (Duflo, Glennerster and Kremer 2007). Our calculations assumed an Intra-Cluster Correlation coefficient (ICC) of 0.1 at 80% power and 95 percent confidence level. This gave a minimum cluster (J) and household (n) size of 80 and 5 respectively. As such, our choice of cluster sizes of 100, 85, 89, and 103 for treatment 1, 2, 3 and control respectively should be enough to power our study based on an assumption that 50 percent of the eligible farm households in any given club were treated. Table 7 in the appendix presents details of actual ICC at baseline.

Three Associations were targeted for the study namely, Chioshya, Mikundi and Mpenu. Since the clubs in each Association are sub-grouped into GACs, we randomly selected 12 GACs in each of the targeted Associations. Then, within each of the selected GAC, we randomly selected 12 clubs of which three clubs were randomly assigned to each of the four study groups (control + three treatment wings). Our treatment assignment was, therefore, at club level and within each GAC (or community), an equal number of clubs were randomly assigned to each of the four study groups. Since members within a club are likely to have similar characteristics, we clustered our standard errors at club level. Five farmers from each club were randomly selected into the study. However, for the control group ten farmers per club were randomly selected into the study. In some situations, we were unable to recruit the targeted five (ten) farmers per club for the treatment (control) group due to low farmer turn-up on scheduled survey days. As such, we used sampling weights in our regression analysis to control for the unequal probability of a household being selected to participate based on the size of the club and the number of members who attended training. In addition, since our main study focus was on legumes, we also excluded farmers that did not plant legumes in the 2017/2018 cropping season.

Background on legume price seasonality and post-harvest losses in Malawi

Legumes crops including soybeans, common beans, sesame, groundnuts, pigeon peas, and cowpeas are an important source of inexpensive proteins relative to animal proteins for most households in SSA and for smallholder farmers, in particular; legumes are an important source of income. While governments in most of SSA interfere in the maize market to stabilize maize prices, there is generally limited government interference in legume markets[4]. This is because for most of SSA, maize is a key staple food crop with its availability and accessibility largely defining the state of food security. As such, food security policies are largely focused on maize with frequent government interventions in the maize market including marketing boards involvement in maize trade, governments food reserves to regulate maize supply, maize trade restrictions using export bans and ceiling prices as well as input subsidies aimed at reducing the marginal cost of producing maize. For this study, therefore, we focused on legumes because legume prices exhibit relatively more significant seasonal variations compared to maize. This is in line with empirical evidence from some recent studies in SSA that find no significant price seasonality in maize (Abass et al. 2014; Burke et al. 2019; Channa 2019). The Ministry of Agriculture's monthly price data for Malawi from 1989 to 2017 also shows larger seasonal variations in average prices for other crops including legumes relative to maize prices with the average seasonal price differences of 25, 19, 18, 15 and 13 percent for common beans, rice, soybeans, groundnuts and maize respectively (See Figure 4). As such, legume crops like soybeans and groundnuts can be considered more viable for storage to exploit price arbitrage opportunities compared to maize.

[4] In Malawi for example, the Ministry of Agriculture sets price controls through the Control of Goods Acts annually and also imposes export bans on maize depending on aggregate maize production each year.

In terms of grain Post-Harvest Losses (PHLs), there is contrasting empirical evidence regarding households' PHLs in SSA with wide variations in reported PHL for maize, for example, ranging from 1.4 to 18 percent (i.e. 1.4 to 5.0 percent estimate by Kaminski and Christiaensen, 2014; 8 percent by FAO 2011 and 14 to18 percent by The African Post-Harvest Losses Information System (APHLIS)). To our knowledge, very few studies in the past have estimated PHL for specific legume crops in SSA. Among the few studies that provide PHL estimates for specific legumes include Mutungi and Affognon, (2013) and Amber et al (2018). Mutungi and Affognon, (2013) shows that about 4.2 to 9.1 (7.7) percent of beans and 10 percent of groundnuts is lost during storage in Malawi (Kenya) while Amber et al. (2017) reports that 8 percent for soybeans, and 12 percent for groundnuts is lost during and after harvest in Malawi. It is clear from the literature that PHL vary depending on the crop type and variety, stage of the value chain (i.e. harvesting, processing or storage) and region (Affognon et al. 2015; Kaminski and Christiaensen 2014; Worldbank 2011). There is empirical evidence that suggest a significant reduction in grain market value due to PHL (Kadjo et al. 2016). In this paper, therefore, we evaluate how providing an effective storage technology that may help farmer reduce both quantity and quality loss may influence their grain storage behavior.

Our Intervention

The physical storage technology (Treatment 1)

In treatment 1 (T1: PICS technology intervention), households were trained about the PICS technology and given two 100 kilograms PICS bags for free. The PICS bag is a 3-layer hermetic storage bag that effectively protects grain from pests and molds without the use of chemicals. The treatment was designed to help smallholder farmers overcome the storage technology constraint they face from insects and molds. We chose to provide only two 100 kilograms bags to avoid creating an incentive for sharing across households which could result into treatment spillover or contamination. However, these two 100-kilogram bags allowed farmers to effectively store up to 200 kilograms of legumes which is just enough to enable a substantial impact. This treatment was also aimed at informing smallholder farmers about the benefits of using PICS bags as well as the storage prospects it presents for exploitation of seasonal price arbitrage opportunities. This treatment is, therefore, expected to help reduce the expected quality and quantity losses for farmers and thus induce them to store more at harvest, so that they can sell good quality grain at a higher price later in the year.

The village storage program (Treatment 2)

In Treatment 2 (T2: The PICS technology + Village group storage arrangements), households also received two 100 kilograms PICS bags and committed to store their grain with their clubs within their villages. Each club selected a stock-keeper responsible for the club's stocks based on trust and storage capacity. This treatment was designed to help farmers overcome the storage technology constraint as well as the behavioral challenges associated with individual storage of grain in homes where farmers often face some social pressures to share, impatience, limited self-control and mental accounting problems (Aggarwal et al. 2018; Brune et al. 2011; Baland, Guirkinger and Mali 2011; Ashraf, Karlan and Yin 2006). In this treatment, the group storage arrangement allowed farmers to separate and deposit part of their grain stocks in a club-managed stock that was stored away from home for liquidation when prices rise. For the village storage program, each club independently agreed on storage length, a reservation price and procedures for grain withdraw which included getting the club's consent and or a penalty for early withdraw. The set procedures for withdrawing grain from the group stocks may be a disincentive for an individual farmer seeking an unnecessary early liquidation of grain from the stocks. As such, farmers may have been influenced to store longer through village group storage arrangements than they would have otherwise. In addition, the amount of grain deposited into the group stocks by an individual farmer may also likely be influenced by his or her peers in the group depending on the groups' anticipated gains of storage. Given self-control and "other"-control problems that may influence farmers to liquidate stocks early, we designed this storage intervention to understand how group storage arrangements implemented locally within the village with smaller groups would induce farmers to store more grain at harvest.

The warehouses storage program (Treatment 3)

In Treatment 3 (T3: The PICS technology + Warehouse group storage arrangements), farmers received Treatment 1 (T1) as well as a different variation of group storage arrangements that involved some information in financial management and storage of grain at a NASFAM warehouses within their Group Action Centres (GAC). The group storage arrangement under this treatment was more centralized using warehouses that catered to the entire GAC or community. Unlike the village storage program, this implied that more than one club stored in each centralized warehouse. Not only that, clubs using the same warehouse were encouraged to synchronize their grain deposit and withdraw conditions and these were more stringent than the village storage program[5]. In addition, for this treatment intervention, the centralized storage locations were much further away from their households. This treatment, however, helped farmers to assemble their produce with known quality and quantity description for easy off-taking by big traders and processors facilitating trade as well as eliminating possible information asymmetry. The cost of

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[5]This intervention was initially supposed to include a loan product from a bank where the grain stored in the warehouses was meant to be collateral for the loan that had a maximum repayment period of up to three months. However, the bank backed out last minute. This meant the deposit and withdraw conditions for clubs in this treatment were tied to the loans' repayment conditions.

produce aggregation and quality control may discourage big traders, exporters and processors from engaging in direct trade with smallholder farmers. Increasing smallholders' access to improved storage technologies (PICS bags) and some form of warehousing and aggregation facilities may help increase farmers' access to better markets (i.e. exporters and processors who may offer higher price). Poor financial management knowledge and skills may be a key driver of liquidity constraints for farm enterprises. For smallholders in SSA operating under subsistence farming, the lack of proper financial management knowledge may be one of the factors driving their liquidity constraints at harvest. We offered farmers information about the benefits of grain storage (a form of savings) and strategically marketing of their produce to exploit better prices as part of this intervention. This treatment, therefore, was designed to test how increased knowledge in financial management and access to specialized storage facilities influence farmers' storage and marketing choices. This treatment was also designed to provide some empirical insights on the impact and viability of warehouse programs for smallholder farmers in developing countries which generally have low smallholder's participation rate.

Control group

The control group of farmers (C) included households that did not receive any treatment but reside in the same area as treated farmers. We use the multinomial logit model to evaluate the significance of pre-treatment differences in our outcome variables and household characteristics. Our baseline balance analysis shows that our observable variables are jointly equal to zero with very few being individually significant. These include for example, quantity of legumes stored at harvest where households in treatment 1 and Treatment 2 are observed to significantly have stored 0.000842 kgs and 0.000775kgs more than control households in the baseline year. Similarly, we observe some minor significant differences in households' expenditure on storage pesticides for households in

Treatment 1 and Treatment 3 who spent MK0.000058 and MK0.000051 less compared to control households respectively[6]. Generally, the magnitudes of the differences for variables that are significantly different between treated and control households are very small. Hence, farmers in the control group are on average similar to the treated farmers *ex ante*. Members of the control group were followed throughout the intervention period to keep track of all programs they were exposed to. The farmers in this group were also asked if they purchased PICS bags on their own or if they stored their grain in groups as a measure to determine existence of possible attenuation bias caused by the control group engaging in these activities. Only 12 households in the control group reported having bought PICS bags with the number of bags bought per household ranging from 1 to 10 bags. However, none of the households in the control group reported storing their legumes in groups.

Data and Estimation Methods

The study used panel data from household-level surveys that was collected from a sample of 1739 NASFAM farmers in Malawi. The baseline was conducted between April and May of 2018. This was followed by the implementation of the randomized treatment interventions. During the intervention period, supplementary data on the key outcomes was collected quarterly through follow-up surveys with respondents. The end-line survey was conducted between April and May of 2019. Our results are based on data from three follow-up surveys conducted in August 2018, December 2018 and April/May 2019 (See Study timeline in Appendix Figure 5). For all surveys, a structured, pre-tested questionnaire was used to capture data on farmers' grain storage and marketing practices. This included data on quantities of legumes stored at harvest, weeks stored

[6] US$1=MK730

before largest sell, quantity sold and bought in each quarter, selling and purchasing prices and households' sales revenue.

Estimation of Treatment Effects

In order to understand the factors driving farmers' storage and marketing decisions, we used a clustered RCT with three storage interventions. We follow the estimation framework by Burke (2019) to estimate treatments effects of the interventions on our outcomes including households' quantity stored at harvest, grain inventories, number of weeks stored before largest sell; total sales revenue, net quantity of sales and household's net value of sales. The net quantity of sales is the difference between quantity sold and quantity purchased in a given quarter while net value of sales looks at the monetary value, that is, the difference between value of sales and purchases in every given quarter. We estimate both aggregate and quarterly treatment effects where for aggregate treatment effects, we focus on outcome variables for which we only have an annual observation including quantity stored at harvest(kg), number of weeks stored before largest sell and total sales revenue (MK). We, therefore, use simple Ordinary Least Squares and Analysis of Covariance (ANCOVA) to estimate aggregate intention to treat (ITT) effects on these outcomes of interest as specified below:

$$y_{i,j} = \alpha + \beta PICS_{ij} + \lambda Villagestore_{ij} + \mu Warehousestore_{ij} + \gamma A + \sum_{d=2}^{d=4} \partial_d Q_d + \delta yo_{ij} + \varepsilon_{ij} \quad (1)$$

$$y_{i,j} = \alpha + \beta PICS_{ij} + \lambda Villagestore_{ij} + \mu Warehousestore_{ij} + \sigma_1 PICS_{ij} * Z_{i,j} + \sigma_2 Villagestore_{ij} * Z_{i,j} + \sigma_3 Warehousestore_{ij} * Z_{i,j} + \ + \gamma A + \sum_{d=2}^{d=4} \partial_d Q_d + \delta yo_{ij} + \varepsilon_{ij} \quad (2)$$

In equation (1) above, y_{ij} is observed outcome; $PICS_{ij}$, $Villagestore_{ij}$ and $Warehousestore_{ij}$ are binary variables =1 if household received Treatment 1, Treatment 2 and Treatment 3 respectively for i=1,2,…, n farmers in groups j. $yo_{i,j}$ is the baseline outcome value for the ANCOVA analysis, A is the Association location dummy variable while Q_d represents a set of quarterly dummies. We clustered our standard errors at club-level and ε_{ij} is the idiosyncratic error term. Our parameter of interest includes coefficients, $\hat{\beta}$, $\hat{\lambda}$ and $\hat{\mu}$ which capture the average aggregate effects (ITT) of being randomly offered the $PICS_{ij}$, $Villagestore_{ij}$ and $Warehousestore_{ij}$ treatments respectively. The comparison group is the control households, who did not receive any treatments. We estimate equation (2) to explore heterogeneity in aggregate treatment effects and $Z_{i,j}$ represents a set of baseline variables that are likely to influence heterogeneity in treatment effects including baseline access to credit and access to markets. Our treatment heterogeneity parameters of interest include σ_1 to σ_3.

For outcome variables with quarterly observations including, legume inventories (kgs), net quantity of sales (kg) and net value of sales (MK), we estimate quarterly intention to treat (ITT) effects on outcomes as specified below:

$$y_{i,j,t} = \alpha + \sum_{d=2}^{d=4} \beta_{\mathrm{d}} Q_d * PICS_{ijt} + \sum_{d=2}^{d=4} \lambda_{\mathrm{d}} Q_d * Villagestore_{ijt} + \sum_{d=2}^{d=4} \mu_{\mathrm{d}} Q_d * Warehousestore_{ijt}$$

$$+ \textstyle\sum_{d=2}^{d=4} \partial_d Q_d + \gamma A + \delta yo_{ijt} + \varepsilon_{ijt} \qquad (2)$$

In equation (3) above unlike equation (1), we have quarterly observations of the outcome variables and, thus, have four waves of data including three post-intervention periods. As such, the subscript t represents the quarter or time period 1 to 4 and $yo_{i,jt}$ is the lagged quarterly outcome variable for the ANCOVA estimation to control for quarterly initial differences (i.e. in the post intervention waves, treatment effects from the previous quarter) assuming that the parallel trends assumption holds. A and Q_q are a set of Association and quarterly dummy variables respectively and ε_{ijt} is the idiosyncratic error term. Our parameter of interest includes the quarter and treatment dummy interaction coefficients, $\hat{\beta}_q$, $\hat{\lambda}_q$ and $\hat{\mu}_q$ which capture the average quarterly effects (ITT) of being randomly offered the $PICS_{ijt}$, $Villagestore_{ijt}$ and $Warehousestore_{ijt}$ treatments respectively. The comparison group is the control group in each quarter, who did not receive any treatments.

In terms of treatment take-up rate, all households recruited into the study accepted treatments. However, upon follow-up, 89 percent of the respondent that received the PICs bags reported actually using the PICS bag to store legumes with the rest indicating that they used the bags to store maize instead because they did not harvest enough legumes. As for group storage, only 72 percent of the households in Treatment 2 and 68 percent of the households in Treatment 3 reported actually storing in groups (See Figure 5). We had a relatively low compliance for the warehouse group storage (Treatment 3) as most farmers reported having challenges with transportation of grain to the NASFAM warehouses. We estimate our ITT for offering the three storage interventions. For robustness checks, we compare our ITT estimates across OLS and ANCOVA.

Sampling weights

All farmers in the clubs were informed about our research surveys through lead farmers in their villages. During study recruitment, we sampled 5 farmers per treated club and 10 farmers per control club regardless of club size or number of farmers that showed up on the day of survey in that club. As such, it is likely that the probability of a farmer being sampled varied across clubs. To deal with this issue, we used sampling weights based on the inverse proportionality to probability of being sampled based on the number of club members who showed up on the day of training. (Cameron and Trivedi 2005).

Testing for Potential Attrition Bias

After the implementation of treatment intervention in April 2018, we conducted follow-ups surveys every four months (August 2018, December 2018 and April 2019). As such, we have an attrition dummy variable for each follow up indicating the number of households that were missed at that given follow-up survey. Seven percent of the households (127 households) were missed during the first follow and these comprised of 15, 35, 27 and 50 households from Treatment 1, 2, 3 and control groups respectively. Similarly, for the second follow-up survey, Fourteen percent (236 households) were missed and these comprised of 34, 54, 52 and 96 households from Treatment 1, 2, 3 and control groups respectively and for the final follow-up survey, twenty four percent (416 households) of the sample households were missed and these comprised of 81, 94, 98 and 143 households from Treatment 1, 2, 3 and control groups respectively[7].

In order to determine the possibility for attrition bias, we perform a joint orthogonality test using the multinomial logit to evaluate if the attrition variables are correlated with treatment variable or other household characteristics. Our F-test results from Table 6 (prob>Chi2=0.0057, 0.4111 and 0.3725 for Follow-up 1, 2, and 3 attrition variables respectively) suggest that our treatment variables, outcome and independent variables are jointly equal to zero for the follow up 2 and follow-up 3 attrition variables. This suggest that the follow-up 2 and 3 attrition variables are not correlated to the treatment variables and households' observable characteristics. However, for the follow-up 1 attrition variable, our F-test results suggests some correlation with the treatment variables and some observables as we observe that households that received Treatment 1 were

[7] During the second and third follow up surveys, households that were missed in the previous follow ups went through multiple survey modules to collect data for the previous quarters that were missed (recall data) as well as the current quarter.

significantly less likely to be missed compared to control households during the first follow-up survey. This suggests that our results are not likely to be affected by follow up 2 and 3 attrition. However, attrition in follow-up one is likely to affect our results. As such, we control for attrition in our analysis.

Multiple Hypothesis Testing

Considering that we have multiple outcome variables, we correct our standard errors to account for multiple hypotheses testing using Anderson' sharpened q-values. Table 8 presents the adjusted sharpened q-values for our outcome variables. Our findings are generally robust even after adjusting our standard errors to account for multiple hypotheses testing.

Results and Discussions

Baseline randomization balance checks

We start our analysis by evaluating the success of the randomization process. Thereafter, we present the estimate of treatment effects (ITT) on our outcome variables. Table 1 presents results for our pre-treatment balance checks for our baseline randomization. Column (1-3) show results of the joint orthogonality test for our three treatment groups relative to the control group using a multinomial logit model with standard errors clustered at club level. Although some coefficients for some demographic variables are individually statistically significant, our results suggest that the estimated coefficients for all our variables are jointly equal to zero indicating that there is limited correlation between our treatment variables and our outcome variables of interest (Prob>chi2=0.1428). It is, therefore, likely that our estimate of treatment effects will not be biased if we only use the post-intervention data to estimate treatment effect. We, however, include Association location controls, in our estimation for precision.

[Insert Table 1]

Summary statistics

Table 2 below presents our baseline summary statistics. We notice from our descriptive statistics that about 71 percent (28 percent) of the farmers in our sample reported that soybean (groundnuts) was their major legume in the baseline year, that is, in terms of quantity harvested, while 1 percent of the sample had other legume crops including pigeon peas and common beans as their major legume. We also learn that on average farmers stored 189 kgs (660 kgs) of their major legume (maize) at harvest and that the average number of weeks farmers stored their grains before the largest sell in the baseline year was 10 and 13 weeks for their major legume and maize respectively. We also learn from our summary statistics that on average farmers made a net sales revenue, that is, sales less purchase values, of about MK 142,773 and MK23,043 (US$1=MK730) from sales of their major legume and maize respectively with an average total sales revenue of about MK259,194, that is total value of sales only. We also observe from the baseline data that only about 33 percent of the farmers in our sample commercialize maize and that the average reported percent post-harvest loss (PHL) out of their grain inventory is about 6.7 percent and 6.6 percent for the major legume and maize respectively.

[insert Table 2]

Aggregate impacts on farmers' storage behavior

We start out our analysis by evaluating the aggregate impacts of our interventions on farmers' storage and marketing behavior. We do this by estimating the treatment effects on three outcome variables including (i) quantities of the major legume stored at harvest for sell later in the year, (ii) number of weeks the major legume is kept in storage before the largest sell as well as (iii) the farmers' total crop sales revenue.

Quantities stored at harvest (kgs)

Table 3 presents the treatment effects of the randomly assigned interventions on household's quantity of major legume stored at harvest. These estimates test whether households that are treated are subsequently more likely to store more legume at harvest for sell later at a higher lean season price. Columns (1) to (2) show the Simple Mean Difference (SMD) and ANCOVA estimates on households' quantity of legumes stored at harvest respectively. Our estimates of treatment effects on legumes stored at harvest are statistically significant for all treatment group. This suggest that overall, households in all three treatment groups are likely to store more legumes at harvest (27 to 54 kgs) compared to control households. Our F-test results for the ANCOVA estimates, also suggest households in treatment 2 (the village storage program) are likely to store more legumes at harvest than households in treatment 1 and 3, the PICS program and the warehouse storage program respectively. However, we do not observe a significant difference in quantities stored at harvest between households in treatment 1 and 3. This finding suggests a significant marginal effect of village group storage arrangements on legume quantity stored at harvest of about 24 to 27 kgs and no significant marginal effect of the warehouse group storage arrangements on the PICS only treatment. These results suggest that although households in all treatment groups performed better than the control households, the village storage program (treatment 2) is relatively more efficient at incentivizing farmers to store more legumes at harvest compared to the other two treatment interventions.

Weeks stored before largest sale

Columns (3) and (4) presents SMD and ANCOVA estimates of treatment effects on period of storage before largest sell respectively. Our estimates from both estimators are significant for all treatment groups suggesting that treated households are likely to store their major legume longer

(1 to 2 weeks longer) than control households. We also observe from our ANCOVA F-test results that households in the village storage program are likely to store their major legumes longer (1 week longer) than households in the warehouse storage program and PICS program. This finding also suggests a significant marginal effect of village group storage arrangements on length of storage of about 1 week and no significant marginal effect of the warehouse group storage above the PICS only treatment. This also suggest that the village storage program is relatively more effective at incentivizing farmers to store their legumes longer compared to the other two treatment interventions.

Total sales revenue

Columns (5) and (6) presents SMD and ANCOVA estimates of the treatment effects on farmers' total crop sales revenue (i.e. the annual sum of sales revenue for the major legume). Our estimates from both estimators are significant for all treatment groups suggesting that households in all three treatment groups are likely to have higher total crop sales revenue (MK21,000 to MK30,000 more) than control households. We also observe from our ANCOVA F-test results that there are no significant differences in the total sales revenue for households in all three interventions groups. Although we find evidence that suggest that households in the village storage program are likely to store relatively more legumes (between 24 to 27kgs) and for a longer period (about 1 week longer) than households in the other two treatment groups, this does not translate into significant difference in the total sales revenues. This is possibly because the differences in quantities stored are not very large and that the one-week storage difference may not have resulted in a substantial difference in price.

[insert Table 3]

Quarterly impact on farmers' storage behavior

We collected four waves of data on our outcome variables with the first wave, the baseline, collected during the 2018 harvest season, and the second and third waves collected four and eight months after the 2018 harvest respectively while the last wave, the end line, was collected during the 2019 harvest season. In order to understand the inter-year effects of the interventions on farmers' storage and marketing behavior, we estimate the quarterly treatment effects on three outcome variables including (i) quantities of the major legume inventories at the end of every period or quarter, (ii) net quantity of legume sales, that is, the difference between quantities sold and quantities purchased in every quarter; and lastly (iii) the net value of the major legume sales, that is, the difference between value of legume sales and purchases in every quarter.

Impact on major legume inventories (kgs)

Columns (1) to (2) of Table 4 presents the quarterly treatment effects on household's quantity of legume inventories at the end of each period. Our ANCOVA estimates suggest that households in the village storage program and households in the warehouse storage program are likely to have more legume inventories (45 to 55 kgs more) at the end of period 2 compared to control households. However, we do not observe a significant difference in legume inventories between households in the PICS program and control households. Similarly, our F-test results also show that there is no significant difference in legume inventories for households in the village storage program and households in the warehouse storage program for this period. These results suggest that in the first four months after harvest, both treatment 2 and 3 are likely to be equally effective at incentivizing households to store more legumes compared to households in the control group. Our ANCOVA estimates for period four suggest that only households in Treatment 2, the village storage program, are likely to have more legume inventories than control households while period four ANCOVA estimates suggest no significant difference in inventories for all treated households compared to control households. Although our estimates of the aggregate treatment effects help to show how Treatment 2, the village storage program, out-performs the other two treatment groups in general, these quarterly estimates highlight the variations of the effects over time. We observe that Treatment 2 and 3 are equally effective in the first four months after harvest, and that Treatment 2, the village storage program is likely to be effective even after a longer period compared to the other treatment programs.

Impact on net legumes sales (kgs)

Columns (3) to (4) of Table 4 present the SMD and ANCOVA quarterly estimates of our treatment effects on net legume sales. Since this variable is the difference between quantities sold and quantities purchased, a negative observation indicates that a household had more legume purchases than sells. Ideally, for a "*selling-high and buying-low*" scenario, we would expect a negative observation for this variable during the harvest periods when prices are expected to be lower and some positive observation for the post-harvest periods given that prices pick up. Our ANCOVA results for period 2 suggest that households in all three treatment groups are likely to have more net legume sales (between 26 to 44 kgs) compared to households in the control group. We also observe that household in Treatment group 1 and 2 are likely to have more net legume sales than control households in period 3 (17 to 27 kgs less) and that households in treatment group 2 are likely to have less net legume sales in period 4, the harvest period, than households in the control group. The quarterly treatment effect suggests that the interventions may have significantly influenced treated households (treatment 2) to sell less legumes at harvest (period 4) and significantly have more sells than purchases in the post-harvest periods (period 2) compared to control households.

Impact on net value of legume sales (Malawi Kwacha)

Our earlier results show significant differences in the trends of net quantity of legume sales between treated and control households which is likely due to the differences in inventories or storage behavior. In order to evaluate the monetary gains from such shifts in selling trends, we evaluate the quarterly impacts of the interventions on the farmers' net value of legume sales. We define the net value of sales as difference between the value of legume sales and purchases. Our ANCOVA estimates of treatment effects on net value of legume sales in period 2 are not significant for households from all three treatment groups. However, for period 3, households in Treatment group 1 and 2, PICS program and village storage program have statistically higher net value of legume sales compared to control households. For these groups, this implies that having significantly more inventories (treatment 2) and more sales quantities (treatment 1 and 2) in period 3 compared to control households, may have enabled these treated households to take advantage of a higher price faced in that period.

[insert Table 4]

Heterogeneity in aggregate treatment effects

Literature suggest that access to credit markets and input or output markets can influence famers' demand for storage. As such, we further examine how access to credit and markets could influence heterogeneity in our aggregate treatment effects. We interact our treatment variables with the credit access variable and market access variable to determine the marginal treatment effects of a farmer having access to credit and output markets. Table 5 present our results showing estimates on households' quantity of legumes stored at harvest, length of storage and total sales revenue. Panel A shows the results when we interact our treatment variable with the credit access dummy variable while Panel B shows results for market access, a continuous variable captured by distance to the nearest input or output market. Our results suggest no significant heterogeneity in treatment effects in both credit and market access analysis.

[insert Table 5]

Conclusion

We estimate the impacts of the three storage interventions including (i) receipt of PICS bags and storage at the producer's house, (ii) receipt of PICS bags and village group storage, and (iii) receipt of PICS bags, and warehouse group storage on smallholder farmers' storage behaviors in SSA. Our paper advances literature on storage interventions in SSA by evaluating the impact of two grain storage commitment devices in the form of group storage in combination with the PICS technology. We examine the effects of the three storage interventions on our outcome variables including quantity stored at harvest, length of storage, total sales revenue, grain inventory, net quantities and value of legume sales. This helps in determining effective incentive mechanisms for farmers to exploit inter-seasonal price arbitrage opportunities in SSA.

Our aggregate estimates of treatment effects show a significant difference in quantities of legumes stored, length of storage and total sales revenue for all households in all three treatment groups compared to households in the control group. Although households in all treatment groups performed better than the control households, our results suggest that the village storage program is relatively more effective at incentivizing farmers to store more legumes at harvest as well as store relatively longer compared to the other two treatment interventions. We used the F-test to tease out the impact of the two grain storage commitment devices implemented in our study and find a significant marginal effect of the village group storage on quantity stored at harvest of about 24 to 27 kgs as well as on length of storage of about a week. However, we do not find significant marginal effects of the warehouse group storage above the PICS only treatment. This implies that village group storage is an effective grain commitment device compared to warehouse group storage. This is likely because of the low uptake rate in the warehouse storage program which may have resulted from the transportation costs incurred and club's limited commitment to store with a larger group at the warehouse which are further away from farmers villages. These empirical findings helps to give some insight on the viability of warehouse programs for smallholder farmers as we learn that incentivizing smallholder farmers to store together locally within their villages may be more effective than a centralized warehouse program.

Our estimate of quarterly treatment effects helps to highlight the inter-year effects of the interventions on farmers' storage and marketing behavior. We find that households in the village storage program and households in the warehouse storage program are likely to have more legume inventories (45 to 55 kgs more) in period 2 compared to control households. However, we do not observe a significant difference in legume inventories between households in the PICS programs and control households. These results suggest that in the first four months after harvest, both grain storage commitment devices, that is, village group storage and warehouse group storage interventions, were equally effective at incentivizing households to store more legumes compared to households in the control group. However, in period 4, twelve months after harvest, we find that only households in treatment 2, the village storage program, are likely to have more legume inventories than control households. We also find that in period 3, households in all treatment groups are likely to have no significant different in legume inventories compared to control households.

Our results also show that households in all three groups are likely to have more net legume sales (between 27 to 43 kgs) compared to households in the control group in period 2, four months after harvest. However, only household in treatment group 1 and 2 are likely to have more net legume sales than control households in period 3, eight months after harvest and that households in treatment 2 are likely have less net legume sales (29 kgs less) in period 4, the harvest period, than households in the control group. This quarterly treatment effects for period 4, the endline harvest season, suggest that the interventions may have significantly influenced treatment households (treatment 2) to sell less legumes at harvest compared to control households. These results imply that treated households (Treatment 1, 2) are likely to engage in significantly more sells than purchases in the post-harvest periods (period 2 and 3) and more purchases than sells in the harvest period (Treatment 2 in period 4) compared to control households.

Our estimates of treatment effects on net value of legume sales suggest that having significantly more inventories and more sales in period 3, compared to control households, may have enabled treated households to take advance of a higher price faced in that period. However, in period 2 and 4 we do not observe significant difference in net value of legume sales for households in all three treatment groups. This is likely because the magnitudes of the marginal differences in inventory and net legume sales for the treated groups in these periods may not have translated into a significant impact on value of sales. Although our estimates of the aggregate treatment effects show how Treatment 2, the village storage program, out-performs the other two treatment groups in general, the quarterly estimates highlight the variations of the treatment effects over time as we observe that for all three quarterly outcome variables; the village storage program and the warehouse storage program, are equally effective in the first four months after harvest. However, we observe that only the village storage program is likely to be effective even after a longer period.

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Table 1: Baseline balance checks using a multinomial logit model

VARIABLES	(1) Treatment 1	(2) Treatment 2	(3) Treatment 3
Kgs of maize harvested April,2018	0.000138	0.000024	0.000053
	(0.000189)	(0.000198)	(0.000194)
Kgs of maize stored at harvest	-0.000376	-0.000342	-0.000079
	(0.000249)	(0.000261)	(0.000268)
Maize inventory (kgs)	0.000266	0.000198	0.000291*
	(0.000198)	(0.000187)	(0.000175)
Weeks of maize storage before largest sale	0.006116	0.000184	0.007080
	(0.010632)	(0.009578)	(0.009116)
Net value of maize sales (MK)	0.000003	0.000005	0.000003
	(0.000007)	(0.000007)	(0.000007)
Net maize sales (kgs)	-0.000766	-0.000493	-0.000659
	(0.000998)	(0.001041)	(0.001009)
Maize PHL % out of inventory	-0.000128	0.001048	-0.011337
	(0.008404)	(0.008554)	(0.008868)
Kgs of major legumes harvested April, 2018	-0.000126	-0.000434	-0.000078
	(0.000300)	(0.000288)	(0.000275)
Kgs of major legumes stored at harvest	0.000842**	0.000775**	0.000329
	(0.000376)	(0.000359)	(0.000368)
Major legume inventory(kgs)	0.000072	0.000208	-0.000029
	(0.000241)	(0.000214)	(0.000222)
Weeks of legume storage before largest sale	0.017120	0.022057	0.020477
	(0.017645)	(0.017990)	(0.018723)
Net value of legume sales (kgs)	-0.000000	-0.000001	-0.000001
	(0.000002)	(0.000002)	(0.000002)
Net legume sales (kgs)	-0.001086*	-0.000388	-0.000158
	(0.000638)	(0.000664)	(0.000663)
Legume PHL % out of Inventory	-0.004949	-0.006836	-0.006847
	(0.006707)	(0.006667)	(0.006203)
=1 if soya	0.181820	0.174752	0.272043
	(0.185900)	(0.179288)	(0.189190)
Expenditure on Storage Pesticides (MK)	-0.000058*	-0.000051	-0.000051*
	(0.000035)	(0.000034)	(0.000030)
=1 if use Actellic	0.049200	-0.109578	-0.167315
	(0.298806)	(0.316962)	(0.331500)
Baseline total income from all sources in MK	-0.000000	0.000000	-0.000000
	(0.000000)	(0.000000)	(0.000000)
Number of people in household	-0.075581	-0.015597	-0.000441
	(0.068528)	(0.062040)	(0.070549)
Age of head	0.004665	-0.001964	-0.003392
	(0.006216)	(0.006596)	(0.006033)
=1 if household head is female	-0.206829	-0.177802	-0.487632**
	(0.226260)	(0.211264)	(0.222345)
=1 if no education	-0.221336	0.183216	0.013518
	(0.221053)	(0.218588)	(0.218317)
number of school goers in household	-0.061483	-0.035897	-0.014522
	(0.073797)	(0.068585)	(0.073324)
years NASFAM Experience	0.005413	0.013925	0.016631
	(0.032203)	(0.026995)	(0.026997)
Landholding in acres	0.073610	0.111887*	0.053802
	(0.063323)	(0.058649)	(0.059330)
Total Credit over last year (MK)	-0.000005	-0.000006*	-0.000000
	(0.000004)	(0.000004)	(0.000002)
Savings (MK)	-0.000001	0.000003	0.000001
	(0.000004)	(0.000004)	(0.000004)
No of Extension Contacts (annually)	0.022091	-0.028951	-0.041446
	(0.045300)	(0.046173)	(0.045152)
Distance to closest input supplier (km)	-0.008811	-0.000212	0.001647
	(0.009331)	(0.008207)	(0.007853)
Total expenditure on woven bags	0.000006	0.000001	-0.000018
	(0.000022)	(0.000022)	(0.000022)
Amount spent on Fertilizer (MK)	0.000003	0.000001	0.000002
	(0.000003)	(0.000003)	(0.000003)
=1 if sell any of maize harvest	0.239233	-0.014571	0.153957
	(0.250660)	(0.245188)	(0.258936)
Association = 2, Mikundi	-0.321939	-0.230328	-0.206899
	(0.356821)	(0.345262)	(0.337794)
Association = 3, Mpenu	0.450309	0.349185	0.813871*
	(0.473354)	(0.462426)	(0.445159)
Constant	-0.085556	-0.217560	-0.387423
	(0.530486)	(0.501926)	(0.538285)
Observations	1,739	1,739	1,739

Note: Standard errors clustered at club level in parentheses & *** p<0.01, ** p<0.05, * p<0.1 and (Prob>chi2=0.1428)

Table 2: Baseline Summary Statitics

Panel A: Outcome variables	**Count**	**Mean**	**Std Dev.**	**Min**	**Max**
Maize harvest (kg)	1739	980.73	839.49	0.00	3728.00
Maize stored at harvest(kg)	1739	659.61	591.75	0.00	2450.00
Maize inventory (kg)	1739	603.76	517.82	0.00	2045.00
Storage length maize (Weeks)	1739	12.67	7.69	0.00	32.00
Net maize sales value (MK)	1739	23042.87	49358.61	0.00	230240.00
Net maize sales (kg)	1739	153.53	341.90	0.00	1584.40
Maize PHL out of inventory (%)	1739	6.63	10.05	0.00	50.00
Legume harvest (kg)	1739	517.63	390.39	0.00	1750.00
Legume stored at harvest (kg)	1739	276.99	271.03	0.00	1135.00
Legume inventory (kg)	1739	188.66	349.74	1.00	1095.00
Storage length legume (Weeks)	1739	10.35	6.42	0.00	28.00
Net legume sales value (MK)	1739	142773.20	86326.82	0.00	656463.10
Net legumes sales (kgs)	1739	393.38	213.89	0.00	629.07
Legume PHL (%)	1739	6.72	11.54	0.00	50.00
Storage chemicals Expenses (MK)	1739	4335.46	2171.79	0.00	12000.00
Total crop sales revenue (MK)	1739	259194.50	175353.60	7030.00	899547.50
Panel B: Household variables					
Household size	1739	5.02	1.83	1.00	13.00
Household head Age	1739	41.00	12.69	0.00	70.00
=1 if household head female	1739	0.13	0.34	0.00	1.00
Number of students in household	1739	2.23	1.74	0.00	11.00
Number of children under10	1739	1.65	1.23	0.00	8.00
Number of adults over 18	1739	2.37	1.00	0.00	8.00
Number of NASFAM members	1739	4.79	55.14	0.00	2300.00
Landholding (acres)	1739	3.69	4.06	0.25	149.00
=1 if borrowed cash past year	1739	0.31	0.46	0.00	1.00
Credit Amount (MK)	1739	8822.95	33924.94	0.00	1050000.00
Savings Amount (MK)	1739	8692.50	56156.84	0.00	1800000.00
Extension Contacts (Annually)	1739	2.20	2.20	0.00	20.00
Distance to market (km)	1739	42.55	737.93	0.00	20000.00
Expenditure on woven bags (MK)	1739	3871.49	5534.08	0.00	100000.00
Fertilizer Expenditure (MK)	1739	39521.52	48564.61	0.00	770000.00
=1 if Major legume is Soybeans	1739	0.70	0.46	0.00	1.00
=1 if use Actellic	1739	0.05	0.20	0.00	1.00
=1 if household sells maize (%)	1739	0.33	0.47	0.00	1.00

Note: Std Dev. is standard deviation and Min and Max are minimum and Maximum respectively

Table 3: Aggregate Treatment Effects on Key Outcomes

Panel A: Levels of Outcome	Legume stored at harvest (kg)		Weeks stored before largest sell		Total revenue from crop sales (MK)	
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	SMD	ANCOVA	SMD	ANCOVA	SMD	ANCOVA
=1 for PICS only(T1)	38.45***	27.06***	1.25***	1.01***	26,634.72***	20,703.98***
	(8.94)	(3.44)	(0.37)	(0.27)	(8,983.43)	(5,297.85)
=1 for PICS+ Village group store(T2)	48.19***	53.73***	1.89***	1.89***	36,007.01***	29,711.32***
	(8.94)	(3.47)	(0.37)	(0.27)	(9,408.70)	(5,332.68)
=1 for PICS+ Warehouse group store(T3)	32.37***	30.52***	1.31***	1.01***	32,016.19***	27,085.02***
	(8.48)	(3.38)	(0.37)	(0.26)	(10,186.29)	(5,198.00)
=1 for Chioshya association	16.69**	7.78**	-0.46	-0.32	-1,625.04	-5,856.10
	(7.83)	(3.38)	(0.39)	(0.26)	(10,141.49)	(5,193.98)
=1 for Mikundi association	30.48***	5.94*	-0.82**	-0.79***	9,607.52	3,137.55
	(8.82)	(3.49)	(0.41)	(0.27)	(11,008.18)	(5,370.88)
Baseline outcome variable		1.001**		0.279***		0.925***
		(1.332)		(0.012)		(0.006)
=1 If missed follow up 1	36.88*	21.98***	0.22	0.94*	-34,029.11***	-21,259.08**
	(21.46)	(6.47)	(0.73)	(0.50)	(12,552.41)	(9,954.64)
Constant	218.35***		8.90***		99,359.98***	
	(11.33)		(0.55)		(9,907.87)	
Observations	6,172	6,177	6,172	6,177	6,172	6,177
R-squared	0.34	0.79	0.06	0.10	0.12	0.49
F-Test	**Prob > F**	**Prob > F**	**Prob > F**	**Prob > F**	**Prob > F**	**Prob > F**
Treatment 1=Treatment 2	0.3053	<0.001	0.0851	0.0016	0.4900	0.1083
Treatment 1=Treatment 3	0.4974	0.3092	0.8550	0.9770	0.7127	0.3751
Treatment 2=Treatment 3	0.0895	<0.001	0.1291	0.0017	0.6997	0.6382

Note: Clustered standard errors in parentheses and *** p<0.01, ** p<0.05, * p<0.1

Table 4: Quarterly Treatment Effects on Key Outcomes

VARIABLES	Legume inventory at end of quarter (kg)		Net legume sales (kgs)		Value of net legume sales (MK)	
	(1)	(2)	(3)	(4)	(5)	(6)
	(SMD)	**(ANCOVA)**	**(SMD)**	**(ANCOVA)**	**(SMD)**	**(ANCOVA)**
Panel A: Four months after harvest season, August 2018 (Period 2)						
Treatment 1: PICS only (T1)	4.41	8.75	29.42***	26.67***	37,826.84***	3,687.65
	(19.08)	(15.16)	(4.03)	(7.38)	(11,667.93)	(8,793.08)
Treatment 2: PICS+ Group store at village (T2)	46.16**	54.51***	44.63***	43.64***	35,645.47***	2,759.02
	(21.36)	(15.45)	(2.21)	(7.52)	(11,178.17)	(8,964.39)
Treatment 3: PICS+ Group store at warehouse (T3)	35.09	44.73***	34.49***	32.44***	35,796.86***	8,247.52
	(23.77)	(14.94)	(3.01)	(7.27)	(11,258.84)	(8,664.77)
Treatment 1=Treatment 2	**0.0292**	**0.0161**	**0.0011**	**0.0073**	**0.0031**	**0.0001**
Treatment 1=Treatment 3	**0.1537**	**0.0735**	**0.2560**	**0.3619**	**0.2518**	**0.349**
Treatment 2=Treatment 3	**0.6405**	**0.4958**	**0.0004**	**0.0686**	**0.0767**	**0.0577**
Panel B: Eight months after harvest season, December 2018 (Period 3)						
Treatment 1: PICS only (T1)	44.30***	25.86	19.57	17.32**	20,859.72	16,458.18*
	(14.73)	(15.76)	(13.81)	(7.67)	(12,656.58)	(9,136.35)
Treatment 2: PICS+ Group store at village (T2)	36.60***	23.97	30.20*	27.23***	34,065.81**	18,584.69**
	(13.30)	(15.99)	(16.38)	(7.78)	(13,266.02)	(9,259.73)
Treatment 3: PICS+ Group store at warehouse (T3)	9.96	7.06	5.05	10.41	24,786.89*	13,553.71
	(10.81)	(15.55)	(13.05)	(7.57)	(13,618.69)	(9,008.12)
Treatment 1=Treatment 2	**0.6211**	**0.7710**	**0.5087**	**0.1039**	**0.0578**	**0.0027**
Treatment 1=Treatment 3	**0.0140**	**0.7257**	**0.2554**	**0.3892**	**0.4987**	**0.2342**
Treatment 2=Treatment 3	**0.0337**	**0.7545**	**0.1056**	**0.0126**	**0.2008**	**0.0619**
Panel C: End line Harvest Season, April 2019 (Period 4)						
Treatment 1: PICS only (T1)	10.20	7.00	-6.86	-9.78	20,251.20	-886.64
	(20.98)	(16.82)	(6.45)	(8.19)	(13,417.35)	(9,751.34)
Treatment 2: PICS+ Group store at village (T2)	41.91*	32.10*	-23.54***	-29.41***	44,622.41***	-1,374.81
	(23.69)	(16.96)	(7.57)	(8.26)	(14,751.70)	(9,838.69)
Treatment 3: PICS+ Group store at warehouse (T3)	17.17	15.53	0.78	-10.79	41,513.62***	234.13
	(19.53)	(16.52)	(10.29)	(8.05)	(15,460.38)	(9,585.47)
Treatment 1=Treatment 2	**0.1632**	**0.1897**	**0.0031**	**0.0083**	**0.0040**	**0.0001**
Treatment 1=Treatment 3	**0.7077**	**0.2951**	**0.3732**	**0.8448**	**0.3729**	**0.0022**
Treatment 2=Treatment 3	**0.2518**	**0.2971**	**0.0131**	**0.0129**	**0.0447**	**0.3949**
=1 If missed follow up 1	1.56	43.03**	4.41	6.81	-8,594.94	-81,287.93***
	(19.93)	(21.19)	(15.37)	(10.68)	(9,121.18)	(6,961.43)
Constant	142.78***		378.56***		165,642.28***	
	(12.05)		(9.10)		(13,145.18)	
Observations	6,172	4,438	6,172	4,438	6,172	4,438
R-squared	0.08	0.38	0.50	0.39	0.23	0.44

Note: Clustered standard errors in parentheses and *** p<0.01, ** p<0.05, * p<0.1

Table 5: Heterogeneity in Overall Treatment Effects on Key Outcomes

VARIABLES	Legume stored at harvest kg		Weeks stored before largest sell		Total value of legume Sales (MK)	
PANEL A: Baseline Credit Access	SMD	ANCOVA	SMD	ANCOVA	SMD4	ANCOVA4
=1 for PICS only (T1)	36.57***	26.21***	1.28***	1.01***	33,584.31***	23,438.63***
	(9.03)	(3.53)	(0.38)	(0.27)	(8,825.09)	(4,724.43)
=1 for PICS+ Group store at village(T2)	53.84***	54.82***	1.85***	1.85***	42,765.07***	32,136.38***
	(9.12)	(3.56)	(0.38)	(0.27)	(10,633.42)	(4,777.60)
=1 for PICS+ Group store at warehouse (T3)	34.18***	30.05***	1.26***	0.96***	39,397.82***	28,258.71***
	(7.91)	(3.48)	(0.38)	(0.27)	(11,703.43)	(4,668.40)
=1 for PICS only # =1 if borrowed cash past year	12.79	3.93	-0.53	-0.23	40,142.85	-6,514.60
	(28.71)	(10.20)	(0.53)	(0.78)	(26,709.91)	(13,679.47)
=1 for PICS+ Group store at village # =1 if borrowed cash past year	-60.09**	-14.63	0.39	0.46	10,423.42	-15,159.69
	(25.09)	(9.82)	(0.72)	(0.76)	(22,130.04)	(13,152.09)
=1 for PICS+ Group store at warehouse # =1 if borrowed cash past year	-24.26	1.14	0.54	0.41	13,341.21	-11,219.28
	(39.46)	(8.97)	(0.70)	(0.69)	(20,953.18)	(12,016.66)
Constant	216.56***		8.76***		99,482.30***	
	(11.19)		(0.56)		(10,069.78)	
Observations	6,172	6,177	6,172	6,177	6,172	6,177
R-squared	0.35	0.79	0.06	0.10	0.12	0.49
F-Test:	Prob > F	Prob > F	Prob > F	Prob > F	Prob > F	Prob > F
Treatment 1=Treatment 2	0.0438	0.1774	0.4870	0.2811	0.2860	0.3730
Treatment 1=Treatment 3	0.4260	0.8320	0.5648	0.1959	0.7159	0.4066
Treatment 2=Treatment 3	0.4348	0.2203	0.2145	0.8765	0.1745	0.9202
PANEL B: Baseline Market Access						
=1 for PICS only (T1)	31.92***	24.67***	0.85*	0.90***	38,422.59***	19,985.73***
	(11.20)	(4.37)	(0.45)	(0.34)	(11,678.63)	(5,853.20)
=1 for PICS+ Group store at village(T2)	49.93***	53.78***	2.16***	1.97***	49,156.36***	28,927.91***
	(11.28)	(4.47)	(0.47)	(0.34)	(15,119.76)	(5,988.74)
=1 for PICS+ Group store at warehouse (T3)	30.35***	30.22***	0.99**	0.63*	38,126.49***	18,952.51***
	(9.77)	(4.37)	(0.48)	(0.34)	(13,854.28)	(5,858.01)
=1 for PICS only # Distance to closest market	0.52	0.17	0.04	0.01	-157.19	268.48
	(0.52)	(0.25)	(0.03)	(0.02)	(829.34)	(336.97)
=1 for PICS+ Group store at village # Distance to closest market	-0.14	-0.01	-0.02	-0.01	-455.70	162.22
	(0.48)	(0.24)	(0.02)	(0.02)	(699.08)	(320.61)
=1 for PICS+ Group store at warehouse # Distance to closest market	0.11	-0.01	0.03	0.03*	211.83	689.63**
	(0.60)	(0.23)	(0.02)	(0.02)	(669.24)	(310.22)
Constant	216.82***		8.82***		109,305.86***	
	(11.59)		(0.60)		(11,481.50)	
Observations	6,172	6,177	6,172	6,177	6,172	6,177
R-squared	0.34	0.79	0.06	0.10	0.12	0.49
F-Test:	Prob > F	Prob > F	Prob > F	Prob > F	Prob > F	Prob > F
Treatment 1=Treatment 2	0.3492	0.6060	0.4870	0.0717	0.7860	0.8197
Treatment 1=Treatment 3	0.6048	0.5943	0.5648	0.7430	0.7359	0.3585
Treatment 2=Treatment 3	0.7436	0.9790	0.2145	0.1051	0.4845	0.2365

Note: clustered standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 6: Attrition bias checks using joint orthogonality test

VARIABLES	Follow-up 1	Follow-up 2	Follow-up 3
=1 for PICS only(T1)	-0.969424**	-0.827242***	-0.251905
	(0.426154)	(0.307003)	(0.285145)
=1 for PICS+ Group store at village(T2)	-0.083899	-0.324642	-0.104202
	(0.345420)	(0.277487)	(0.284518)
=1 for PICS+ Group store at warehouse (T3)	-0.402351	-0.461263*	-0.243956
	(0.354784)	(0.271474)	(0.269432)
Kgs of maize harvested April,2018	0.000483*	0.000099	0.000161
	(0.000251)	(0.000207)	(0.000156)
Kgs of maize stored at harvest	-0.000918***	-0.000240	-0.000077
	(0.000280)	(0.000250)	(0.000221)
Maize inventory (kgs)	-0.000158	-0.000156	-0.000168
	(0.000240)	(0.000208)	(0.000159)
Weeks of maize storage before largest sale	0.006137	-0.008785	-0.002148
	(0.013899)	(0.010198)	(0.008655)
Net value of maize sales (MK)	0.000009	0.000000	0.000001
	(0.000021)	(0.000012)	(0.000010)
Net maize sales (kgs)	-0.001308	0.000114	-0.000449
	(0.003147)	(0.001835)	(0.001518)
Maize PHL % out of inventory	-0.002192	-0.002317	-0.005904
	(0.008525)	(0.007127)	(0.006389)
Kgs of major legumes harvested April, 2018	-0.000624	-0.000128	-0.000387*
	(0.000424)	(0.000312)	(0.000231)
Kgs of major legumes stored at harvest	0.000589	0.000480	-0.000429
	(0.000478)	(0.000350)	(0.000311)
Major legume inventory(kgs)	-0.000402	0.000243	-0.000369*
	(0.000287)	(0.000205)	(0.000196)
Weeks of legume storage before largest sale	0.020331	0.021863	-0.000243
	(0.019800)	(0.016278)	(0.013956)
Net value of legume sales (kgs)	0.000005*	0.000003	0.000002
	(0.000003)	(0.000002)	(0.000002)
Net legume sales (kgs)	-0.001266	-0.000801	0.000264
	(0.001089)	(0.000721)	(0.000619)
Legume PHL % out of Inventory	0.010748	0.001108	0.003609
	(0.007800)	(0.006403)	(0.004760)
=1 if soya	-0.281580	-0.339754**	-0.234586*
	(0.198217)	(0.161510)	(0.132867)
Expenditure on Storage Pesticides MK	0.000070	0.000024	0.000014
	(0.000046)	(0.000040)	(0.000029)
=1 if use Actellic	-0.033813	0.020497	-0.212740
	(0.451716)	(0.335035)	(0.273160)
Baseline total income from all sources in MK	0.000000	0.000000	0.000000
	(0.000000)	(0.000000)	(0.000000)
Number of people in household	0.000544	-0.103070	-0.051293
	(0.081641)	(0.063261)	(0.058712)
Age of head	-0.008850	0.001412	-0.012042**
	(0.009917)	(0.006598)	(0.005606)
=1 if household head is female	0.042776	-0.182743	-0.173333
	(0.262081)	(0.197583)	(0.202329)
=1 if no education	0.664302**	0.284430	0.292841
	(0.262188)	(0.198160)	(0.184924)
number of school goers in household	-0.000700	0.102442	0.105480*
	(0.092862)	(0.067218)	(0.060049)
years NASFAM Experience	-0.067738	-0.077910**	-0.010586
	(0.045126)	(0.036435)	(0.025833)
Landholding in acres	0.056489	-0.009919	0.030241
	(0.064283)	(0.053813)	(0.043912)
Total Credit over last year (MK)	-0.000011*	0.000002*	0.000001
	(0.000006)	(0.000001)	(0.000001)
Savings (MK)	0.000000	0.000003	-0.000001
	(0.000006)	(0.000004)	(0.000003)
No of Extension Contacts (annually)	0.057268	0.006122	-0.013287
	(0.048218)	(0.038394)	(0.035458)
Distance to closest input supplier (km)	0.003130	0.001608	0.007732
	(0.009195)	(0.007079)	(0.007093)
Total expenditure on woven bags	-0.000063**	-0.000031	-0.000005
	(0.000028)	(0.000021)	(0.000016)
Amount spent on Fertilizer (MK)	0.000005	0.000001	-0.000001
	(0.000003)	(0.000003)	(0.000002)
=1 if sell any of maize harvest	-0.337646	-0.270833	-0.016530
	(0.298981)	(0.263654)	(0.221742)
Association = 2, Mikundi	0.035267	0.296803	1.237491***
	(0.298446)	(0.247954)	(0.263940)
Association = 3, Mpenu	-0.374091	0.407330	1.462895***
	(0.413019)	(0.290457)	(0.281550)
Constant	-2.252213***	-1.195833**	-1.307521***
	(0.627096)	(0.559433)	(0.470345)
F-Test	0.0057	0.4111	0.3725

Note: Standard errors clustered at club level in parentheses & *** p<0.01, ** p<0.05, * p<0.1

Table 7: Intra-Cluster Correlation Coefficient at Baseline

Outcome Variable	ICC	SE	N
Quantity stored at harvest (Kg)	0.12	0.023	1739
Weeks stored before largest sell (Weeks)	0.08	0.021	1739
Total sales revenue (MK)	0.13	0.023	1739
Inventory (kg)	0.08	0.022	1739
Net sales quantity(kg)	0.06	0.024	
Net Sales Value (MK)	0.07	0.026	1739

Notes: An ICC value closer to 1, implies less variations in farmers within a club hence no power gain in having more farmers within each club. However, a value closer to zero indicates a bigger variation in farmers within clusters, which is beneficial in terms of efficiency as more observations within the cluster implies more power gain.

Table 8: Comparing of p-values and sharpened q-values for multiple hypothesis testing

Outcomes	Legume stored at harvest (kg)		Weeks stored before largest sell		Total revenue from crop sales (MK)		Legume Inventory (kg)		Net Legume Sales (kg)		Net Sales Value (MK)	
Treatment Variables	q-val	p-val	q-val	p-val	q-val	p-val	q-val	p-val	q-val	p-val	q-val	p-val
=1 for PICS only (T1)	9.04	3.44	0.47	0.27	5,973.44	5,297.85	10.07	8.97	4.01	3.09	4,973.44	2,233.85
=1 for PICS+ Village group store(T2)	9.11	3.47	0.41	0.27	5508.40	5,332.68	8.01	6.09	5.02	4.03	5008.43	4,342.68
=1 for PICS+ Warehouse group store(T3)	8.90	3.38	0.30	0.26	6,116.20	5,198.00	7.08	6.01	5.04	4.01	3,106.20	2,197.00
Observations	6,177	6,177	6,177	6,177	6,177	6,177	6,177	6,177	6,177	6,177	6,177	6,177

Note: Clustered standard errors at club level computed following Anderson (2008); US$1=MK730

Figure 1: Baseline respondents' sales and purchases trends

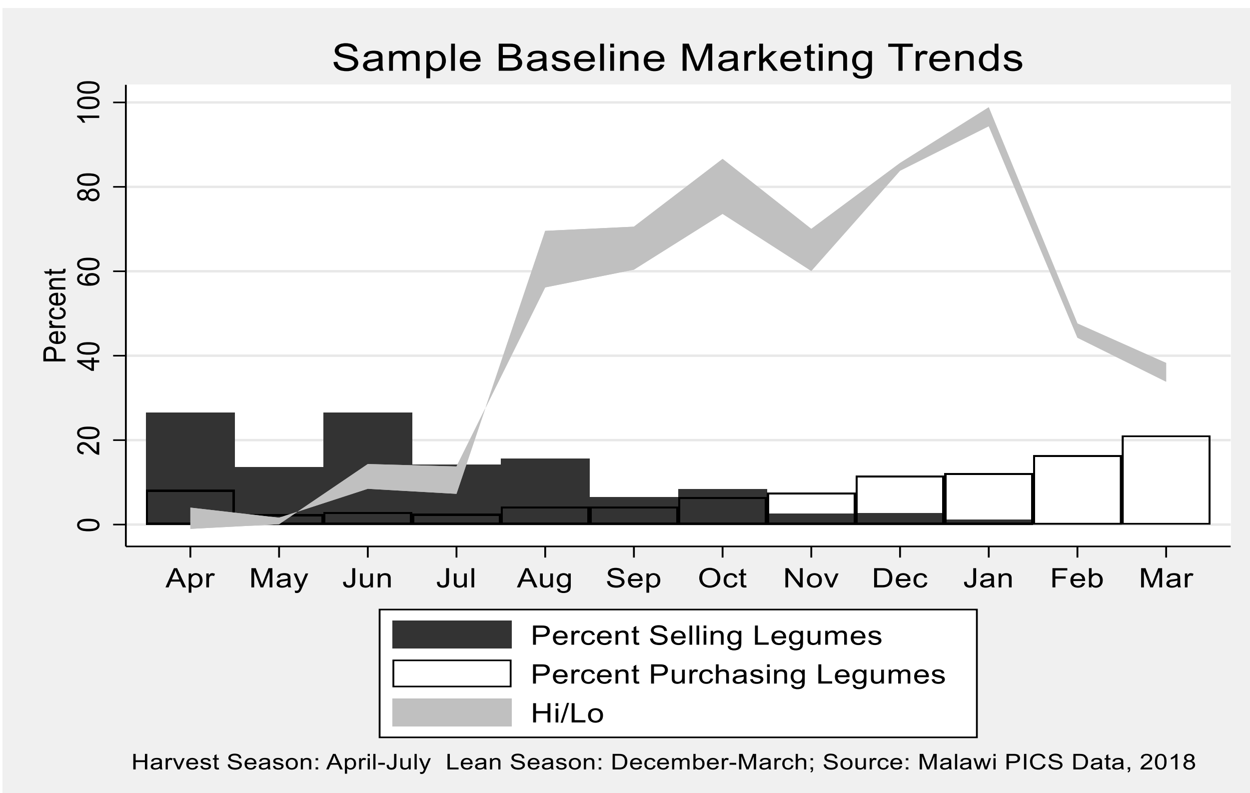

Figure 2: Study Area

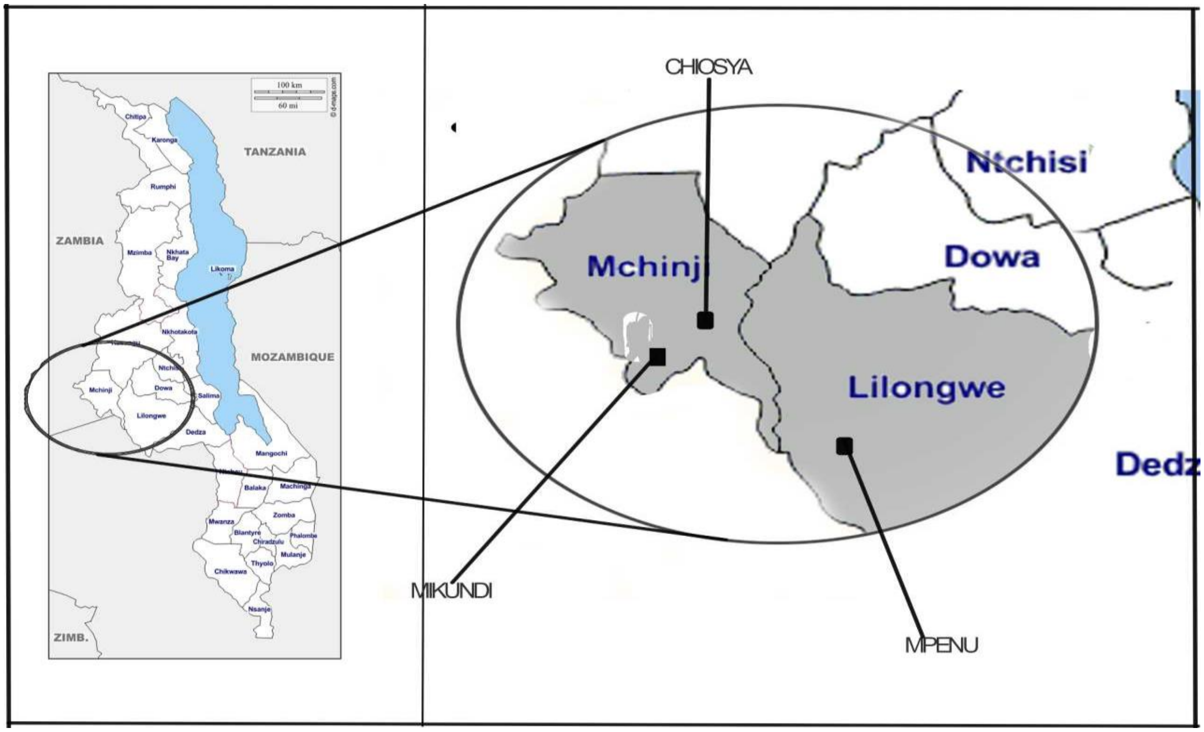

Figure 3 Consort Diagram

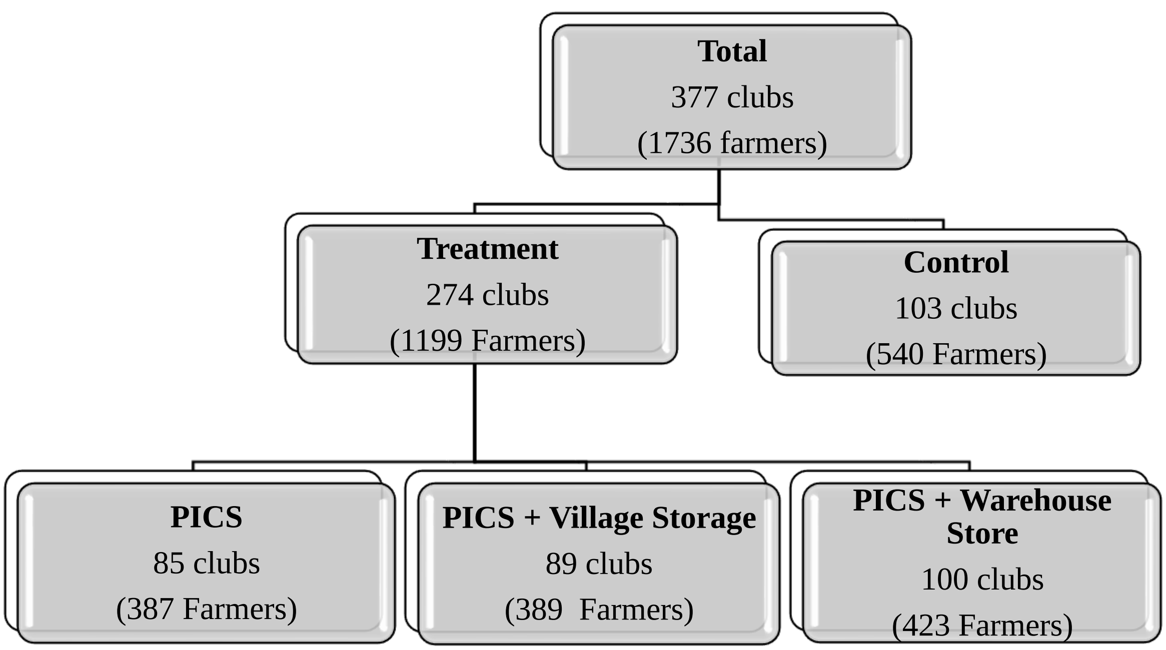

Figure 4: Seasonal Price Variations for Crops in Malawi (1989 to 2017)

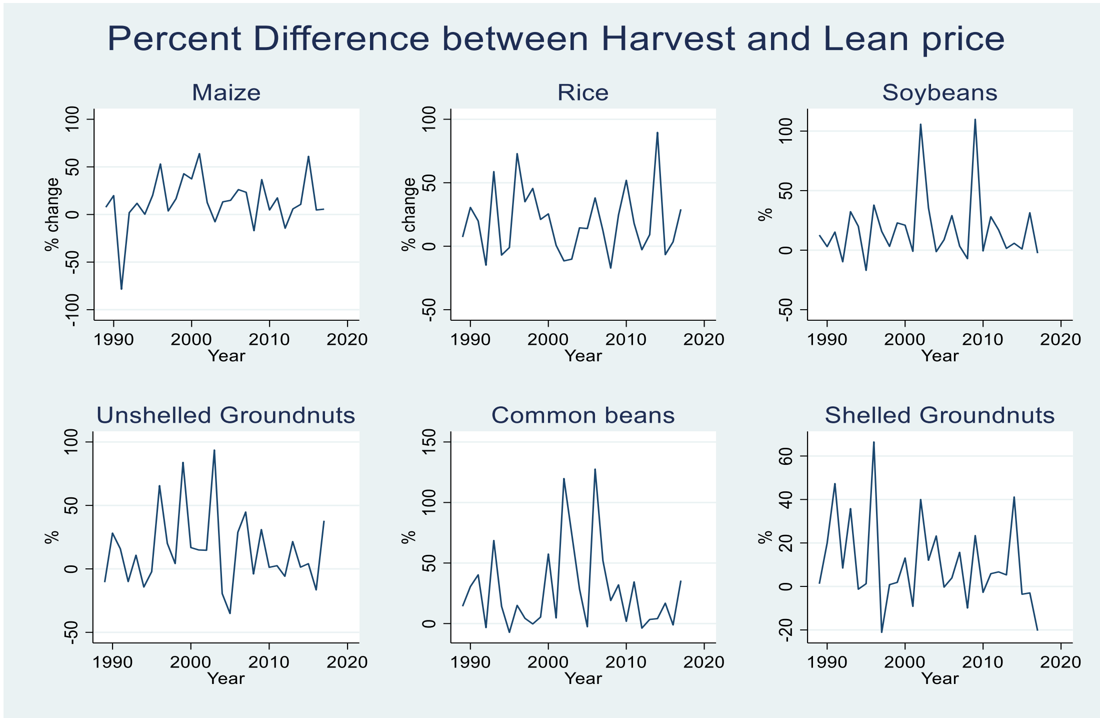

Figure5: Study Timeline.

Time		Study Activity
2017/18 Planting season	**December 2017**	**Study Design & Preparations**
2017/18 Harvest season	**April-May 2018**	**Baseline Study** ✓ 1736 farmers recruited in the study ✓ 379 clubs of which 276 are treated & 103 in control ✓ Detailed survey (Demographics, agricultural production, storage and marketing activities, assets, consumption, expenditures, credit & saving use)
	April-May 2018	**Treatment Assignment** ✓ 103 clubs in control ✓ 88 clubs PICs only ✓ 89 clubs PICS + Village Group storage ✓ 99 clubs PICS + Warehouse Group storage
2017/18 Post- Harvest season	**July-Aug 2018**	**Follow up Round 1** ✓ Outcome variables of interest only
2018/2019 Planting season	**December 2018**	**Follow up Round 2** ✓ Outcome variables of interest only
2018/2019 Harvest season	**April-May 2019**	**End line study** ✓ Detailed survey

Figure 5: Treatment Take-up Rate