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BREAKING DOWN SILOS –
ON POST-HARVEST LOSS INTERVENTIONS
IN TANZANIA

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Abstract

Post-Harvest Losses (PHL) are considered to pose important economic losses for farmers in developing countries. This paper examines the effects of an intervention in Tanzania, aimed at reducing PHL of maize growing farmers during maize storage. Farmers were invited to attend a training on best practices in post-harvest maize management, and a randomized subset of trainees received the opportunity to buy an improved storage facility (silos) at a substantially discounted price. Data collected at 30 days and 90 days after harvest, however, do not point to significant impacts of the treatments offered to the farmers. Receiving training on best practices improved stated knowledge, but training nor the opportunity to purchase an improved storage had a significant effect on maize storage and sales behavior, physical PHL during storage, or the quality of the stored maize. The paper explores potential explanations, and provides some policy recommendations for future learning and decision-making on how to address PHL issues in developing countries.

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1 Introduction

Post-Harvest Losses (PHL) are considered one of the main factors that keep farm incomes low in developing countries, and especially in Sub Saharan Africa (AGRA 2016). Because farmers lose some of their harvested crops along the process to supply food from field to farm, less food is available for household consumption and commercial sales. Once stored, bad storage techniques and facilities reduce the quantity and quality of the stored crop. Reduced food sales not only directly reduce the income of producers, it can also lead to shortages or volatility in local food availability (and prices), thus indirectly affecting (poor) food consumers (Sheahan and Barrett 2018). PHL in food crops are therefore often linked to food insecurity, deteriorating nutrition outcomes, and even persistent rural poverty levels (Affognon et al. 2015).

Yet, evidence shows that the quantitative size of the PHL in food crops (mainly grains) is less substantial than commonly assumed by policy makers and development practitioners. The systematic and selective literature reviews by Sheahan and Barrett (2018) and Affognon et al. (2015) on different PHL aspects in SSA show that the self-reported loss of grains stored on the farm is between two to 7 percent, and dependent on the type of grain, timing in the season, and respondent characteristic (e.g. location). Kaminski and Christiaensen (2014), using nationally representative LSMS data in three SSA countries, similarly show self-reported levels of on-farm PHL of between 2 to 6 percent. Not only are these relative losses low in magnitude and location dependent, they are much lower than the order of magnitude of PHL documented in policy reports.[3]

There are two ways through which policy makers have tried to address the PHL in crop production. First, training on the best practices in harvest and post-harvest management of crops should improve farmers' knowledge on how to properly handle and prepare the harvested crops for storage. Proper transport, threshing, cleaning, and drying of the harvested crop is likely to increase farmers' quantity and quality of the post-harvested crop, and hence training on these practices is considered an important first step to reduce food losses on the farm. For example, research in Tanzania – the country we will focus on – has shown that while the current knowledge of farmers on best practices in post-harvest handling is unsatisfactory (Abass et al. 2014), when farmers apply them, these techniques have been shown to significantly reduce the level of PHL in maize production (Chegere 2018).

Second, once the crop is properly prepared for storage, access to improved storage technologies is expected to reduce PHL during the on-farm storage of crops. This will result in increases in the amount (and

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[3] Part of this mismatch is related to the definition and measurement of PHL and at which stage of the production process it is measured. See Sheahan and Barrett (2018), Bellemare et al. (2017) and Affognon et al. (2015) for a critical discussion of the methodology and size of PHL in academic and policy literature.

quality) of grains preserved during storage, which might turn adopters of improved storage facilities over time into net surplus producers. The quality of the stored crop may also improve through a reduction of contamination and moisture. Especially technologies with hermetic sealing – such as silos or PICS bags – have become popular as these technologies avoid or kill pest and insect infection through oxygen depletion, and thus increase the length that crops can be stored. As such, the crops stored in improved facilities can be sold at a later moment after harvest, allowing farmers to benefit from higher prices, avoid distress sales, avoid buying food crops later in the lean season for consumption (De Groote et al. 2013). Better post-harvest management and storage facilities may over time also induce farmers to grow and store more food crops (Kadjo et al. 2018), or adopt better technologies (e.g. improved seeds – see Omotilewa et al. (2016)), which in turn may reduce seasonality in food prices and consumption (Kaminski, Christiaensen and Gilbert 2016).

However, while there is a flourishing literature on the size and determinants of PHL in food crops, there is limited evidence on the effectiveness of innovations aiming to reduce PHL during storage. In the review paper by Sheahan and Barrett (2017), evidence on the impact of improved storage technologies is documented almost exclusively for PICS bags, and only one study specifically looks at the effectiveness of (metal) silos (Gitoga et al. 2013).[4] More striking is that Sheahan and Barrett (2017) did not find a peer reviewed article looking at the impact of training (or extension) on good practices in post-harvest crop management. The aim of this paper is therefore to assess the impacts of an intervention providing farmers access to both training and improved storage facilities on the farm level PHL outcomes of adopters.

Financed by the World Food Programme (WFP), the NGO Norwegian Church Aid (NCA) implemented an intervention with the aim to reduce PHL in maize production in the districts of Kilosa, located in central Tanzania. Every farmer within the targeted villages was invited by NCA to a training covering topics on the best practices regarding grain quality; PHL problems in maize; and improved harvest and post-harvest management techniques. The training also taught farmers about the benefits and application of improved storage facilities. At the end of the training, a (randomly) selected subset of trainees was offered the opportunity to buy a silo at a discounted rate of 70%. To assess how this intervention has affected the PHL outcomes of the trained farmers in these villages, data was collected from farmers attending the training, as well as from farmers in the same villages not receiving the training. Moreover, we use the random assignment of the opportunity to buy the silo to distinguish two groups of trainees, i.e., those that got the (random) opportunity to buy a silo and those that did not get the opportunity. Data was collected at – on

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[4] Tesfaye and Tirivayi (2018) look at the welfare and food nutrition impacts of the adoption of improved storage technologies in Ethiopia, but silos account for only 1% of the crop storage facilities in their sample.

average – 30 and 90 days after harvest to see the effects of the intervention immediately and a bit later after harvest.[5]

This design, which combines experimental with non-experimental elements for identification, allows to assess the short-run impact of the intervention on different PHL outcomes. The data shows that between 9 to 14 percent of the surveyed households reported to have experienced maize losses during storage, which results in a loss of maize during storage of 1% of the total quantity of maize harvest (for the entire sample). While the sample is not country representative, this finding might question the magnitude of PHL in maize storage in central Tanzania, and more generally the level of food waste in smallholder production and at what stage it occurs (pre- or post-storage), an issue that is well documented in the existing literature (Bellemare et al. 2017; Minten et al. 2016; Kaminski and Christiaensen 2014). Combined with the qualitative response that farmers store maize mainly for consumption purpose, these findings have important policy implications, which we explore in the final section.

Analysis of farmers' decision to participate in training shows that farmers with access to mobile money and those with household heads more active or experienced in (modern) maize production are more likely to participate in the training, while those heads active outside agriculture are less likely to attend. While training was offered to every farmer in the village, and hence farmers self-selected into training, the offer of discounted silos was not, due to a limited number of silos that could be manufactured. However, even when offered at subsidized prices (of 70%) at the end of the training, and despite farmers showing interest in ordering silos when offered (randomly), only 28% of the surveyed farmers were willing or able to pay for silo delivery. Hence, the uptake of silos was low, seemingly related to households limited financial means. This might suggest that farmers do not consider improved storage facilities a profitable investment, even if offered at reduced prices. This might be linked with the small gain in reducing PHL from silo adoption suggested by our finding of low storage losses to begin with. Or even if silos are profitable, it requires complementary interventions to address liquidity and capital constraints for potential adopters.

When examining the effectiveness of the training given and technology used on different PHL outcomes in maize production, we find little short-run impacts of the intervention. Training did increase farmers' knowledge on best practices in post-harvest maize management, but the extent to which this improved knowledge was effectively applied is limited. Moreover, neither training, nor the opportunity to buy a silo did (significantly) reduce the quantity of maize lost during storage, increase the quality of the stored maize, or induce a change in (more) storage or sales behavior. These null results could be related to the fact that

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[5] With the data at hand, we cannot study the impact on longer-term physical losses, second round benefit dynamic effects from changes in economic behavior, or the ultimate welfare impacts of PHL training and silo adoption.

there is not much maize storage losses to begin with, maize harvests are in generally low in the study area, and operational challenges in implementing the intervention further reducing its effectiveness. We provide a detailed discussion of our results at the end of the paper.

2 Background on the project

In 2016, the World Food Programme (WFP) coordinated a multi-stakeholder platform called the Patient Procurement Platform (PPP)[6] designed to support Tanzanian smallholder farmers in the maize sector, through a value chain intervention improving farmers' production and market access. The programme harnessed private sector demand in the form of forward delivery contracts, giving farmers the confidence to invest in improving their production systems. The platform focused on the maize value chain in its first year to improve maize productivity through improved access to agricultural credit and modern inputs, extension training, weather insurance, post-harvest services and marketing. One subcomponent of this intervention was the delivery of training on best practices in post-harvest maize handing, building upon the work of its Global Post-Harvest Knowledge & Operations Centre (Post- Harvest Centre) in Uganda. In combination with training, the intervention provided farmers access to post-harvest technologies by promoting and distributing relevant storage equipment to Tanzanian maize farmers, including plastic silos, metal silos and hermetic bags.

The WFP intervention in Uganda trained 16,000 farmers on harvest and post-harvest management, and on the use of improved storage facilities. At the end of the training, farmers were offered the opportunity to buy an improved facility (silo or hermetic bags) through the training. The results of data collected in 2015 from 1,400 farmers show that – compared to traditional storage facilities – improved storage facilities decreased total average maize losses from 42% to less than 1% within the second and third month of storage (Da Costa 2015).[7] Moreover, the intervention increased maize quality as aflatoxin concentration decreased from 68% to 14% and moisture content from 89% to 4%. The report also states that farmers earned higher crop incomes from selling stored crops later in the post-harvest season, as farm-gate prices of maize 90 days after harvesting had increased by 144%.

Based on the Ugandan experience, WFP rolled out a pilot experiment of PHL training and technology provision in Tanzania in 2016. The Norwegian Church Aid (NCA) collaborated with the WFP to implement the PHL intervention in the field. NCA rolled out an awareness campaign in 32 villages in central Tanzania, where the NGO informed farmers about the importance of PHL in maize production. During these

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[6] The project name was changed to the "Farm to Market Alliance" in 2017.

[7] Crop losses is the percentage of harvested crops that is damaged during storage, and self-reported by farmers 90 days after harvest.

campaigns, it was announced that there would be training on PHL losses and improved storage facilities, which would be open to all farmers interested in attending. The training sessions covered the importance of grain quality, a proper timing of harvest, proper post-harvest handling, and the benefits and use of improved storage technologies. NCA also distributed a manual in Swahili to farmers.

At the end of the training, some farmers were given the opportunity to buy an improved storage facility (see section 3.1). NCA initially asked farmers to pay the silo at the time they made the order using a mobile payment, but relaxed this constraining requirement later and allowed farmers to pay for the silo (in cash) upon delivery. While both metal and plastic silos were made available, the majority (>90%) of the silos offered by NCA were plastic silos that have a capacity of 350kg, because of the lower production costs and easier transport compared to metal silos.[8] As it was the first time that farmers in these villages had access to silos, the silos were offered to (selected) trainees at a discounted rate of 70%, making the price that trainees had to pay 54,000 or 75,000 Tanzanian Shilling (TZS) for plastic or metal silos respectively. Using the third round data (2013) on farmers in Dodoma (the district Kilosa belongs to) from the World Bank's Living Standards Measurement Study (LSMS), the price of the plastic silo is respectively 25% and 8% of the annual net income from crop activities and total household income.[9] Farmers that were not offered the opportunity to buy the silo, could order hermetic bags if they wanted so, which were sold at the fixed market price (4,500 TZS and not offered with a discount).[10]

3 (Non-) Experimental design

3.1 Definition of treatments

We evaluate two aspects of the PHL intervention implemented by the WFP in central Tanzania. We first look at the effect of the training offered by NCA on post-harvest practices, and then at how the combination of training with access to improved storage facilities affected PHL outcomes of maize farmers. To do so, we use elements from the non-experimental set up as well as from the randomization of the offer to buy a silo to a subset of households that attended the training (see below).

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[8] Metal silos have a capacity of 714 liter (i.e. 500kg) and costs 250,000 TZS (including transportation cost from Uganda to Domilla). Plastic silos can store 500 liters (i.e. 350kg) and cost 180,000 TZS. In August, the average conversion rate between USD and TZS was 1:2,181, so a metal or plastic silo costs respectively 115 USD and 83 USD.

[9] The medium value of the annual net income from crop activities and net total household income is respectively 213,150 TZS and 698,417 TSZ.

[10] However, as hermetic bags are locally available, there does not seem to be a particular reason why farmers would have ordered hermetic bags through the NCA training, as it would require them to wait several weeks for the delivery and get no price benefit from it. Farmers not attending the training are also able to buy bags in the village without the NCA training, and thus everyone could buy hermetic bags (from the project or on the market at the same price). We do not see a significant difference in PICS bag usage between different treatment groups in the data.

Access to training was not randomized, as NCA announced that the PHL training sessions were open for everyone in the villages covered by NCA. Thus, NCA has been providing PHL training to all farmers that showed up and were interested in receiving training. However, as not all maize growing farmers showed up to attend the training sessions, we were able to use the subset of the non-trainees in the NCA villages as our comparison group. This control group allows us to analyze selection into training and will be used as counterfactual to measure impacts. However, as this group of farmers was not randomized, the selection bias into training will confound the impacts measured. We explain how we address these biases in section 4.

Randomization of the access to the improved storage facility was done at the individual level. We were able to randomize the offer of silos after training because the number of households attending the training, and hence the pool of potentially interested recipients, was larger than the number of silos available in each village. With this type of oversubscription, we were able to effectively randomize the offer and have sufficient number of trainees that either got the offer to buy the silo or not.[11] However, as the number of NCA training villages was relatively small, and the number of farmers within villages was constrained by the limited number of silos available, a full-blown Randomized Control Trial would likely be underpowered. Moreover, the uptake of silos from first time promotion is not likely to be perfect either. As such, in the analysis of the data, we do not rely entirely on the randomization for identification, and apply a regression approach to identify treatment effects.[12]

This design thus provides us three groups of maize farmers within the NCA villages. The first group of farmers is the control group that did not receive training. From the group of trained farmers, the first treatment ('training only') group are farmers that received training but not the opportunity to buy the silo. The second treatment group ('training & silo') is the subgroup of trainees that received training and the opportunity to buy the silo. These groups are classified according to the treatment that they were assigned to (which we will refer to as assigned treatment t_i) based on the administrative information received from NCA, and not according to actual uptake (which we will refer to as u_i). This distinction is important to identify treatment impacts, as we will discuss in Section 4. t_i refers to a categorical variable that describes the treatment assigned to each individual: the control group is the reference (0), the 'training only' group has value 1, and the 'training & silo' group has value 2. The term treatment assignment is used very loosely,

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[11] The names of all trainees were numbered and put in a bowl to allow for a random selection of numbers. If the selected households were not interested in the offer (at the time of training), they were randomly replaced by other farmers until all silos available in the village were sold (on average 12). Our data shows that most households accepted the offer, but not necessarily ordered or bought the silo.

[12] At the minimum, the randomization should avoid a selection bias into the adoption of the newly introduced and more costly silo (e.g., wealthier farmers adopt silos more easily).

as technically there was no assignment of individuals to training. We use the occurrence of a person's name on the list of trainees shared by NCA as an indicator of training assignment.

It is already important to mention that we observe a mismatch between the treatment that farmers were assigned to (based on the administrative data) and the self-reported uptake of treatment. This mismatch can be the result of several reasons related to the implementation (and record keeping) of the training sessions, or because farmers decide not to comply with the treatment they are assigned to. Table 3-1 shows an overview how the assigned treatments (mis-)match with the actual treatment status for our analytical sample of 495 farmers (see below). The latter is defined based on the response that farmers gave during the survey on whether they were (i) trained on PHL by NCA, (ii) they were offered the opportunity to buy a silo at the end of the training, and (iii) they bought the offered silo. We see that there is a particular mismatch for the two treatment groups. While the NCA administrative data tells us that in total 131 farmers were assigned to the 'training only' treatment, 59 farmers of this group report to have also received the opportunity to buy the silo. Vice versa, of the 191 farmers assigned to the 'training & silo' treatment group, 20 farmers report that they did not get the opportunity to buy the silo (and hence were only trained). We discuss this issue of non-compliance further in Section 4.1.

Table 3-1: Uptake of assigned treatment status

3.2 Sampling of households in the study and data collection

Even though the intervention was rolled out in 32 villages in three districts of central Tanzania, data was collected in 22 villages in which the PHL intervention was successfully implemented (for more details, see appendix 1). Within each of the 22 villages, we decided to sample 24 farmers, where the following distinction was made over the different treatment groups: 8 control farmers, 6 'training only' farmers, and 10 'training & silo' farmers. The latter treatment group was oversampled, as to anticipate that the uptake of silos was expected to be less than perfect. Thus, in total, 526 farmers were selected to be interviewed. However, in some villages, the intended number of farmers in each treatment group could not always be interviewed, and a total of 508 was interviewed. The Table in Appendix 1 provides an overview of the actual number of farmers that were interviewed in each village.

To sample farmers for the different treatment groups within each village, we use two sources of information. First, control farmers are selected by comparing the NCA total list of trained farmers with the list of all maize growing farm households living in the village. To do so, we collected a sampling frame of farm households in the entire village based on the census available in each village. Then, this list was matched with the NCA list of trainees to identify the group of farmers that that was not trained by NCA. From the latter group, we randomly select 8 farmers. Second, from the NCA list of trainees, we know who was randomly offered the silo equipment. This provides us the list of farmers attending training and offered the silo ('training & silo') and those not ('training only') within each village, and we sampled farmers within each of the groups. The total number of farmers sampled within each village is not necessarily the same. As described above, we oversampled the 'training & silo' group of farmers, and we selected 10 farmers from this group in each village. In theory, we randomly selected 6 farmers of the 'training only' group in each village. However, in three villages, there were less than 6 'training only' farmers available and we therefore took more 'training & silo' farmers in these villages (if available).

The data collection of the PHL intervention took place between July 2016 and October 2016 following the maize harvest and a period of storage using two survey rounds. The first survey was conducted end of August 2016, which is about 30 to 40 days after harvest. The first survey collected household baseline characteristics; agricultural plot characteristics; maize input use, sales, storage and losses; and PHL knowledge and training given by NCA. The first survey round was able to interview in total 508 farmers, of which 176 control farmers and 332 treatment farmers. The second survey was fielded 90-100 days after harvest. It followed up on farmers' stored maize and some household indicators. During the second survey round, a total of 495 farmers were interviewed, indicating that 13 households could not be interviewed. The reasons for this attrition was that households could not be located in the village for several reasons.[13]

4 Methodology

4.1 Uptake of training and silo

We first want to understand what drives farmers' participation (selection) in the training on best practices in maize post-harvest management and the (stated) decision to adopt the PHL reducing technologies (when offered). Therefore, we look at which factors determine the actual participation in the training (u_i^T) and the stated interest to adopt the silo (when offered). All of these dummy indicator variables are self-reported by farmers during the first interview. However, some farmers eventually end up not buy the silo, even though they stated an interest to do so. We distinguish further between 'training & silo' farmers that purchased the silo and those that did not (once they made the order at the time of training). This distinction allows to see whether there is a difference between the factors determining the decision to order the silo (u_i^{SO}) and the decision to effectively purchase the silo (u_i^{SP}).

Different (sub-)samples are used to analyze the decisions to participate and to adopt. To analyze the participation into training, we compare farmers that decided not to participate (control) in the training with

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[13] The specific reasons for each household include households that left the village, were not a permanent resident, were hospitalized, travelled for holidays, or were not reachable (even not over the phone).

participants (the two treatment groups). This is the entire sample of 495 farmers in our survey. To analyze the decisions of farmers to order and purchase the silo, we restrict the sample to the (random) subset of farmers that received the opportunity to buy the silo (i.e. the 'training & silo' group ($t_i = 2$) of 190 farmers). Hence, to analyze the decisions to order (purchase) the silo, we compare farmers that ordered (purchased) the silo – when given the opportunity – with those farmers that did not order (purchase) the silo given the opportunity.

The dummy indicators of participation and adoption are regressed on a battery of explanatory variables. We first include some of the more traditional control variables in agricultural technology adoption models. We include characteristics of the household head (age, education, gender) to proxy the human capital of the most important decision maker in the household. We also include the size of the household to capture the need for the household to store more and better maize, and hence their potential gain from improving their knowledge or capacity to store maize (Gitonga et al. 2013). Farmers that produce more maize are more likely to benefit more from training and storage facilities, and we therefore include the area of maize production grown. As the adoption of the silo requires a substantial investment, access to liquidity and credit is likely to be an important determinant of adoption (Beaman et al. 2014). To control for the household's access to financial institutions, we include two dummy variables indicating the use of seasonal agricultural credit and the ownership of a money account (either through a bank or on a mobile phone). We finally proxy for household welfare by including the Principal Component Analysis (PCA) component of different household and livestock assets.

Next to these more 'traditional' indicators, we control for a set of additional indicators that try to capture perceptions, behavioral issues or liquidity constraints to adoption, which are increasingly considered as important determinants of technology adoption in smallholder agriculture (Carter 2016). The construction of these different indicators is explained in Appendix 2. A variable measuring the (relative) amount of maize that farmers expect to lose in storage (using traditional facilities) is included. We include two variables that indicate whether households reported to be very or temporarily credit constrained. We also include two variables indicating if households are considered to be very risk averse or risk loving.[14]

Bringing all of these indicators into a regression model, we regress the uptake of training (u_i^T), silo ordering (u_i^{SO}), and silo purchase (u_i^{SP}) on the vector Z_i including the traditional and non-traditional control variables, and the idiosyncratic error term μ_i for each equation:

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[14] These credit and risk indicators however remain crude measurements, and we by no means claim that these indicators perfectly measure preferences, but we do believe including them is an improvement over the related literature that fails to control for these important adoption predictors.

$$u_i^T = \alpha^T + \gamma^T * Z_i + \mu_i^T \quad (1)$$

$$u_i^{SO} = \alpha^{SO} + \gamma^{SO} * Z_i + \mu_i^{SO} \; if \; t_i = 2 \quad (2)$$

$$u_i^{SP} = \alpha^{SP} + \gamma^{SP} * Z_i + \mu_i^{SP} \; if \; t_i = 2 \quad (3)$$

As the uptake indicators are dummy variables, these equations should, in theory, be estimated using the Probit model. However, we follow the recommendation of Angrist and Pischke (2009) to use the simple OLS estimator, which further allows to bootstrap standard errors to account for the fact that there are only few villages in our sample. Because the decisions to order and purchase the silo are likely be correlated, we estimate Equation (2) and (3) using the Seemingly Uncorrelated Regression (SUR) estimator in Stata.

In a second specification of the above equations, we add village fixed effects, to control for factors within the village – such as market access, prices, climate, etc. – that are likely to be constant across farmers living within the same village but different across villages. The comparison is then made between treatment groups within the same village. The third specification explicitly controls for the link between the decision to order and purchase the silo by applying the Heckman correction. We do so by first estimating the decision to order the silo using the Probit model, calculating the inverse mills ratio (IMR), and including the latter as regressor in Equation (3) for the decisions to purchase the silo (conditionally on ordering the silo).[15] In this way, part of the endogeneity in selecting into silo ordering, i.e. the part of the error term of the decision to order the silo that affects the decision to purchase the silo, is controlled for (to the extent that selection is determined by observed variables). A positive coefficient of the IMR would point to positive selection, and it would lead to an upward bias of the coefficients in the second specification of Equation (3).

4.2 Technology impact

After understanding farmers' decision to participate in training and silo adoption, we want to quantify the impact of the intervention on different PHL outcomes of farmers in central Tanzania. The first impact we want to measure is how the training of maize farmers by NCA in Tanzania has affected their PHL outcomes. To do so, we will compare the control group with the 'training only' group of farmers. The second impact is the additional effect of having access to an improved storage facility over the effect of training on the outcomes of interest. To get at this, we first compare the group of trained farmers that were offered the opportunity to buy the silo with the control group. Then, we compute the difference in effects between 'training only' and 'training & silo', and test whether this effect is statistically significant.[16] There are,

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[15] We use the Heckman estimator in Stata to perform the Heckman correction and report those results in the paper. To estimate the coefficient of the IMR, we manually reconstruct the twostep Heckman estimator.

[16] This is done by testing the null hypothesis that the non-linear combination of the two effects is different from zero.

however, some issues that complicate the simple (mean) comparisons of the treatment groups with the control group to estimate the effect of treatment on PHL outcomes.

First, as we know from Table 3-1, the actual uptake of information or an improved technology might differ from the initial treatment assigned to farmers, as adoption is an individual decision. This introduces non-compliance in the observed behavior. For example, farmers that are offered the silo can still decide not to buy the equipment, and looking at the actual uptake would reflect this (non-random) decision. Instead, we look at the initial random assignment of the opportunity to buy the silo, and look at the difference in PHL outcome (means) based on the treatment assignment (not the actual up take). This effect is the Intention To Treat (ITT) effect and allows to assess how effective the assignment of treatment was (i.e. the intended outcome of the PHL intervention), and is often more relevant from a policy perspective, because for many interventions in developing countries, the planned intervention might differ from actual implementation. The ITT is thus the Average Treatment Effect (ATE) using treatment assignment (instead of the self-reported uptake) and this is the effect we focus on.

Second, as participation in the PHL training was not randomized, the trainings could be attended by anyone in the village. This introduces an element of self-selection in the PHL training indicator variable. Farmers that are more aware of the importance of PHL, or are better entrepreneurs in general, are more likely to participate in agronomic trainings. Hence comparing individuals that were trained with those that did not receive training will capture some of these differences. This is the reason why we randomized the opportunity to buy a silo to a subset of trained farmers, as it introduces exogenous heterogeneity in the uptake of silos, and avoids that better performing farmers self-select into silo adoption (which is a costly investment but with potentially higher gains). However, as explained before, we could not do this for participation into training.

Given our cross-sectional and observational set up, we try to minimize the selection bias by applying estimation techniques that assume that selection is based on observed characteristics. In terms of a regression model, we estimate the following model, where t_i refers to assigned treatment, y_i to the PHL outcome variable of interest, X_i the vector of control variables, and π_i and ϵ_i are unobserved error terms:

$$t_i = \alpha^t + \gamma^t * X_i + \pi_i \tag{4}$$

$$y_i = \alpha^y + \beta * t_i + \gamma^y * Z_i + \epsilon_i \tag{5}$$

We first estimate Equation (4), which models the assignment of the two treatment groups ‘training only’ and ‘training & silo’. Note that the vector X_i is different from Z_i in Equations (1)-(3) and (5), as the former only contains baseline indicators that are unaffected by participation in the project (Caliendo and Kopeining

2008). We include the household head's characteristics (including principal employment indicators), farm size, distance to the nearest regional town, and the two wealth indicators. The model is estimated in Stata using the 'teffects' command, where we use the inverse probability weighting regression adjustment (IPWRA) model as a double robust estimation method. The latter has the advantage that it at the same time allows to control for covariates that affect both treatment and PHL outcomes ('regression adjustment'), but also allows to weight individuals using the probability that an individual is treated using observable characteristics ('inverse probability weighting'). Another advantage of this estimator is that it allows for multivalued treatment indicators and we do not need to select one of the many possible matching techniques.

The IPWRA, however, requires some strict assumptions. The first requirement is the 'conditional independence' assumption, which implies that once we control for observed factors in the model, the PHL outcomes of a farmer are independent of the treatment assigned to this farmer. It thus assumes no unobserved factors that simultaneously affect the decision to participate in treatment and the PHL outcomes. This is a particular strong assumption, especially for the training indicator, as there might be issues of (unobserved) self-selection into training.[17][18] To assess violations of the conditional independence assumption, to the extent possible, we perform different balance checks and select covariates in the treatment model for which the standardized differences after balancing are not too different from zero.[19] The results are reported in Table 4-1 and show that none of the covariates included in the weighting procedure have a standardized difference (between the control group and each treatment group) larger than 0.06 and most variables have a variance ratio close to 1 after weighting.

Table 4-1: Diagnostic statistics for covariate balance over treatment groups

The second assumption is that of sufficient overlap, which requires enough farmers with a different treatment assigned but with a similar (positive) probability to receive treatment(s). It allows to measure impacts by comparing (i.e. giving more weight) to individuals that are similar in observable characteristics. This assumption can be verified in Stata by plotting the kernel densities of the probability of being assigned to one of the treatments, and visually verify whether there is sufficient overlap in the estimated density functions. This is done in Figure 4-1, and the figure shows that each probability density function has a sufficient spread between 0 and 1. Figure 4-1 also illustrates that there is sufficient overlap in the densities for the control, 'training only' and 'training & silo' group (the mass of the densities is around a propensity

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[17] The conditional independent assumption is less problematic for the silo uptake indicator, as assignment was randomized.

[18] Unfortunately, the endogenous treatment effects estimators available in Stata cannot handle multivariate treatment indictors.

[19] We only include the control variables related to the characteristics of the head and household, and that for the latter we did not include any of the dummies reflecting access to finance (e.g. access to bank account). Even then, some of the remaining variables had to be dropped. For example, we did not include the size of the household as the standardized difference after weighting were 0.10 and the variance ratio below 0.75.

score of 0.3). We can thus safely assume that the overlap assumption is not violated. Combined, the results in Table 4-1 and Figure 4-1 assure us that we can apply the IPWRA approach to our data.

Figure 4-1: Estimated densities of the probability of being assigned to a treatment

4.3 Descriptive statistics

Before presenting the results from the empirical analysis, we provide some descriptive statistics for the analytical sample of farmers in Table 4-2. Note that this are in-sample statistics, which are not representative for the average maize farmer in central Tanzania, given our survey design. We present these descriptive statistics to illustrate some of the characteristics of the farmers in our sample.

Of the 495 farmers that grew maize, 465 farmers have a non-zero harvest of maize, which is on average 612 kg.[20] In relative terms, this translates into 474 kg of maize output per hectare. We then asked how farmers used their maize harvest for different purposes (in absolute quantities).[21] We start by looking at how likely farmers are to report a non-negative amount for each element of such 'maize balance'. At 30 days after harvest, more than 3 out of 4 farmers had part of the harvested maize still in storage, while 88% of the households had consumed part of the harvested maize. Only about 25% of the farmers had already sold part of the maize harvested. At 90 days after harvest, as one would expect, the share of households with maize still in storage had decreased to 48%. The share of households that consumed maize from their own harvest had increased to 96%, and a higher share of households (45%) had sold part of their maize harvest. In relative terms, 38% of the harvested maize was in storage after 30 days, while 43% was already consumed and 9% was sold. After 90 days, the share of the harvest in storage had decreased to 17%, while consumption and sales had respectively increased to 62% and 16%.

Table 4-2: Descriptive characteristics of farmers in the sample

Regarding the quantity of maize lost during storage, only 14% of the households reported to have lost part of the maize that was harvested at 30 days after harvest. Surprisingly, the share of households that report to have lost maize at 90 days after harvest is 9%. This could be related to the fact that farmers have difficulties in recalling the correct amount later in the season (we come back to this issue in section 7). Both numbers in Table 4-2 are however in line with published research on PHL in Tanzania or elsewhere in Sub Saharan Africa (Kaminski and Christiaensen 2014). An important finding from a mere descriptive

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[20] 30 farmers did not harvest maize because the maize on the plot was damaged during the production process. For these farmers, we assume a zero output.

[21] Besides the amount of harvested maize stored, consumed, sold and lost in storage; we also asked for the amount used for sharecropping, animal feed, seeds, paying-off debts, and used as gift. These are however minor shares, and for brevity these results are not shown, as access to PHL training and facilities are not hypothesized to have a direct effect.

perspective is that the amount of maize output that farmers self-report to be lost during storage is small in both absolute and relative terms. On average, farmers have lost 10 kgs or 1% of the harvested quantity.

Figure 4-2 describes the main reason(s) why farmers store part of their maize output. The large majority (97%) of farmers does this primarily for preserving maize for household own consumption. Only 12% of the farmers mentions that they store maize to sell it later in the season at a higher price. A small fraction (3%) of farmers mention that they store maize to save seed for planting during the next production season of maize. Hence, it seems that storage of maize is mainly done to increase the maize available for home consumption.

Figure 4-2: Main reason why households store maize (%)

5 Technology uptake

In this section, we explore the qualitative and quantitative reasons why some households decided to participate in PHL training and ordered the silo when offered. We start with exploring the self-reported reasons why farmers attended the PHL training or not. The main reason (50%) for attending the training was because farmers were advised to do so (by village of FO leaders). 39% of the farmers respond that they wanted to be trained on PHL issues and get knowledge on how to handle PHL in maize. Only few households followed the training because they were confronted with large PHL in the past (5%), because they were (mainly) interested in the (potential) access to a silo (4%), or because neighbor/relatives attended the training (2%). When asking control farmers why they did not attend the PHL training, almost half of the control farmers (49%) were unaware that the PHL training was given in their village. 20% of the control farmers were aware of the training, but unable to attend, for a variety of reasons (e.g. absence in the village). Other farmers were not interested in the training (15%) or were not allowed to follow the training (12%).

Especially the uptake of silos is of interest, as one of the key aspects of the PHL intervention is to stimulate the uptake of improved storage facilities. In total, 247 farmers indicate that they were offered the opportunity to buy a silo (see Table 3-1). But not all of these farmers accepted the offer: from this group of randomly selected farmers who got the opportunity to buy a silo, only 104 farmers (or 42%) ordered the silo at the time of the training. The main reason (60%) why farmers ordered the silo when given the opportunity to buy one was that the PHL training made them aware of the importance of PHL losses. Other reasons where the subsidized price (31%), superiority over hermetic bags (7%), and because silos are alternatives to chemicals that could be dangerous for human health (2%). When asking farmers why they did not order the silo when it was offered to them after the training, most farmers (70%) respond that they did not have enough money to finance the purchase. 17% of the farmers respond that they found the silo too expensive, and hence did not believe in the profitability of the silo storage technique. A small fraction of farmers was not interested in the silo equipment even if offered at subsidized prices, while a few others had no more maize to store.

From the 104 farmers that ordered the silo when they were given the opportunity to do so during the training, 70 farmers (or 67%) were able to come up with the required financial means to pay for the silo (upfront, using the mobile payment, or at the time of delivery). Therefore, in total, 28% of the farmers who were randomly offered the opportunity to buy a silo purchased the silo. We then asked the group of farmers that ordered but did not buy the silo why they did not proceed with the payment. The large majority (88%) responded that they could not come up with the money to buy the silo, while the others considered the silo too expensive at the moment of payment.

Figure 5-1 displays the responses to the question why farmers choose to use an improved storage facility to store (part of) the maize harvest. Over 50% of these farmers use an improved storage facility because it increases the quality of the maize that is used for home consumption. 18% of these farmers consider having more maize for household consumption an important reason to use an improved facility. 13% of the farmers store maize in improved storage facilities because there is no need to use chemicals to protect the maize when using this storage facility. Surprisingly, only a minority of the farmers respond that the main reason for using an improved storage facility is to sell higher quality maize (12%) or to sell later in the season when prices are higher (9%). Other reasons mentioned for storing maize in improved storage facilities are the lower wastage of maize and the curiosity of some farmers.

Figure 5-1: Reasons for farmers to use improved storage facility

We now quantitatively analyze the factors that might explain the participation decision in the PHL training and the adoption decision to purchase the silo (conditional on the silo being offered to the household). Table 5-1 reports the results of the regressions of the different specifications discussed in section 4.2 on the dummies indicating whether the household received training (column 2 and 5), ordered the silo (column 3 and 6), and bought the silo (column 4, 7 and 8). In each column, the different rows report the regression coefficient and the bootstrapped standard errors (clustered at village level and reported in parentheses below the coefficient) of the different explanatory variables.

Table 5-1: Determinants of the uptake of PHL training and silos

The second column of Table 5-1 shows that households with older heads, larger household size and more livestock, are more likely to participate in the training. Participation is also higher for households who used seasonal credit for agricultural inputs and have access to a bank account, potentially signaling their improved financial status. The positive effect of household assets on participation in the training points in the same direction. On the contrary, households with a larger size of land allocated to maize are less likely to participate in training. This is surprising, as households with larger maize area are also more likely to harvest substantial amounts of maize, making it more profitable to know about good PHL handling. Whether farmers are more or less risk averse, are credit constrained, or expect higher levels of PHL in traditional facilities does not appear to affect participation in PHL training. The second specification of the participation equation in column 4, where we control for village effects, draws the same conclusions.

Column 3 and 6 of Table 5-1 explain the household's decision to order the silo at the time of training for the group of households (randomly) offered the opportunity to do so. When looking across villages (column 3), male household heads are less likely to order the silo, while older and more educated households, and larger households, are more likely to do so. Households that are considered as temporary credit constrained are significantly less likely to order the silo than those that are considered not risk constrained. This confirms the qualitative response of farmers that indicated that they could not come up with the required credit needed to finance the silo. However, once we compare individuals between different groups within villages in column 6, we see that the liquidity effect becomes insignificant. On the contrary, the household's access to a financial money account significantly increases the likelihood that the household ordered the silo.

Finally, in columns 4, 7 and 8, we estimate the probability that a household has effectively bought the silo. In the specification without village fixed effects (column 4), older household heads, those with secondary education and wealthier households are more likely to purchase the silo. When we control for village effects (column 7), only the secondary education indicator (strongly) and household size (weakly) influence the purchase decision. The importance of secondary education suggests the need for substantial human capital to understand improved storage facilities. Surprisingly, none of the other control factors has a significant effect on the silo purchase decision. In the last column of Table 5-1, we see that once we control for the selection into silo ordering, both risk indicators strongly and significantly reduce the likelihood that a household purchased the silo. Compared to households that are considered as risk neutral, both risk averse and risk liking households are respectively 57% and 66% less likely to have purchased the silo. Put differently, farmers that are risk neutral are more likely to purchase the silo. However, the IMR is estimated to be non-significant, which suggests that the decisions to order and purchase the silo are not significantly linked.

6 Treatment impact on PHL, storage quality, and maize decisions

We start the empirical discussion of the impacts of the PHL intervention by looking at how training affected farmers' knowledge about the best practices in maize post-harvest management. Table 6-1 reports the results, where columns 2 to 5 report the impact on farmers' knowledge on how oxygen should be removed from a silo, how to measure the moisture of the stored maize, how drying should be done, and how shelling should be done. Training had a significant effect on the first three knowledge indicators, as indicated by the significant ITT effects for both treatments. The effect is similar (i.e. the difference is not statistically significant) between those receiving training and those receiving training and the opportunity to buy the silo. Given random assignment of the silo purchasing opportunity among the trained, this is as expected. Training alone did, however, not affect post-harvest handling behavior, but having the opportunity to buy a silo induced a change in cleaning behavior, with those offered to buy a silo 20 percent more likely to clean the maize using a winnow to remove impurities. Hence, while training itself increased farmers' knowledge about several best practice in maize post-harvest handling, it is only when combined with silo ordering that it translated in actual behavioral change.[22][23]

Table 6-1: ITT of training and silo adoption on knowledge and usage of best practices

We now estimate the effect of the treatments on the typical PHL outcome indicators in Table 6-2, i.e. the self-reported share of maize harvest damaged and lost during storage. We differentiate between the share of households that have a non-zero amount of maize damaged and lost during storage (column 2), the amount lost in absolute quantity (column 3), and the quantity relative to the total amount harvested (column 4). Based on this self-reported data, we see that at 30 days after harvest, the group of farmers that received both the training and silo purchase opportunity are less likely to have witnessed a maize loss, and have a lower absolute amount of storage loss. However, none of the effects – in absolute or relative terms – are significant. The training indicator did not have any effect on the share of households that indicated to have lost maize, nor on the absolute or relative quantity of maize lost. When we look at the second-round data, collected 90 days after harvest, training or training combined with the opportunity to buy the silo similarly had no significant effect on any of these self-reported PHL during maize storage.

Table 6-2: ITT of training and silo adoption on self-reported loss of maize during storage

In Table 6-3, we look at whether the access to training and silo affected farmers' maize marketing and consumption behavior of how they allocate the maize harvested across storage, consumption and commercial purpose. These quantities are presented as the shares of total maize harvested. Looking at the mean values for the control group,[24] we see that, at 30 days after harvest, the larger share of the maize harvested by farmers in central Tanzania has been used for consumption. Most of the remaining maize is still in storage. Very little is sold. At 90 days after harvest, 60 percent has been consumed, with the average

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[22] Chegere (2018) argues that while most post-harvest management practices are profitable, some farmers might decide not to adopt them, because the net benefits are small or unknown. Our results (of low PHL losses in the control group) confirm this.

[23] Note also that the knowledge of control farmers is pretty low, reflecting the results of Abass et al. (2014) that farmers' knowledge and skills on post-harvest management are poor in Tanzania.

[24] These numbers are the (estimated) potential-outcome means of the untreated group of farmers.

shares of sales and storage similarly low (around 16-17 percent respectively). Given the limited size of maize harvests, this should not surprise. For most, maize remains primordially a food crop, as opposed to a marketing crop.

Table 6-3: ITT of training and silo adoption on maize harvest usage (%)

In the first-round data, trained farmers have a higher share of maize stored compared to the control group. On the contrary, these famers have sold a smaller share and consumed less, but both effects are very small and not significantly different from zero. We observe similar effects for farmers with training and silo treatment, but none of the effects are statistically significant. In the second-round data, we observe no significant differences between the control group and the two treatment groups in the different uses of harvested maize. Hence, nor the training nor the combination with access to improved storage facilities have induced a behavior change towards longer storage and sale postponement (yet).

The second survey round also collected data on the moisture content of the stored maize as a proxy for maize quality. In theory, each household who still had maize in storage should have been visited for a technical measurement of the moisture content in the (traditional or improved) storage facility used by farmers. However, due to a lack of measurement instruments, not all farmers that stored maize in storage facility could be visited for a technical measurement. As such, the data is only collected on a subset of farmers (n=258) that stored maize, but there is no obvious reason to believe that this process was not random (i.e. some specific households were purposely not visited).[25] Moreover, for each household, we take the mean value of the moisture content over traditional and improved storage facilities if multiple facilities were used by households (but this number is very small). This aggregate (or household level) measure of stored maize quality can then be compared between farmers in different treatment groups.[26]

The first technical measurement of storage quality is the moisture content value – expressed in % of water that is present in the stored grain – of the maize stored by the household. Another technical quality measurement is the moisture content of the stored maize measured in parts per billion (ppb). Finally, a non-technical measurement of quality is the self-reported presence of live and dead weevils in the stored grain. While this measure is less technical than the moisture test, it is a commonly used proxy to assess the quality of stored maize. The results reported in Table 6-4 do not show a significant difference in maize quality –

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[25] When regressing a dummy indicating non missing moisture data (for all households that had maize in storage during the second round of data collection (n=418)) on the indicator whether the trainee was assigned the opportunity to buy a silo and the control variables used in the empirical analysis, there are no significant differences between households for which the moisture data was collected and for those with missing data (results not reported).

[26] The number of observations for the households with a traditional storage facility (n=207) is four times as large as the number of observations of improved storage facilities (n=51). Only 12 farmers had stored maize in both a traditional and improved storage facility, so there are only a few households for which we actually have to take the average over improved and traditional storage. If further implies that we cannot compare technical PHL measures within households.

measured by the moisture content – between households in different (assigned) treatment groups. Similarly, Table 6-4 shows no significant difference in the visibility of weevils between households in the different treatment groups.

Table 6-4: ITT of training and silo adoption on maize quality indicators and PHL knowledge

7 Discussion and conclusions

This paper explores the determinants of farmers' uptake of training on best practices in post-harvest maize handing and improved storage facilities (silos); and the impact of both technologies on different PHL outcomes measured at the farm level. Data was collected on households participating (and a control group) in an intervention designed by the WFP to reduce PHL faced by maize farmer in central Tanzania.

We find that promoting the use of silos by maize farmers is far from straightforward. Even when farmers get the opportunity to buy a silo at discounted prices, the majority of farmers decided (or could) not purchase the silo. The decision to order the silo when offered is positively affected by human capital indicators, access to financial means, and household's wealth. The latter finding confirms the qualitative information received from the group of farmers that got the opportunity to order a silo but did not purchase them complaining that they were not in the financial position to purchase the silo. When analyzing the actual purchase decision of farmers, we find that (only) human capital (proxied by secondary education of the household head) is a strong (statistical) predictors of silo uptake.

Why did not more famers adopt the silo? Was the (discounted) silo then too expensive? A simple back-of-the-envelope exercise shows that it depends on the perspective (and information available) of who makes the calculation. According to the experience of the WFP intervention in Uganda, the amount of maize lost in storage at 90 days after harvest is 1% in improved storage facilities, while it is 42% for traditional storage facilities (Da Costa 2015). Hence, from the policymaker's perspective, silos will reduce maize storage losses by 41%. Within our sample, harvest is about 620 kg, and 38% of the harvest is initially stored (Table 4-2). Access to the improved storage facility will thus provide farmers 97kg more maize in storage. If we assume that they sell this surplus harvest – at the self-reported median market price of 500 TSZ per kg at 90 days after harvest – farmers' gross return would be 48,298 TSZ. Hence, from the policy makers' perspective, farmers can earn back the cost of the silo almost within the first year. However, from the farmer's perspective, with the self-reported numbers of maize losses in Table 4-2, the maximum gain in storage quantity of having the silo is 1% (for the whole sample) or 13% (for those farmers with a non-zero loss). Using the latter amount in a similar calculation, it would take nearly 4 years to pay back the subsidized silo. Moreover, farmers report that the prime reason for improved storage is more and better maize for consumption, not sales.

Profitability of silo adoption at the farm level therefore remains uncertain. De Groote et al. (2013) argue and show that silos are effective in controlling insect pests and therefore can be profitable, even in smallholder settings in SSA. More research is thus needed to understand farmers' willingness to pay for silos, and the cost effectiveness of silos in real farm conditions. Evidence is missing whether silos are a better investment compared to PIC bags, which would cost one third for the same storage capacity (even at highly subsidized prices of silos).[27] So whether policy makers should promote the adoption of silos and at what price remains an important policy and research question. From the policy marker's perspective, it seems difficult to implement a cost effective PHL intervention that provides farmers access to improved silo facilities at even lower prices than 70% of the market price.

The impact assessment shows that the first roll out of the PHL training package and the associated distribution of silos to farmers had limited success in central Tanzania. The good news was that training increased farmers' knowledge about good practices in maize post-harvest handling. However, this knowledge has induced little systematic behavioral change in post-harvest handling, marketing behavior or post-harvest loss or quality. We also find no evidence of an additional impact of the silo over training (with the exception of a decline in self-reported loss during storage).

We explore several reasons that could potentially explain the limited short-term impact of silos. It is important to note that we are not directly evaluating the technical effectiveness of improved storage facilities (silo) over traditional storage facilities. With the data at hand, we are evaluating the impact of an intervention that distributed silos to a randomized subset of trainees on their PHL outcomes. Therefore, our results should not be interpreted as evidence that silos do not perform well for maize storage in Tanzania. The data tells us that the intervention to promote the uptake of silos did not have significant or tangible effects on adopters' PHL outcomes.

A first potential explanation is that the intervention is trying to address a problem that appears to be less problematic for farmers in central Tanzania – as assumed by WFP – and more generally in SSA – as assumed by many development practitioners. The self-reported data from our sample of farmers shows that 9 to 14% of the households respond to have lost maize during storage. On average, the quantity of maize lost is only 1% of the harvested maize for the whole sample. Hence, the PHL that occur at the stage of on-farm storage are not that substantial in magnitude as is commonly assumed. Maybe, most of the losses in maize happens between harvest and storage (e.g. during harvest or transport as found by Ambler, de Brauw and Godlonton

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[27] As a quick back of the envelope calculation, a plastic silo can store 370kg of maize and costs 54,000 TZS at subsidized prices. PICs bags can store 100kg of maize and cost 4,500 THS per bag (which can be reused); and hence farmers would have to buy 4 bags to store the same amount of maize as in the silo (at a total cost of 18,000 TZS).

(2017) in Malawi), and so interventions could be better channeled to other stages of the post-harvest process (than storage). Many of our findings, unfortunately, are not new to the academic literature, and confirm the findings of Sheahan and Barrett (2018) and Affognon et al. (2015). Therefore, wider dissemination of these findings is called for.

While we anticipated a low uptake, we see that the random offering of the silo induced 28% of the famers to actually purchase the silo in our sample. This obviously dilutes the strength of our instrument, but the Local Average Treatment Effect on the Treated (LATE) – where actual uptake is instrumented by assignment – does not point to significant impacts for compliers either.[28] As explained in section 4, we define treatment as the household level opportunity to buy the silo. This does not tell us whether the household actually used the silo for maize production as intended, or put it to use at all. However, when we look at the actual adoption behavior indicator – confounding the results because of selection biases – we still see do not measure significant impacts. It could also be that the control group is doing remarkably well in managing PHL in maize production. They do not fare worse in terms of the probability to have lost (stored) maize or in the size of maize lost. Moreover, the quality of their stored maize – measured in moisture content – is already well below the threshold of 12-14 percent for safe storage for maize (Bradford et al. 2018).

As with any first-time intervention in a complex setting, there was limited operational capacity to implement the (semi-)experimental design. There were operational issues in the distribution of the silos. Most of the silos were manufactured in Uganda as they could not be manufactured in Tanzania during the project time period. This of course adds to the production cost of the silo, and hence makes the silo more expensive for Tanzanian farmers. Additionally, issues around the permit for import of silos and last mile storage issues for the manufacturers resulted in only a limited number of farmers receiving the silo. These operational constrains further reduced the number of farmers that received training and bought the silo, and hence further dilute the ITT impacts measured.

We however want to point out some of the limitations of this study. The maize harvest of farmers in the sample was quite low, on average 612 kg or just above 0.5 ton/ha. It seems with this low level of maize output, mainly produced for auto consumption, there is little use of having a plastic silo that can store up to 350 kg (as farmers reported to have stored – on average – 275kg of maize during round 1). At the time of the (second) survey, most of the stored maize might already be taken out of storage for one reason or another.

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[28] We do not report the results of the LATE in the paper, as the (strict) assumptions needed to identify the LATE are likely to be violated in our data set. Most importantly, we have two-sided compliance, and the issues of defiers cannot be ruled out (Angrist and Pischke (2009)).

The benefit of improved storage facilities (and PHL knowledge) are likely to occur when maize can be stored for a longer period. It is only after 3-4 months that the quality of stored maize starts to decay rapidly, and the benefits from storage would thus especially manifest themselves if storage goes beyond 3-4 months.[29] That's also when prices start to rise. For example, the only other published article looking at the impact of metal silos in Kenya shows that silo adoption prolonged on-farm storage of maize by two years, which allowed adopters to sell maize up to 5 months after harvest (Gitonga et al. 2013).[30]

Recall is likely to be an issue in the self-reported data (Beegle, Carletto and Himelein 2012). The longer the recall period, the more likely the respondent will have difficulties in correctly remembering, for example, the amount of maize initially stored. We observe this phenomenon in the data, as illustrated by the (potential outcome) mean values of the control group reported in Table 6-2 and Table 6-3. In Table 6-2, one would expect that the share of households that faced maize storage losses in round two would at least be equal to the share reported in the first round. This is however not the case.

Some important policy recommendations can be drawn from the study. First, on-farm PHL during storage seem to be a (relative) smaller concern to farmers in Tanzania, at least smaller than is commonly expected. Second, farmers that store maize in improved storage facilities do this mainly to obtain more and better-quality maize for household consumption. Economic motives to sell more maize or later in the season at higher price appear less important. Yet, most interventions are motivated (and accounted) on the premise that farmers will sell the stored maize at a later point in the season, when prices are higher.[31]

Third, the uptake of silos is limited and significantly related to the financial and wealth status of households. This suggests that the promotion of improved but costly storage facilities – such as silos – should be complemented with improved access to capital or liquidity for households that relax their financial constraints in the purchase of silos (Sheahan and Barrett 2018). This can be done by explicitly linking saving schemes or loans with the silo, as is recently being tested, see e.g. Aggarwal, Francis and Robinson (2018). Finally, the current (first year) implementation of the training and equipment distribution to reduce PHL did not bring about much behavioral change. This calls for a better understanding of what PHL issues farmers

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[29] Better post-harvest management and storage facilities may have important second round benefits in changing farmers' maize production and storage behavior. For example, it might induce farmers to grow and store more maize over time, which in turn may reduce seasonality in maize prices and consumption (Kaminski et al. 2016).

[30] Additional analysis on indirect welfare effects – prices that farmers received for sales reported in both rounds of the data collection, the number of days between harvest and first sale, the likelihood that farmers expect to buy maize later in the season, and the usage of the maize silo for other crops – of the adoption of training and silos did not point to significant (short term) welfare impacts.

[31] However, as noted before, maize harvest levels of surveyed farmers are low, and it may be the case that farmers just did not produce (and hence store) enough maize to defer sales to a later moment in the season, as most of it would be used for home consumption.

are confronted with, and how farmers understand and apply the information received during PHL trainings, and how they can apply them once they get access to improved storage facilities.

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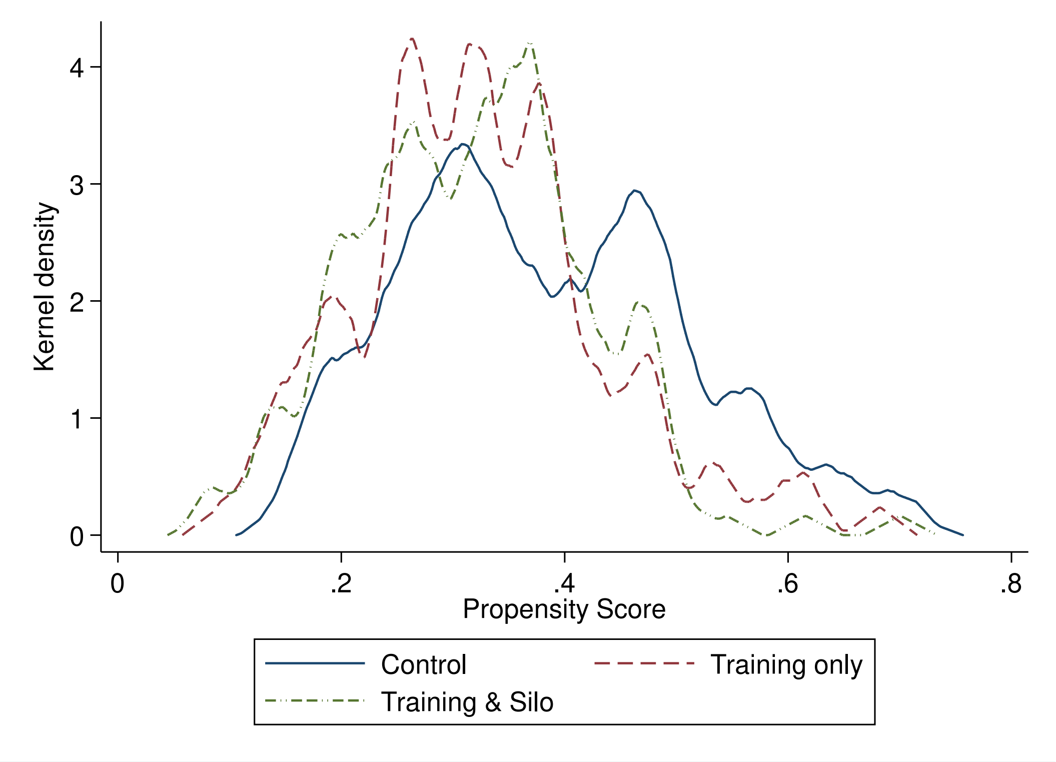
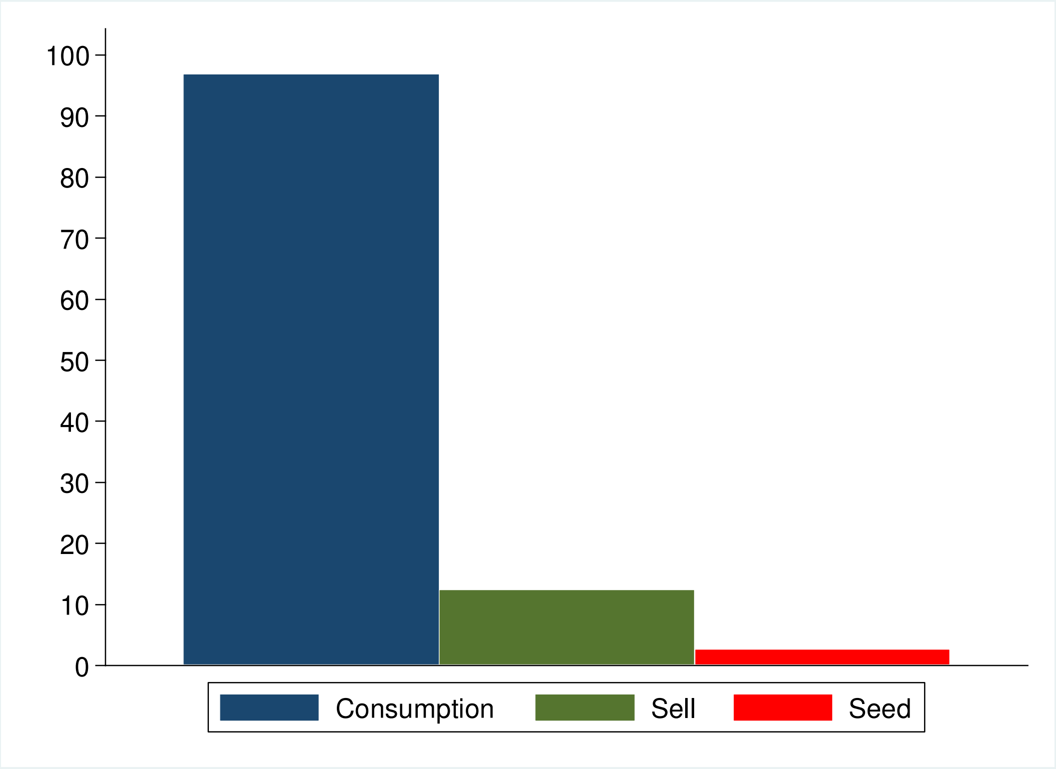
9 Tables and Figures

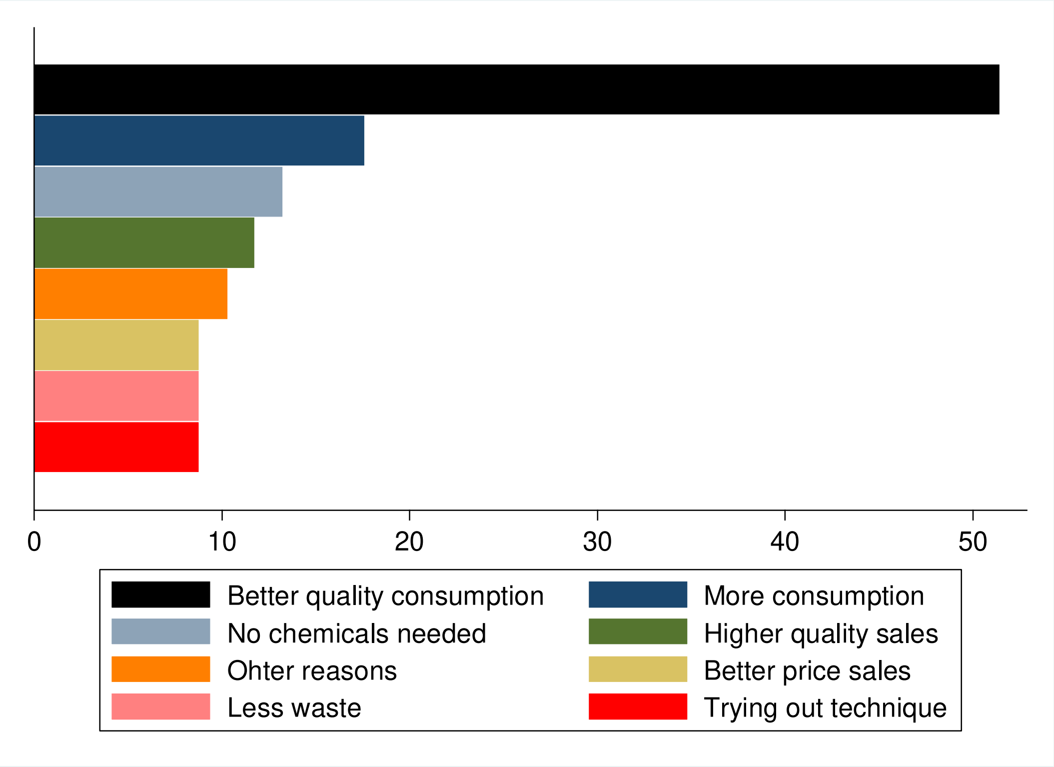
9.1 Figure 4-1: Estimated density functions of the probability of being assigned to a treatment



9.2 Figure 4-2: Main reason why households store maize (%)



9.3 Figure 5-1: Reasons for farmers to use improved storage facility (%)



9.4 Table 3-1: Uptake of assigned treatment status

Assigned treatment (t) based on administrative data	Self-reported uptake of treatment (u) Control	Training only	Training & Silo	Total
Control	158	4	11	**173**
Training only	5	67	59	**131**
Training & Silo	1	20	170	**191**
Total	**164**	**91**	**240**	**495**

Note: There are three groups of farmers. The control group that did not receive training. From the group of trained farmers, the first treatment ('training only') group are farmers that received training but not the opportunity to buy the silo. The second treatment group ('training & silo') is the subgroup of trainees that received training and the opportunity to buy the silo. Assigned treatment is based on the treatment that farmers received during the training session, and we retrieved this information from the administrative data on attendance lists of NCA. The self-reported uptake of treatment (u) is defined based on the response that farmers gave during the survey on whether they participated in the PHL training, were offered the opportunity to buy a silo at the end of the training, and bought the offered silo. The elements in the diagonal of the matrix indicate compliance, all the elements off-diagonal indicate compliance issues.

9.5 Table 4-1: Diagnostic statistics for covariate balance over treatment groups

	Standardized differences		Variance ratio		Standardized differences		Variance ratio	
	Raw	Weighted	Raw	Weighted	Raw	Weighted	Raw	Weighted
Variables used in weighting	Training only				Training & Silo			
Head is male (%)	0.034	-0.038	0.945	1.071	0.107	-0.019	0.820	1.035
Age of the head (years)	0.370	-0.038	1.132	1.019	0.291	0.000	0.926	0.847
Head has primary education (%)	-0.005	0.014	1.009	0.978	0.155	0.069	0.768	0.891
Head has secondary education (%)	-0.129	0.005	0.706	1.011	0.242	0.041	1.569	1.092
Head's primary employment is wage employment (%)	0.002	-0.021	1.009	0.949	0.232	0.028	1.713	1.069
Head's primary employment is self-employment (%)	-0.101	0.038	1.006	0.998	-0.069	0.004	1.004	1.000
Head's primary employment is family work (%)	-0.085	-0.038	0.897	0.949	-0.087	0.008	0.892	1.011
Head's primary employment is household work (%)	0.159	0.019	1.419	1.046	-0.045	-0.015	0.886	0.964
Sector of head's employment is agriculture (%)	0.138	0.058	0.706	0.873	-0.062	0.006	1.135	0.987
Farm size (hectare)	-0.051	-0.029	0.936	1.052	0.075	0.015	1.344	1.281
Household distance to Kilosa (km)	0.134	0.014	0.927	0.917	-0.055	-0.007	1.059	1.004
PCA index of housing assets (.)	0.173	-0.005	0.914	0.952	0.370	-0.011	1.064	1.082
PCA index of livestock assets (.)	0.125	0.043	1.544	1.129	0.123	0.029	1.449	0.975

Note: Standardized differences for each variable are the difference between means for the control group and the training only group (column 1 – 4) and the control group and the training & silo group (column 5 – 8) after the mean of each group has been scaled by the average of the group variance. The variance ratio is the ratio of the variance of the variable for the control group over the variance of the (relevant) treatment group. 'Raw' refers to the unmatched raw data; 'weighted' refers to the comparison in group means after the data is weighted by the IPWRA methodology explained in the text.

9.6 Table 4-2: Descriptive characteristics of farmers in the sample

	30 days		90 days	
	mean	sd	mean	sd
Maize output [n=495]				
Maize harvest quantity (kg)	612	746		
Maize plot size	1.4	1.2		
Maize yield (kg per hectare)	539	576		
Maize balance - occurrence (%) [n=465]				
Stored	77	42	48	50
Consumed	88	32	96	20
Sold	25	43	45	50
Maize balance - share of harvest (%) [n=465]				
Stored	38	30	17	23
Consumed	43	31	62	32
Sold	9.3	20	16	22
Quantity of storage losses [n=465]				
Occurrence of storage loss	14	35	9.0	29
Absolute quantity of storage loss	10.0	48	9.5	59
Relative quantity if storage loss	1.1	3.7	1.2	5.0
Quality of maize stored [n=246]				
Moisture content (%)			9.6	1.4
Moisture content (ppb)			9.7	1.1
Visible weevils (% of households)			65	48

Note: 30 days refers to the data collected – on average – 30 days after harvest. 90 days refers to the data collected – on average – 90 days after harvest. 'mean' refers to the sample mean and 'sd' refers to the standard deviation. 'n' is the number of observations.

9.7 Table 5-1: Determinants of the uptake of PHL training and silos

	Specification 1			*Specification 2*		*Specification 3*	
	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	Participation in training (%)	Order of silo (%)	Purchase of silo (%)	Participation in training (%)	Order of silo (%)	Purchase of silo (%)	Purchase of silo (%)
Head is male (%)	5.4	-22.7**	3.5	5.3	-20.8**	-2.6	26.4
	(4.7)	(9.6)	(7.6)	(6.2)	(9.8)	(9.2)	(19.1)
Age of the head (years)	0.4***	0.9***	0.7**	0.5***	0.8***	0.4	-0.5
	(0.1)	(0.2)	(0.3)	(0.2)	(0.3)	(0.3)	(0.6)
Head has primary education (%)	6.0	23.4**	4.3	6.5	19.3*	0.3	-39.1*
	(6.7)	(9.1)	(9.2)	(6.4)	(10.5)	(10.2)	(21.3)
Head has secondary education (%)	-5.5	20.7*	33.3***	-3.5	22.7**	29.7***	7.3
	(5.5)	(11.1)	(11.6)	(6.1)	(9.8)	(9.4)	(19.1)
Household size (persons)	2.0*	4.9**	3.8**	2.5**	3.0	3.5*	2.5
	(1.0)	(2.1)	(1.8)	(1.3)	(2.1)	(1.9)	(3.3)
Maize area size (hectare)	-4.7***	4.7	-1.3	-5.0**	5.0	2.4	-3.1
	(1.7)	(3.2)	(3.5)	(2.1)	(3.9)	(3.8)	(5.5)
Household used seasonal credit for agricultural inputs (%)	16.2**	6.7	15.4	17.1**	2.7	8.2	9.0
	(6.8)	(14.5)	(15.2)	(8.2)	(12.3)	(12.3)	(14.6)
Household has a money account (%)	11.7**	14.8	15.3	12.6*	25.4**	17.4	-17.6
	(5.4)	(11.2)	(10.3)	(6.5)	(11.6)	(10.8)	(26.8)
PCA index of housing assets (.)	9.4***	3.3	8.8*	10.4**	5.4	9.9	11.4
	(3.7)	(5.6)	(5.0)	(4.3)	(6.7)	(6.3)	(10.3)
PCA index of livestock assets (.)	12.6***	3.1	-4.5	14.0**	1.9	3.3	-7.1
	(3.9)	(10.3)	(13.1)	(5.8)	(12.8)	(11.1)	(11.6)
Expectations of PHL (%)	-0.2	0.0	-0.0	-0.2	0.4	0.1	-0.7
	(0.2)	(0.3)	(0.3)	(0.2)	(0.3)	(0.3)	(0.4)
Household is considered as very credit constrained (%)	-3.2	-15.6	1.3	-4.7	2.5	9.3	-1.4
	(5.6)	(10.9)	(10.1)	(7.2)	(10.7)	(11.0)	(18.1)
Household is considered as temporarily credit constrained (%)	-0.9	-22.8**	-9.8	-2.2	-7.8	-6.8	5.1
	(5.8)	(8.8)	(7.5)	(5.4)	(9.2)	(8.3)	(18.0)
Household is considered as risk liking (%)	-9.5	10.4	-5.3	-7.2	14.3	-9.2	-66.2**
	(9.2)	(19.1)	(22.5)	(11.6)	(23.1)	(22.1)	(31.4)
Household is considered as very risk averse (%)	-4.1	9.8	-8.2	-3.6	14.5	-2.0	-56.8**
	(7.1)	(11.0)	(13.9)	(7.3)	(14.3)	(15.5)	(22.6)
Constant	18.6	-52.1*	-47.5*	3.5	-93.8***	-83.5***	120.9
	(12.9)	(27.1)	(28.0)	(20.2)	(33.3)	(28.5)	(128.7)
Village fixed effects?	No	No	No	Yes	Yes	Yes	Yes
Inverse Mills Ratio							-0.4
							(0.5)
Observations	495	190	190	495	190	190	190
R-squared	0.095	0.299	0.242	0.112	0.470	0.458	0.718

*Note: Bootstrapped standard errors clustered at village level are reported in parentheses, *** p<0.01, ** p<0.05, * p<0.1*

9.8 Table 6-1: ITT of training and silo adoption on knowledge and usage of best practices

	ITT					
	Knowledge on (%)				**Uptake of (%)**	
VARIABLES	Oxygen removal	Moisture measurement	Drying maize on carpet	Shelling maize using machine	Mechanized shelling (%)	Cleaning using sieving (%)
Mean for control group	3.21**	3.25**	17.95***	37.12***	35.05***	55.03***
	(1.48)	(1.53)	(2.95)	(3.67)	(3.88)	(4.12)
Effect of training	33.65***	9.36***	16.17***	4.06	0.58	3.74
	(4.29)	(3.30)	(4.79)	(5.42)	(5.46)	(6.30)
Effect of training & silo	40.11***	8.04***	11.06***	5.02	5.18	20.08***
	(3.68)	(2.67)	(4.21)	(4.71)	(5.29)	(5.28)
F statistic that effects are significantly different	-0.06	0.01	0.05	-0.01	-0.05	-0.16***
	(0.05)	(0.04)	(0.05)	(0.05)	(0.05)	(0.06)
Observations	495	495	495	495	432	432

*Note: ITT = Intention To Treat effects for 'training only' and 'training & silo' treatment groups. Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1*

9.9 Table 6-2: ITT of training and silo adoption on self-reported loss of maize during storage

	ITT					
	Round 1			*Round 2*		
VARIABLES	Occurrence (%)	Absolute quantity (kg)	Share (%)	Occurrence (%)	Absolute quantity (kg)	Share (%)
Mean for control group	15.17***	11.31***	1.00***	7.48***	4.76***	1.02***
	(2.82)	(4.26)	(0.25)	(2.05)	(1.50)	(0.32)
Effect of training	-0.97	0.95	0.25	3.01	0.62	-0.16
	(4.27)	(6.94)	(0.48)	(3.47)	(2.40)	(0.46)
Effect of training & silo	-3.14	-3.35	0.11	2.73	8.51	0.32
	(3.67)	(4.50)	(0.35)	(3.00)	(5.44)	(0.51)
F statistic that effects are significantly different	0.02	4.30	0.14	0.00	-7.88	-0.48
	(0.04)	(5.76)	(0.47)	(0.04)	(5.58)	(0.50)
Observations	465	465	465	465	465	465

*Note: ITT = Intention To Treat effects for 'training only' and 'training & silo' treatment groups. Round 1 refers to data collected 30 days after harvest and round 2 refers to the data collected 90 days after harvest. Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1*

9.10 Table 63: ITT of training and silo adoption on maize harvest usage (%)

	ITT					
	Round 1			*Round 2*		
VARIABLES	Stored	Consumed	Sold	Stored	Consumed	Sold
Mean for control group	35.41***	45.14***	9.61***	15.51***	61.72***	16.78***
	(2.18)	(2.47)	(1.59)	(1.66)	(2.38)	(1.92)
Effect of training	5.53*	-0.91	-1.78	4.26	0.10	-3.21
	(3.30)	(3.58)	(2.24)	(3.02)	(3.88)	(2.59)
Effect of training & silo	1.88	-3.06	1.43	0.55	-1.15	0.46
	(3.07)	(3.33)	(2.28)	(2.32)	(3.27)	(2.64)
F statistic that effects are significantly	3.65	2.15	-3.22	3.70	1.24	-3.67
different	(3.28)	(3.42)	(2.22)	(2.95)	(3.85)	(2.50)
Observations	465	465	465	465	465	465

*Note: ITT = Intention To Treat effects for 'training only' and 'training & silo' treatment groups. Round 1 refers to data collected 30 days after harvest and round 2 refers to the data collected 90 days after harvest. Stored, consumed and sold respectively refer to the share of maize harvest that is allocated by the household to the specific output usage. Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1*

9.11 Table 6-4: ITT of training and silo adoption on maize quality indicators and PHL knowledge

	ITT		
		Round 2	
VARIABLES	Moisture content (%)	Moisture content (ppb)	% household with visible weevils
Mean for control group	9.50***	9.57***	63.44***
	(0.15)	(0.13)	(5.03)
Effect of training	0.14	0.06	-3.91
	(0.19)	(0.16)	(7.76)
Effect of training & silo	0.12	0.22	3.88
	(0.20)	(0.16)	(6.66)
F statistic that effects are significantly different	0.02	-0.16	-7.79
	(0.19)	(0.14)	(7.40)
Observations	246	246	246

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

10 Appendices

10.1 Sampling of villages and farmers

The awareness campaign and trainings organized by NCA covered 32 villages in 3 districts of Tanzania (villages were selected along the road going from Kiteto to Kisanga, passing through Kilosa) where NCA has been active in other projects in the past. We will refer to these villages as 'NCA' (training) villages. The majority of the villages (and hence the targeted farmers) are located in Kilosa, as NCA has been operating in this district before during the small scale (500 farmers) SHE intervention (SmallHolder Empowerment to assure market access – part of the Patient Procurement Platform (PPP)). According NCA, these villages are not particularly different in terms of maize Post Harvest Losses (PHL) compared to non-NCA villages.

The target number of farmers to be trained was 60 farmers in most villages, although more farmers were expected to be trained in larger villages. However, in some villages there was no training given, while in other villages many more farmers showed up for training. NCA decided to give no PHL training when villages were already covered by the Swiss NGO Helvetas on PHL training or when there was limited cooperation with the local government. In some villages of Kilosa, NCA is doing several interventions to address poverty in the village, and better awareness and positive attitude of farmers in these villages might explain larger number of trained farmers achieved here. In total, 2,061 farmers were trained by NCA.

Even though the intervention was rolled out in 32 villages in three districts, the data collection only focused on villages located in the Kilosa district for two reasons. First, there was only one trained village in Kongwa, and we therefore dropped the district. Second, in Kiteto district, many farmers from outside the training were able to buy a silo when they were delivered in the village, due to a miscommunication issue. The low uptake of silos (i.e. the low number of payments) induced some NGO agents to announce to everyone in these villages that silos would be delivered and could be bought on the spot (even for non-trained participants). This miscommunication was avoided in other districts. As farmers in Kiteto could buy silos on the spot when delivered, we decided to drop the district of Kiteto from the sample.

Hence, the data collection focused only on the district of Kilosa. Within the Kilosa district, we further had to drop 6 villages. First, there are 3 villages in Kilosa where no farmers where trained. Second, in Dumila Chini and Dumila Juu, farmers from outside the training were also allowed to buy silos on the spot. This brings the total sample down to 22 villages.

With 22 villages, we decided to sample 24 farmers within each village. The following distinction was made over the different treatment arms: 8 control farmers, 6 treatment 'training only' (T1) farmers and 10 treatment 'training & silo' (T2) farmers. The latter group of treated farmers were oversampled, as to anticipate that the uptake of silos is less than perfect. Table 10-1 provides an overview of the number of farmers sampled in each village. To sample farmers for these 3 treatment groups within the village, we use two sources of information. First, we use the information provided by NCA with an overview of which farmers were offered the silo (T2) and those who were not (T1) at the end of the training in each village. We will use this list to sample treatment farmers. Second, we use the census list of all farm households within a village to sample control farmers. Below, we provide specific information for each type of treatment group.

Control farmers are selected within the NCA villages, by comparing the NCA total list of trained farmers with the list of all farm households living in the village. To do so, we collected a sampling frame of the entire village based on the census available in each village. Then, this list is matched with the NCA list to identify the group of farmers that were trained by NCA and the group that was not trained by NCA. From the latter group, we randomly select 8 farmers.

The selection of T1 and T2 treatment farmers for survey interviews was done randomly for each village and was documented in excel spreadsheets. The total number of farmers that needed to be sampled in each village is reported in Table 10-1 but is not necessarily the same in each village. To select the **T1 farmers**, we look at the NCA total list of farmers, and select those from the list that were not offered the silo. From this group, we randomly select 6 farmers in each of the 22 villages. There are two exceptions. First, there were not enough T1 farmers to sample in Kilosa town, so we decided to take two additional T2 farmers. Second, in Mandela more than 10 T2 farmers were available and all were included in the sample (reducing the sample of T1 farmers to 5).

The group of **T2 farmers** consists of two subgroups, i.e., (i) T2 farmers that were offered the silo, but did not buy it and (ii) T2 farmers that were offered the silo and bought the silo. Given the low number of farmers that actually bought the silo, we sample both groups of T2farmers. Hence, sample numbers for treatment group T2 are constructed as follows: we take all farmers that bought the silo, and if there are not enough farmers that bought the silo; we added farmers that were offered the silo but did not buy it, to reach a total of 10 farmers.

Table 10-1: Overview of number of farmers for each treatment groups over villages

VILLAGE	**Control group**	**T1: Trained**	**T2: Total trained and offered silo**
Berega	8	6	6
Changalawe	8	6	10
Chanzulu	8	6	10
Dakawa	8	6	9

Kilosa	8	2	12
Kimamba	9	6	9
Kisanga	8	6	10
Kitete	8	7	9
Kitundueta	7	9	7
Kiyegea	7	8	6
Madudumizi	8	6	8
Magubike	8	7	10
Maguha	8	6	10
Mandela	8	5	9
Mfuru	8	6	8
Mhenda	9	6	10
Msowero	8	8	8
Mvomero	8	5	8
Nyameni	8	6	10
Rudewa	8	6	8
Ulaya mbuyuni	8	6	10
Zombo	8	7	9
Total	176	136	196

10.2 Explanation of variables used

Wealth indicators: The PCA was performed in Stata on the list of (i) self-reported household and (ii) livestock assets separately, where we respectively include ownership dummies of (i) a tv, radio, lantern, table, motorized vehicle, mobile phone, kerosene stove, hoe and plough; and (ii) bulls, cows, setters, heifers, calves and oxen.

Credit constraint indicators: Each household was asked two questions. The first question asked whether the household would be able to raise 50,000 shillings one week before the harvest of maize if needed. The second question was the same but with a different reference period, i.e., one week after the maize harvest. If a household responded 'no' to both questions, we consider them as credit constrained. If the household responded 'no' to the first question, but 'yes' to the second, we consider them as temporary credit constrained. The reference group is the group of farmers that responded 'yes' to both questions.

Risk indicators: to incur households' risk preferences, we asked two questions in which the households had to choose between two options to receive a payment. We asked the household (head) whether they prefer to have a smaller amount of money for sure at a certain point in time or whether they preferred to have a 50% chance of winning a larger amount of money but with the 50% chance of not winning anything. The first question asked 'Would you prefer 25,000 Tanzanian Shillings (TZS) for sure or do you prefer to flip a coin and get 50,000 TZS if it is heads and 0 if it is tails'? If a household responded 'no' to the first question, the subsequent question asked whether the household 'Would you prefer 37,500 TZS for sure or do you prefer to flip a coin and get 50,000 TZS if it is heads and 0 if it is tails?'. If a household responded 'yes' to the first question, the subsequent question was whether the household 'Would you prefer 12,500 TZS for sure or do you prefer to flip a coin and get 50,000 TZS if it is heads and 0 if it is tails?'. If the household answered 'yes' to both, we consider them as a risk averse household, if they answered 'no' to both questions; we consider them as a risk liking household.

Spillover effects: to measure the potential effect of spillover effects from treated farmers to non-treated farmers (or farmers with a different treatment), we include the number of farmers that are considered as 'training only' farmers and the number of 'training & silo' farmers within a distance of 1km from each household. This is done using the 'geonear' package in Stata developed by Picard (2010), using the GPS coordinates collected during the first survey round. The results reported in the paper are robust to different specifications of the distance threshold (e.g. 0.5 km).

Knowledge questions: the knowledge questions were asked as open-ended questions to farmers. For each question, a correct answer was pre-determined, but not shared with the enumerator. Based on the qualitative response of farmers, we manually indicated whether the response of the farmer was correct. The following questions were used in the analysis (with the correct answer in brackets): On what material should maize be dried? (Plastic sheet or special drying crib). How should you shell the grain? (With a proper machine). How do you measure the moisture content of stored maize? (Using the ‘salt and bottle’ method" or a moisture meter). How do you remove the oxygen from metal silos? (Place a burning candle on top of grain inside the metal silo). A dummy indicator for each question indicates whether the household could provide the correct answer.

All the data comes from farmers’ self-reported recall response. While the data has gone through several rounds of data cleaning and quality checks, in some cases, outliers might still be present in the data. To avoid outliers to bias the summary statistics, we use trimmed values when presenting (most) continuous variables. The trimming procedure used here looks at the distribution of each variable and detects outliers in the top and bottom 1% of the distribution in the sample, and replaces outliers by the median value of the distribution (if any).