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Adoption of small metallic grain silos in Malawi: A farm level cross-sectional study

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Abstract

Postharvest damage and loss of staple grains are a common problem in Malawi which undermines household food security. This has raised the need for households to adopt improved grain storage technologies. Using cross-sectional data, this study examined farmers' perception of metallic silo technology and the underlying socioeconomic determinants of its adoption. A multi-stage random sampling technique was employed to draw a sample of 133 households for analysis. Technology adoption was analyzed using Probit model. The findings show that farmers perceived of metallic silos as more effective in reducing postharvest grain losses and more secure than other grain storage methods. Key determinants of adoption of metallic silo technology included age, education, farm size and access to agricultural extension. Farm size may not be expanded however; improving productivity of the farmland currently used by farmers would increase farm level production and enhance technology adoption. Increasing extension training, awareness and technology demonstrations would also enhance adoption of metallic silo technology.

Keywords: Technology adoption, Metallic grain silos, Probit model, Malawi

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1. Introduction

For most Sub-Saharan African (SSA) countries, agriculture is crucial to achieving broad based pro-poor economic growth and attaining the Millennium Development Goal of halving poverty and hunger by 2015 (World Bank, 2007). This is because a large number of countries in the SSA region depend heavily on agricultural production particularly, on staple grain such as maize, beans, rice and sorghum. It is estimated that approximately 70-80% of employment and 40% of Africa's export earnings are derived from agricultural activities (Food and Agriculture Organization [FAO], 2006). However, despite the economic significance of agriculture, many countries in Africa are characterized by low production of agricultural commodities per unit of land. As a result, many SSA countries experience acute food security problems and face hunger and starvation almost annually. In Malawi, maize is a staple food of great socioeconomic importance like in other sub-Saharan African countries. This staple grain crop plays a crucial role for food security, income generation, as well as the livelihoods of rural inhabitants in Malawi.

Postharvest losses are a permanent reduction to crop harvest that result from one or a combination of factors such as storage pest infestation, rodents and moulding (Malawi Government and FAO, 2010). Postharvest damage (by biotic and abiotic agents) and loss of staple grains due to insect pests, rodents and birds are a common problem in developing countries including Malawi. However, precise information on postharvest losses of grains in Malawi is scanty. Nevertheless, observations indicate that more than 70% of maize stored on the cob is severely damaged by larger grain borer (*Postephanus truncates*) and other associated grain pests after 6 to 8 months of storage (Department of Crop Production, 2007). Other estimates of postharvest loss indicate that Malawi loses between 10% and 40% of the harvested maize annually (Malawi Government and FAO, 2010).

To reinforce the economic importance of postharvest grain management in Malawi, FAO provided support to Malawi Government through the Ministry of Agriculture and Food Security in the "Artisanal Manufacturing of Small Metallic Silos Project" which was launched in 2007, aiming at improving household and community level storage capacities through the provision of grain and food storage facilities and to enhance local technical capacity for construction of small-to-medium scale grain storage silos. It was hoped that the project would improve grain quality, increase farmers' income by allowing them to sell grain during the lean food period (January to February) when prices are more favourable, and enhance household food security.

Sometimes governments play a benign role in supporting smallholder farmers to improve adoption of agricultural technologies by making the technical innovations and their complementary inputs more easily accessible and cheaply available to farmers. The Malawi Government in collaboration with FAO followed a similar approach by giving out the initial fabricated small metallic silos to smallholder farmers' communities through a project. In India, Butzer et al. (2002) in Baird (2003, p.2) used a choice technique framework to characterize the decision to adopt High Yielding Varieties (HYVs) and found that "since HYVs require higher levels of fertilizer and irrigation to realize their yield level, their introduction corresponded with a large jump in the demand for fertilizer and irrigated land." As for Malawi, individual grain metallic silos were provided to rural households in various agro-ecological zones known as Extension Planning Areas. Farmers received technical assistance and training on storage technology with the aim of improving food security at household level and increase their income through better market integration. Following the completion of the project, Ministry of Agriculture and Food Security commissioned production of another stock of metallic silos for distribution to farmers throughout the country at a discounted price.

Despite wide distribution of metallic grain silos across Malawi after the phasing out of the project, none of adoption studies has attempted to profile perception and determinants of adopting metallic grain silos in the country. In a stream of previous studies, Coulter et al. (1995) studied farmers in Salvador, Guatemala, Honduras and Nicaragua, and found that those with metallic grain silos stored more grain than previously. Gladstone et al. (2002) noted that about 60% of the farmers surveyed were found to still have maize grain in their silos at the beginning of the next harvest in comparison with only 29% of the non-users. With grain silos, farmers are able to take advantage of the volatility in grain prices (Florkowski and Xi-Ling, 1990), as demand and supply of grain switch levels. In a similar study, Hermann (1991) found that metallic grain silo users sold 66% of the stored maize before the new harvest while non users sold 50% of their maize grain immediately after harvest. In Malawi maize prices are low just after new harvest while they hike several times high prior to the new harvest.

There exists a vast array of literature on agricultural technology adoption by farmers. Several authors including Feder et al. (1985); Foster and Rosenzweig (1995); and Kohli and Singh (1997) have observed that generally studies on agricultural technology adoption concentrated on overcoming constraints related to information asymmetry, risk aversion, uncertainty, institutional, infrastructural and markets as factors affecting farmers' decisions to adopt. Recently, studies have focused on local institutions and social networks as important determinants of technology adoption.

To explain adoption behavior and determinants of technology adoption, three paradigms are commonly used: the innovation-diffusion model, the adoption perception and the economic constraints models (Uaiene, et al., 2009). According to Feder and Slade (1984); Shampine (1998); Smale et al. (1994) in (Uaiene, et al., 2009, p.5), "the underlying assumption of the innovation-diffusion model is that the technology is technically and culturally appropriate but the problem of adoption is one of asymmetric information and very high search cost". Uaiene et al. (2009, p.5) states that "the adopters' perception paradigm on the other hand, suggests that basically the perceived attributes of the technology determine adoption behavior of farmers". "This means that even with full farm household information, farmers may subjectively evaluate the technology differently than scientists" (Ashby and Sperling, 1992) in Uaiene et al. (2009, p.5). "Thus, understanding farmers' perception of a given technology is crucial in the generation and diffusion of new technologies and farm household information dissemination" (Uaiene et al., 2009, p.5). According to Aikens et al. (1975); Smale et al. (1994); Shampine (1998) in Uaiene et al. (2009, p.5), "the economic constraint model contends that input fixity in the short run, such as access to credit, land, labor or other critical inputs limits production flexibility and conditions technology adoption decisions". Recently, some researchers such as Adesina and Zinnah (1993); Gemeda et al. (2001) and Uaiene et al. (2009, p.5) have expressed that "modeling technology adoption" is better explained when all the three paradigms are used.

The above reviewed grain silo studies have shown a positive effect that adopting metallic grain silos have on general livelihoods of users. But what is the perception of farmers about metallic grain silos and what are the key socioeconomic determinants of adopting the same? This study commits to answer these research questions. The rest of the paper is organized as follows: The next section presents methodology, data and description of the variables used in the analysis. Results and discussion are found in section 3, while section 4 draws conclusion.

2. Methodology

2.1. The Data

This study was conducted between July and September 2011 through a field survey. The study covered 20 agro-ecological zones (Extension Planning Areas) in 10 districts: Balaka, Blantyre, Chikhwawa, Chiradzulu and Phalombe in the South; Lilongwe, Mchinji, and Salima in the Center; and Mzimba, and Rumphi in the North of Malawi. These districts were purposively targeted and selected because they had prominent activities in postharvest grain management by non-Governmental Organizations and projects and were among the 17 districts where the silo project was implemented.

A multi-stage (four stages) cluster sampling procedure involving a combination of purposive and random sampling was used to draw a sample of 133 households. Purposive random sampling strategy was used because it adds credibility of the findings when potential sample is larger than one can handle; it also helps to reduce bias within the purposive category (Patton, 2002). The first three steps involved purposive selection of districts, Extension Planning Areas, traditional authorities and villages. The selected sites were within the "Artisanal Manufacturing of Small Metallic Silos Project" area. The fourth stage involved simple random sampling of households from the list of villages. In this stage, households in villages with a larger population had a proportionally greater chance of being selected into the sample. Sampled households were interviewed using a semi-structured questionnaire. Focus group discussions were conducted at randomly selected sites with organized groups of farmers to substantiate the quantitative semi-structured questionnaire. Stakeholder interviews were conducted with purposively selected representatives of organizations involved in postharvest grain storage and management in the selected districts.

2.2. Data analysis

Factors hypothesized to influence adoption of small metallic silo technology by farmers in Malawi were categorized into two: farmer characteristics and farm characteristics.

2.2.1. Farmer characteristics

2.2.1.1. AGE

In line with general literature, farmers' age on technology adoption is found to have a negative effect, older farmers being more reluctant to change or the expected return being lower (Bocquého et al., 2011). In this study we hypothesized technology adoption to increase with age at least to a certain level considering the fact that older farmers have a longer experience than young ones of the grain damage associated with poor storage facilities.

2.2.1.2. SEX

We analyzed the effect of sex on technology adoption from the gender perspective in which women and men play different economic roles on the farm. Field observations across Malawi revealed that men are generally concerned with management of cash enterprises on the farm while women take care of household food security. We therefore, expected sex to have a positive effect on the adoption of small metallic silo technology because women dominate in the smallholder food grain production in the country.

2.2.1.3. MARITAL STATUS

The issue of marital status is very tricky in technology adoption. It is not known how being married or otherwise influences the farmers' decision to adopt a new technology. We however, hypothesized that farmers who are married could easily make a unified decision with minimum risk aversion to adopt improved technology if it is deemed to improve household socioeconomic status.

2.2.1.4. EDUCATION

Education was hypothesized to positively affect adoption of metallic silo technology. This is based on the fact that educated farmers stand a better chance to acquire new information and appreciate the importance of modern technologies through improved understanding.

2.2.1.5. HOUSEHOLD SIZE

Household size (HHSIZE) is a proxy for labour availability on the farm. This becomes more important when the household mainly uses family labour. Thus, the new technology can be classified as either labour intensive or extensive. In this study, we classified the metallic silo as labour extensive, and expected the variable (HHSIZE) to influence technology adoption negatively.

2.2.1.6. OCCUPATION

We hypothesized agricultural related occupation to have positive effect on the technology adoption because farmers would be more concerned with management of agricultural enterprises than those who derive their livelihood from other forms of occupation.

2.2.2. Farm characteristics

2.2.2.1. FARM SIZE

Farm size was measured as the total land that farmers used to produce different types of grains. Like age, farm size is a usual factor explaining technology adoption, both in theoretical models and empirical models (Bocquého et al., 2011). The size of landholding, and therefore farm size impacts on the household's land use decisions in terms of type and diversity of farm enterprises, as well as cropping systems and patterns (Maonga, 2005). Farm size was therefore expected to have positive effect on adoption of metallic silos.

Within the domain of farm characteristics, we hypothesized PRODUCTION to be a major factor affecting adoption of the metallic silo technology. The amount of production determines the type and size of storage facilities that farmers consider in postharvest farm planning. We considered production as an estimated total quantity of grain produced by farmers in each of the respective households. Like farm size, grain production was hypothesized to exert a positive impact on technology adoption. However, the variable was dropped due to its high collinearity with farm size. Unacceptable level of multicollinearity between farm size and production reflects the fact that when there is limited use of other high productivity inputs such as fertilizer, the quantity of crop production varies directly with the farm size. Most smallholder farmers in Malawi do not use the recommended amounts of fertilizers. Therefore, high grain production is to some extent a reflection of farm size.

2.2.2.2. EXTENSION

Access to agricultural extension messages is believed to have positive influence on technology adoption by farmers. Extension improves farmers' awareness of the available new technologies. We expected agricultural extension to play a positive role in the adoption of the metallic silo technology. INCOME: Generally, farmers with larger financial capabilities are considered to be more prone to technology adoption, especially if the technology requires some important investment (Bocquého, et al., 2011). When the technology tends to entail large financial obligations, more risk averse farmers are expected to be more reluctant to adopt it. Farmers tend to be more sensitive to the uncertainty relative to their total income rather than the uncertainty relative to the income from the new technology (Bocquého, et al., 2011). In this study, total household income comprises both farm and off-farm income. Table 1 defines the variables included in the analytical model of the adoption of small metallic silo technology.

Table 1. Definition of variables used in the small metallic silo adoption model

Variable	Definition
Dependent variable	
Adopter	1 = Uses small metallic silo for grain storage; 0 = otherwise
Explanatory variables	
Age	Age (years)
Sex	1 = Female; 0 = otherwise
Marital status	1 = Married; 0 = otherwise
Education	Highest level of education attained (years)
Household size	Number of people in the household
Occupation	1 = Farming; 0 = otherwise
Farm size	Area of land used to produce grain (ha)
Production	Estimated quantity of grain production in 2010/2011 (kg)
Extension	1 = Has access to agricultural extension; 0 = otherwise
Income	Estimated total annual household income (MK)

2.3. Theoretical underpinnings and empirical model used in data analysis

Famers are rational in their decision making and maximize their utility by adopting different types of post harvest technologies. Farmers compare the new technologies with their traditional technology to see whether characteristics of the new technology promise a higher utility than the traditional one. In this study, we hypothesized that adoption of the metallic silos by farmers depends on different factors that influence the choice or preference among different types of post harvest storage technologies. Thus, farmer's preference to adopt a particular technology at farm level is motivated by random utility function expressed as:

$$U_j = \beta_j x_i + e_j \qquad (1)$$

Where U_j is the utility to be obtained from using a given post harvest storage technology, x_i is a vector of attributes of the technology and the farm household characteristics, β_j is a parameter vector to be estimated, e_j is the disturbance term and assumed to be distributed normally, and *j* is the choice of farmer to adopt among different post harvest storage technologies.

Assume that a farmer derives utility from adopting small metallic silo technology, given the resource endowment and farm household characteristics. Let us assume that the farmer's choice to adopt or not to adopt small metallic silo technology is represented by utility function U_1 and U_0, respectively; i.e.

$$U_1 = (1,z,y) \text{ and } U_0 = (0, z, y) \qquad (2)$$

Where U_1 and U_0 are the farmer utility obtained from the chosen post harvest storage technology due to the choice of adoption of small metallic silo technology and non adoption of the same, respectively. Thus, the utility function of farmer subject to the resource endowment constraint (z), and other observable attributes (y) of the farm household can affect the adoption decision of farmers.

From the theoretical specification of utility function, we assume an additively separable utility function in the deterministic and stochastic component that can be expressed as:

$$U_1 = U(1, z, y) = D_1(1, z, y) + e_1 \qquad (3)$$

and

$$U_0 = U(0, z, y) = D_0(0, z, y) + e_0$$

where U_j (.) is the utility obtained from the chosen post harvest storage technology, D_j (.) is the deterministic part of the utility and e_j is the stochastic component known to the farmer but unobservable to the researcher. The farmer's decision process is modeled using the random utility framework. From the utility theoretical stand point, a farmer prefers to adopt small metallic silo technology if the return with this technology, minus its cost, is at least greater than the return from not adopting small metallic silos;

$$U_1(.) \geq U_0(.) \qquad (4)$$

$$D_1(1, z\text{-}c; y) + e_1 \geq D_0(0, z, y) + e_0$$

Thus c is the cost of adoption of the small metallic silo technology that includes the implicit and explicit cost to the farmer. The existence of the stochastic component allows us to apply probabilistic distribution about a decision-makers behavior. The probability distribution of the adoption and non-adoption of small metallic silo technology can be expressed in equations (5) and (6), respectively as follows:

$$P_1 = P(choice) = \Pr(D_1(1, z-c; y) + e_1 \geq \Pr(D_0(0, z, y) + e_0 \qquad (5)$$

$$P_0 = \Pr(D_0(0, z, y) + e_0 \geq \Pr(D_1(1, z-c; y) + e_1 \qquad (6)$$

The choice of farmer to adopt the improved practice (small metallic silo technology) in terms of utility function of probability distribution can be expressed as:

$$\Pr(choice) = \Pr(U_1) \geq \Pr(U_0) \qquad (7)$$

The dichotomous nature of our dependent variable suggests that either a probit/normit or a logit model is appropriate (Pindyck and Rubinfeld, 1981, Maddala, 1990; Gujarat, 2004; and Wooldridge, 2006). We use probit model to analyze the factors affecting the adoption of small metallic silo technology. Due to deficiency on the cost, c, of the technology in question, the model in this study only includes other observable variables specified as follows:

$$Y_i = \beta_0 + \beta_1 AGE_i + \beta_2 AGESQUARED_i + \beta_3 SEX + \beta_4 MARITALSTATUS + \beta_5 EDUCATION + \beta_6 HHSIZE + \beta_6 OCCUPATION + \beta_7 FARMSIZE + \beta_8 EXTENSION + \beta_9 INCOME + e_j \qquad (8)$$

The dependent variable of the model represents whether a smallholder farmer is an adopter or a non-adopter of small metallic grain silo technology.

3. Results and discussion

In this section we explore descriptive statistics followed by an examination of farmers' perception of small metallic silo technology. We finally proceed with a discussion of the results of the probit model that was used to analyze adoption of small metallic silo technology in Malawi.

3.1. Descriptive statistics of sampled households

Table 2 presents a summary of the descriptive statistics indicating the variable means, standard deviations and differences between the variable means of each of the variables used in the probit model. The differences between most of the means of the explanatory variables for the adopters and non-adopters of small metallic silos were not statistically significant. The mean differences in education and extension between the two sub-samples were however statistically significant at 5% and 1% levels, respectively.

Table 2. Descriptive statistics by sample and sub-sample categories

Variable	Sample (n=133)		Adopter (n=60)		Non-Adopters(n=73)		Mean Difference
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	
Y (Dep. Var)	0.4511	0.043					
AGE	42.744	1.260	42.48	12.47	42.95	16.11	0.4755
GENDER	0.5413	0.043	0.55	0.501	0.534	0.502	-0.0157
MARITALSTATUS	0.7669	0.036	0.733	0.445	0.794	0.406	0.0611
EDUCATION	5.7218	0.302	6.566	3.604	5.027	3.261	-1.539**
HOUSEHOLD SIZE	5.7518	0.196	5.583	2.226	5.890	2.300	0.3070
OCCUPATION	0.9699	0.014	0.983	0.129	0.958	0.199	0.0367
FARMSIZE	1.1206	0.059	1.280	0.698	0.989	0.651	-0.2916
EXTENSION	0.4736	0.043	0.716	0.454	0.273	0.449	-0.4426***
INCOME	76753	7953	83431	11288	71264	7009	-0.0010

***p<0.01 **p<0.05

3.2. Farmer perception of the small metallic silo technology

Farmers' perception of small metallic silo technology was examined from three perspectives: (1) Effectiveness; (2) Expensiveness; and (3) Security of the stored grain. The findings revealed that generally an increased number of smallholder farmers in Malawi perceived of small metallic silos as a technology that is more effective, more expensive and more secure than other storage methods (Table 3). It is worth noting that 18.8% of the sampled households were not sure about the cost of the metallic silos. During focus group discussions it was revealed that the project staff did not tell farmers the cost incurred in the fabrication of the small metallic silos donated to the farming communities.

The focus group discussions also unearthed what farmers perceived as benefits of the small metallic silos over the traditional storage methods. Common among the perceived benefits of the metallic silos included full protection of grain against pests (rodents, weevils, larger grain borer and termites), water moisture and fire as well as potential theft.

Long-term grain storage was perceived to help farmers and the communities at large to avert hunger. Most metallic silos serve as a bulk store for maize grain that helps people in the community to buy food when national grain markets such as the Agricultural Development and Marketing Corporation run out of food (maize) stock during critical food lean periods (January and February). Continued access to food even during the lean food periods enabled farmers to concentrate more on cultivating their own farms and reduced the tendency of engaging in casual labour as a coping mechanism to food insecurity. Small metallic silos were also touted as beneficial in terms of offering long-term storage of grain for food security and for better market prices. When the grain was meant for sale, long-term storage enabled farmers to sell their grain at high prices during the lean months. This helped to increase and spread farm household income over the year. Thus, if well managed, storage of grain in the metallic silo was perceived to have potential to improve food security and farm income at household level. Where the grain was meant for seed, some farmers had successfully stored seed grain in the communal metal silos, and were therefore, able to plant with the first rains. It was also observed that metallic silo technology helped to maintain quality of the stored grain over a relatively longer period of time; as such, the grain attracted competitive prices during the time of sale.

Table 3. Farmers' perception of the small metallic silo technology

Perception response scale*	Percentage response (%) (n = 133)		
	Metal silo is *more effective* than other methods	Metal silo is *more expensive* than other methods	Metal silo is *more secure* than other methods
Strongly agree	59.4	36.8	46.6
Mostly agree	3.0	12.8	15.8
Do not know; Not sure (yes/no.)	6.8	18.8	8.3
Mostly disagree	1.5	3.8	0.8
Strongly disagree	1.5	0.0	0.8

On the cost-effectiveness, farmers perceived metallic silo technology as relatively cheaper in the long-run. It was learned that working on hermetic principles, the metallic silo did not require pesticides because with time, most of the living organisms inside the silo would suffocate and die. This saved money on pesticides. In principle, storage of grain for food in the metallic silo eliminated the need for bags and served as another cost-saving measure. In addition, farmers perceived small metallic silo technology as long-lasting investment; this offered the benefit of exempting farmers from incurring huge sums of short-run variable costs which are common with traditional storage methods such as bags and bamboo woven granaries. It was also reported that, as a vertically erected structure, the small metallic silo did not take up much ground space compared to stacking of bags inside the house.

Farmers also perceived small metallic silo technology as environmentally friendly. In focus group discussions it was pointed out that using the metallic silos helped to preserve trees, bamboos and grass since the technology does not require intensive use of such forestry products. Thus, the metallic silo technology has potential to contribute to environmental conservation efforts. Nevertheless, the issue of cost remains highly contentious. Extension workers hinted that generally the price of the small metallic silo was prohibitive to an average smallholder farmer in Malawi; and indicated that farmers could not effectively demand and purchase the small metallic silos because they were perceived and found to be relatively more expensive than traditional storage structures. For instance, the cost of an average small metallic silo was US$364, while mean annual household income was US$180.

3.3. Determinants of adoption of small metallic silo technology

Table 4 presents the effects of the explanatory variables on farmers' decision to adopt small metallic silo technology. The probit model was estimated to identify the important factors that influenced adoption of small metallic silos by farmers in Malawi. Overall, the model was statistically significant at 1% level, an indication that the model passed goodness of fit test. The results show that under farmer characteristics, two variables (age and education) were significant determinants of adoption of small metallic silo technology by smallholder farmers. Under farm characteristics, farm size and extension were found to be major and significant determinants of the metallic silo technology adoption by farmers.

Age (AGE) was significant at 5% level with a positive sign, and had a probability of increasing adoption of small metallic silos by 3.56%. However, age squared (AGESQUARED), decreased the probability to adopt the silo technology ($p<0.05$) by a margin of 0.03%. This implies that after passing a certain age bracket, probability of adopting new agricultural technologies by farmers tends to decline. This indicates that older farmers are not motivated to adopt new technologies; they become more risk averse and therefore, prone to resist change of the status quo in farming activities.

Formal education (EDUCATION) of household head also had a consistently positive relationship to adoption of small metallic silo technology. The effect was stronger for higher levels of education. Thus, education is a strong determinant of adoption of small metallic silo technology in Malawi and was highly significant at 1% level. The positive sign meant that higher levels of education increased the probability of adoption of small metallic silos by farmers. A unit increase in the level of education increased probability of technology adoption by 4.02%. Completing at least 6 years of schooling indicates being in the higher primary school. This finding is consistent with Uaiene, et al. (2009, p.18) who studied determinants of agricultural technology adoption in Mozambique and found that "completion of at least lower primary school implies a much higher propensity to adopt new technology than lower or zero levels of education".

Farm size (FARMSIZE) was significant at 5% level. Increasing the size of farmland for grain production improved the probability of adopting the small metallic silo technology by 15.4%. Farm size was a proxy for quantity of grain production especially with regards to smallholder farming where use of high productivity inputs such as fertilizer is constrained by its prohibitive cost. This finding implies that in the absence of improved land productivity, smallholder farmers with large pieces of farmland have increased chance to produce large quantities of grain; therefore, they have higher probability to adopt the small metallic silos. This result is consistent with the findings of Bocquého, et al. (2011) on *miscanthus* adoption in France, and Barungi et al. (2013) on adoption of tree planting as soil conservation control technology in Uganda. Thus, embedding small metallic silo programme with land productivity programmes would likely improve adoption of the grain storage technology.

As expected, extension (EXTENSION) had a positive effect on farmers' decision to adopt small metallic silo technology. Significant at 1% level, extension was the most influential factor determining adoption of the metallic silo. The probability of adopting small metallic silo technology was 44.5% higher for smallholder farmers with access to agricultural extension services than those without extension contact. Barungi et al. (2013) found that the probability of adopting Napier grass in Uganda was 25.6% higher for farmers with access to extension services than for those without access. Extension services create awareness and enable farmers to get information about improved technologies. Such information is crucial for decision making by farmers in the process of new technology adoption. Farmers must have access to information about improved technologies before they can consider adopting them (Doss, 2003).

Table 4. Probit model results showing coefficients and marginal effects

Variables	Coefficient	P-Value	Marginal Effects	P-value
AGE	0.0901** (0.0426)	0.034	0.0356 (0.0168)**	0.034
AGESQUARED	-0.0008** (0.0004)	0.035	-0.0003** (0.0001)	0.034
GENDER	0.3184 (0.2818)	0.258	0.125 (0.109)	0.252
MARITALSTATUS	-0.4267 (0.9236)	0.644	-0.164 (0.363)	0.652
EDUCATION	0.1017*** (0.0379)	0.007	0.0402*** (0.0149)	0.007
HOUSEHOLD SIZE	-0.0914 (0.0614)	0.137	-0.0360 (0.0242)	0.137
OCCUPATION	0.5326 (0.8648)	0.538	0.198 (0.310)	0.523
FARM SIZE	0.3903 ** (0.1882)	0.038	0.154** (0.0740)	0.037
EXTENSION	1.1885*** (0.2509)	0.000	0.445*** (0.0832)	0.000
INCOME	-2.1991 (3.2783)	0.502	-0.183 (0.261)	0.484
Constant	-0.1652 (5.0541)	0.974		
Number of observations	133			
Wald $\chi^2(10)$	37.33***			
Prob>χ^2	0.0000			
Loglikelihood	-69.7263			
Pseudo R^2	0.2384			

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

4. Conclusion

Postharvest damage and loss of staple grains are a common problem in Malawi which undermines household food security. To reinforce the economic importance of postharvest grain management in Malawi, FAO in corroboration with Ministry of Agriculture and Food Security implemented the "Artisanal Manufacturing of Small Metallic Silos Project" which was launched in 2007, to reduce farm level postharvest losses through adoption of small metallic silo technology. This study examined farmers' perception of small metallic silo and the underlying determinants of adoption of the postharvest grain storage technology by smallholder farmers in Malawi.

The findings revealed that farmers perceived and acknowledged that small metallic silo technology was more effective in reducing postharvest grain losses and more secure than other grain storage methods. It has also been adequately shown that farmers perceived the silo's high purchase price as the major limiting factor to the adoption of the technology. Due to low income levels, high purchase price of the metallic silo proved to be the most important deterrent to the silo technology adoption. Key determinants of adoption of small metallic silo technology included age, education, farm size and access to agricultural extension services. Farm size, education and extension positively influenced adoption of the metallic silo technology in Malawi. Education and extension were however, the most critical determinants of adoption of the metallic silo technology.

With large household sizes whose farming heavily relies on sharing of the available land under customary land tenure, it would be a daunting task to expand farm size in Malawi's smallholder agriculture set-up. Improving productivity of the available farmland currently used by smallholder farmers would therefore increase farm level production and possibly enhance adoption of the small metallic silo technology. The study further asserts that increased extension training, awareness and demonstrations to enhance technical knowhow in all stakeholders in the silo programme with emphasis on extension workers, silo artisans and farmers would also likely lead to improved adoption of the metallic silo technology. In the long-run, increased adoption of small metallic silo technology in Malawi hinges on combining education, extension and improving farm productivity, with effective information dissemination and communication.

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