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Strengthening storage, credit, and food security linkages

The role and potential impact of warehouse receipt systems in Malawi

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ABSTRACT

This study considers the extent to which smallholder farmers, including those who do not necessarily produce a surplus for the market, might benefit from participating in warehouse receipt systems (WRS) in terms of improved income and food security. We consider three potential channels: efficient food markets; reduced post-harvest losses; and access to credit. Firstly, we find that WRS, through its potential to increase demand for storage and facilitate temporal arbitrage, could address high price seasonality driven by high transport margins and thin commodity markets. By lowering price seasonality, WRS would benefit net-consuming households that tend to sell low and buy high. However, since temporal arbitrage transactions are associated with costs and price risks, engaging in them becomes undesirable if prices do not follow predictable seasonal patterns. Prices tend to be less predictable in countries such as Malawi where government market intervention is highly discretionary. This hinders the development of a well-functioning WRS. Secondly, as WRS guarantees the quantity and quality of the commodity stored, such systems could improve food security in Malawi by reducing post-harvest losses. Storage-related maize losses are currently thought to be between 5 and 10 percent in Malawi. The combined benefit of reduced storage losses and higher expected future prices provides an opportunity for smallholder farmers to benefit from temporal arbitrage. The extent of post-harvest losses under home storage and the distance to the WRS storage facility are important determinants of whether home storage is more cost-effective than WRS. Thirdly, the use of WRS-stored commodity as collateral for accessing formal credit could enable households to obtain cash for immediate needs, while better timing their commodity sales and avoiding having to use the grain market as a lender of last resort when prices are low, particularly shortly after harvest. Currently only around two percent of farm households in Malawi have access to formal credit, suggesting considerable potential for WRS as a market mechanism for credit access. The study concludes by considering factors that discourage farmers from participating in WRS. These include high minimum commodity deposit quantities; high transport costs; lack of trust in and difficulties understanding WRS; and problems in accessing WRS credit.

1. INTRODUCTION

Warehouse receipt systems (WRS) are a relatively new commercial instrument in Malawi that offers owners of agricultural commodities, such as maize, groundnut, and soyabean, certified storage as an alternative to traditional storage options. Before being accepted for storage in a WRS facility, the commodity must undergo inspection to verify that it complies with set quality standards. Once accepted, a detailed contractual document, known as a warehouse receipt, is drawn up. The warehouse receipt guarantees the depositor a specified grade, quantity, and security of the stored agricultural commodity. The issued warehouse receipt may then either be used by the depositor as collateral for accessing loans, traded, or used for delivery against financial instruments, such as forward contracts. The depositor pays once-off handling fees and time-dependent storage costs, as well as interest, if the credit facility is utilized (ACE 2012). Through providing commodity market access to buyers and sellers, WRS can facilitate trade and enhance overall market efficiency to the benefit of the broader public.

WRS can also bring about private gains to smallholder farmers or traders that make use of storage and credit facilities. Firstly, since WRS storage facilities are accredited and professionally managed, the depositor is guaranteed zero storage losses due to pests and theft. The value of this benefit can be measured in terms of the expected storage losses a farmer or trader faces under alternative private storage options. Secondly, WRS can facilitate access to formal credit with WRS-stored commodities serving as collateral. Traders may use this credit to invest in additional stock, while smallholder farmers can use credit to settle household expenses or operational costs without having to sell their commodity when prices are low, particularly shortly after harvest.

Seasonality of prices lies at the heart of demand for storage. In countries with a single harvest season and a limited number of staple crops—Malawi being a prime example—a considerable degree of seasonality can be expected. Prices of staple grains are typically low shortly after harvest and rise progressively throughout the selling season. In the case of traders—those that buy and sell commodities—WRS offers an opportunity to engage in so-called temporal arbitrage, a trading practice whereby goods are stored from one time period to a later period when the expected price will be sufficiently higher to cover the cost of storage, a normal profit margin, and a risk premium. As storage capacity increases, storage risks decline, or access to credit improves, more people may hold stock during periods of low prices with the intention of releasing stocks during periods of high prices, thus essentially smoothing commodity supply over time. In a normal functioning market, the opportunities to benefit from temporal arbitrage transactions will therefore eventually become fewer until a breakeven point is reached. As Brennan (1958, 50) explains, “[i]t is a familiar proposition that the amount of a commodity held in storage is determined by the equality of the marginal cost of storage and the temporal price spread.”

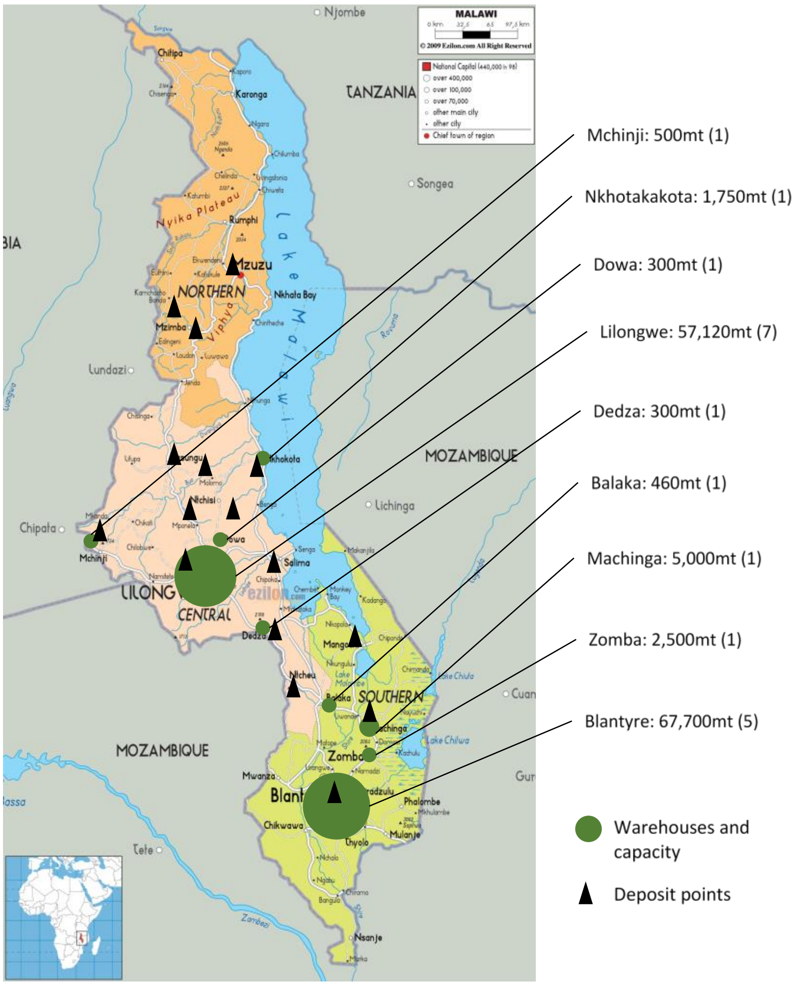
Seasonal price patterns are not necessarily always stable and clear. External factors may exert upward or downward pressure on prices in an ad hoc or stochastic manner such that prices are less predictable. A high degree of unpredictability may act as a deterrent to storing commodities, since it would require a high risk-premium to be built into the temporal price spread equation. In summary, in well-functioning markets with fairly predictable prices, grain traders may demand storage combined with a credit facility, such as is offered by WRS. Increased use of storage may have the potential to reduce seasonality of food prices, which may improve food security, particularly among net consumers (defined as those that consume more of a commodity than they produce in a year). However, of particular interest in this study is whether smallholder farmers, including those that engage in limited or no market activity can benefit from WRS. To assess this, it is necessary to look beyond the traditional rationale for storing goods and consider the overall benefits and costs to smallholders using WRS compared to alternative or traditional storage methods at home or within a village or community.

In light of these research questions, this paper considers several aspects broadly related to commodity storage, credit, and food security. We start by providing descriptive details about WRS in Malawi. We then present findings from a literature review, which is complemented by quantitative analysis and qualitative data from various key informant interviews and focus group discussions. Specific issues covered include smallholder maize production and marketing trends in Malawi, including an analysis of price trends and selling behavior of different types of farm households; home storage options available and smallholder choices in this regard, as well as post-harvest losses; access to formal credit and collateral; and barriers to accessing WRS.

2. WAREHOUSE RECEIPT SYSTEMS IN MALAWI

In Malawi, the two providers of WRS services are the Agricultural Commodity Exchange for Africa (ACE) and Auction Holdings Limited Commodities Exchange (AHCX). ACE is a non-profit commodity exchange platform that links farmers to markets through four complementary services: market information collection and dissemination; trade facilitation; warehouse receipt system; and forward contracts. ACE has developed a fairly extensive network of warehouses and deposit centers (Figure 1). There are currently 19 ACE-certified warehouses in Lilongwe, Blantyre, Dowa, Balaka, Dedza, and Zomba districts. Twelve of these are located in the urban centers of Lilongwe and Blantyre. These urban warehouses account for the bulk of ACE's overall storage capacity. ACE also operates 15 deposit points in Mchinji, Kasungu, Ntchisi, Lilongwe, Dedza, Salima, Nkhotakota, Mzuzu, Mzimba, Ntcheu, Dowa, and Mangochi districts. The deposit points function as aggregator centers from which commodities are collected and transported to the warehouses for storage.

Figure 1—ACE warehouse and deposit point locations



Source: ACE (2014)

AHCX is a for-profit exchange where buyers and sellers can trade commodities via grading and certification, electronic warehouse receipts, trading floor operations, clearing and settlement, and market information dissemination. Maize, soyabean, groundnut, cowpea, pigeonpea, and rice can be deposited under AHCX.

Although the WRS services provided by the two institutions are not identical, they share the following core steps: (1) deposit is made at a certified warehouse or deposit point; (2) grading and certification of the deposit; (3) issuance of the warehouse receipt; (4) potential financing using the warehouse receipt as collateral; (5) depositor follows market prices; (6) withdrawal or trading of commodity; and (7) collection or transfer of ownership.

Once deposits are brought to the warehouse or deposit point, ACE provides the farmers with a delivery note. This note cannot be used for collateral. The two WRS providers require farmers to be ultimately financially responsible for transporting the commodity to the warehouse. ACE provides transport to their warehouses from various deposit points, but deducts transport costs from the final sale or withdrawal of the commodity. At the warehouse, the deposit is sampled and graded by warehouse operators or by an independent third party, as in the case of AHCX. Both providers have provisions for cases where the deposit is rejected if it does not meet their requirements, e.g., the moisture content of the deposit may be too high. However, such rejections are not formally documented and are usually communicated orally.

If the commodity is accepted, the service providers issue a warehouse receipt to the depositor. The costs associated with bagging, sampling and grading, and storing the deposit are assessed by the warehouse operators. Storage and management of the commodity comprises security, insurance, pest control and fumigation, utilities, and weekly monitoring of the moisture content. AHCX offers a subsidized storage fee of MK30 per ton per day, which breaks even with the cost of property rent. Costs of security, insurance, utilities, and fumigation result in an additional MK20 to MK35 per ton per day for farmers, but ACHX does not charge the full amount in an attempt to attract more depositors. ACE has a variable maintenance charge of about MK31 per ton per day. In addition, one percent of the deposit's weight is deducted from the overall quantity of the deposit to account for moisture loss while in storage. If the WRS operator facilitates the sale of the commodity, a sales commission is also deducted from the proceeds received by the depositor; ACE, for example, charges a one percent sales commission.

Both services provide an electronic receipt with detailed information about the commodity and depositor. In particular, the WRS receipts of ACE, which can be accessed publicly online, include detailed information on the depositor, warehouse, commodity, storage cost, and audit trail. Changes made to the deposit, such as withdrawals, additional deposits, or changes of ownership, are shown in the audit trail. Similarly, AHCX provide receipts online which specify the ownership, volume, and quality of the commodity. However, in order to deposit commodities and access receipts online, AHCX requires that the user be a member of the AHCX, a cost which amounts to USD300 annually.

Depositors can choose to use the receipt as collateral for credit from banks that currently recognize the warehouse receipt of the service provider. Generally, loans of up to 70 percent of the value of the commodity can be obtained. ACE maintains overdraft facilities with several commercial banks and facilitates loans for depositors directly. ACHX, on the other hand, does not offer credit directly to its depositors, but their warehouse receipts are recognized by several banks.

The receipt may be put up for sale or used to withdraw the stored commodity at any time. It is the depositor's responsibility to check prices of their commodities and sell at a high enough price to cover the costs of storage and management. Both service providers facilitate farmers' decisions to sell their commodity by offering market price information on commodities on their websites and through local newspapers, radio stations, or mobile phone text messages.

Smallholder maize production and marketing in Malawi

Maize is the main staple food in Malawi. Data from the third Integrated Household Survey (IHS3) (NSO 2012), which was conducted in 2010/11 and captured crop production statistics from the 2008/09 and 2009/10 rainy seasons, suggest that approximately 2.6 million of Malawi's three million households (or 85 percent) engage in farming activities. Of these, 2.4 million households cultivate maize, among other crops. Maize is not only an important production crop; it also accounts for up to two-thirds of calories available to the average household (Verduzco-Gallo et al. 2014). Given the dominance of maize in household diets, household-level food security is often equated to household-level access to maize, while national-level food security is equated to national maize self-sufficiency (GoM 2012). The country's major agricultural policy intervention since 2005/06, the Farm Input Subsidy Programme (FISP), therefore has also focused predominantly on promoting maize production (see Pauw and Thurlow 2014 for a review of the FISP).

Official estimates suggest that maize yields have doubled since the introduction of FISP (MoAIWD 2014b), thus enabling the country to maintain a surplus of maize (Dorward and Chirwa 2014).[1] Despite maize being a widely cultivated

[1] Production estimates are based on the Agricultural Production Estimates Survey (APES) (MoAIWD 2014b). These are widely believed to be inflated or biased upward (Dorward and Chirwa 2014; Jayne et al. 2009). Following Dorward and Chirwa's (2014) approach, in our analysis here we scale back production estimates by 10 percent.

crop, production tends to be concentrated within Malawi's Central region, which over the past six cropping seasons has accounted for an average of 55.7 percent of national production (Table 1). The Southern region contributed 30.6 percent, despite being more populous and having more maize-growing households, while the Northern region contributed 13.7 percent. A comparison of regional production and consumption levels shows that the Central region produces a surplus of close to 500,000 metric tons per annum, with Lilongwe and Kasungu Agricultural Development Divisions (ADD) being the two major surplus-producing ADDs.[2] At the national level, a surplus of around 177,000 metric tons of maize is produced annually—roughly five percent of national production.

In per capita production terms, the Central region also stands out as an important surplus region. The average farmer in the Central region produces around 1,400 kilograms of maize, compared to maize demand of around 1,250 kilogram for the average household in Malawi. In neither of the other two regions of Malawi does the average farming household produce a surplus. Larger producers are more likely to actively engage in marketing or selling of produce. The final column shows the distribution of "large" maize producers, defined here for simplicity as those producing more than three metric tons of maize per annum. In both the Southern and Northern regions, fewer than 10,000 smallholder farming households achieve this level of production (this excludes estate farms), whereas in Kasungu and Lilongwe ADDs combined there are about 100,000 such large farmers.

Table 1—Maize production estimates for Malawi

Region, Agricultural Development Division (ADD)	Agricultural Production Estimates Survey (APES) average for 2008/09 to 2013/14 cropping seasons			Third Integrated Household Survey (IHS3) average for 2008/09 and 2009/10 cropping seasons		
	Production (metric tons per year)	Share of national production (%)	Estimated surplus or deficit (metric tons per year)	Average production per maize farmer (kg per year)	No. of maize farmers	Number of large maize farmers (production > 3,000kg per year)
North	**451,944**	**13.7**	**30,027**	**777**	**307,711**	**8,945**
Karonga	135,812	4.1	39,424	629	88,330	964
Mzuzu	316,132	9.6	(9,397)	836	219,381	7,981
Central	**1,830,134**	**55.7**	**488,955**	**1,400**	**1,059,936**	**104,352**
Kasungu	890,615	27.1	396,347	1,966	386,293	61,637
Salima	141,572	4.3	(20,063)	899	120,777	5,270
Lilongwe	797,946	24.3	112,671	1,114	552,866	37,445
South	**1,005,301**	**30.6**	**(341,687)**	**529**	**1,075,672**	**9,567**
Machinga	384,281	11.7	(118,646)	546	505,994	4,585
Blantyre	543,648	16.5	(151,824)	530	508,384	4,131
Shire Valley	77,372	2.4	(71,217)	384	61,294	851
National	**3,287,378**	**100.0**	**177,295**	**938**	**2,443,319**	**122,864**

Source: Authors' calculations based on MoAIWD (2014b) and IHS3 (NSO 2012)

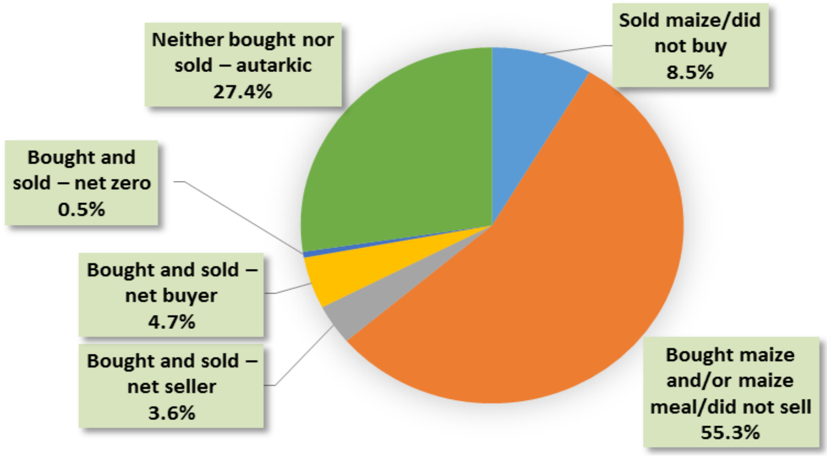
Statistics of this nature can inform decision-making of a commodity exchange such as ACE or AHCX, particularly as far as infrastructure expansion is concerned. As shown in Figure 1, the majority of ACE collection points, which are managed mainly by partner institutions, are located in the Central region where the larger maize farmers are located. Lilongwe district is home to seven of the 19 warehouses and about 42 percent of its domestic storage capacity managed by ACE. Storage could help facilitate trade in areas where there is a maize production deficit and where most households (including maize producers) are net-buyers of maize. With the Southern region being a major deficit region, it therefore also makes sense to have sufficient storage capacity there, although the maize typically would have to be transported to these storage facilities from the Central region.

Markets are said to be thin when there are very few buyers or sellers, or when the percentage of product volume traded in that particular market is low compared to the total product volume available for trade. With only a five percent production surplus (Table 1) and relatively few farmers producing surplus maize that is marketed, the Malawian maize market can be described as thin. Jayne et al. (2010) use data from 2006/07 to 2008/09 cropping seasons to study Malawian households' engagement in the maize commodity market. They find that, on average over the years analyzed, just over one-quarter (27.4 percent) of maize farmers neither bought nor sold maize, i.e., they are completely autarkic (Figure 2). A further 55.3 percent of maize farmers bought maize but did not sell any maize. These households are

[2] The surplus (deficit) in the third column is estimated on the basis of reported maize consumption data in the IHS3. According to this data, the median adult in Malawi consumes about 260 kilograms of maize per year (children consume less as a result of their lower caloric needs). The maize requirement per district is then estimated on the basis of population census data on adult equivalent population size. This approach is slightly different from that of Dorward and Chirwa (2014) in which the annual maize requirement is set at 193 kilogram per person, based on caloric needs, as opposed to actual consumption demand.

generally the poorest, have relatively small farm sizes and asset holdings, and their welfare levels deteriorate when maize prices rise throughout the season (Jayne et al. 2010).

Figure 2—Maize farmers' engagement in maize market transactions



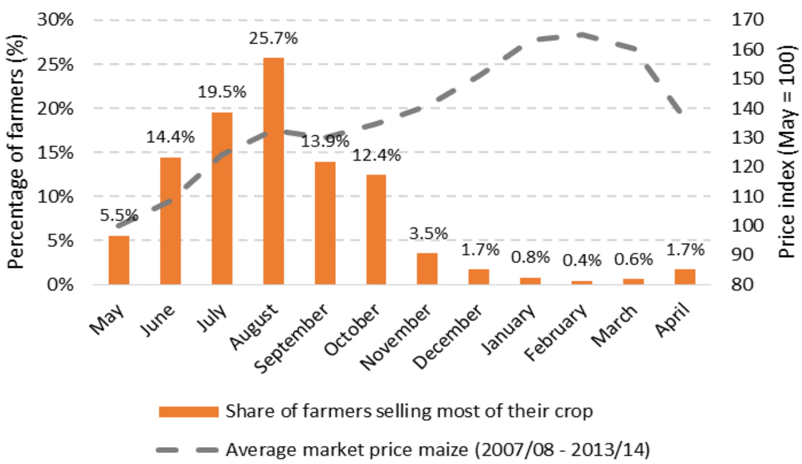
Source: Authors' calculations based on Jayne et al.'s (2010) estimates for 2006/07 to 2008/09.

Only about one-in-six households sell at least some of their maize. Half of this group consists of smallholder farmers that are outright sellers, while the other half engage in both maize buying and selling. The outright sellers—about 8.5 percent of households—can typically be divided into two subgroups: a small group of commercialized farmers with relatively large landholdings (4 to 10 hectares); and a large group of smaller farmers who sell small amounts of maize. Jayne et al. (2010) find that many of these farmers sell part of their maize immediately after harvest in April or May to access much-needed cash, whereas the better off farmers are able to hold onto their stocks and sell in October or November at higher prices, but still in time to finance the purchasing of farm inputs for the following cropping season.

Those classified as both buyers and sellers of maize—about 8.9 percent of households—can also be disaggregated into several subgroups: approximately 4.7 percent are net buyers, i.e., they consume more than they produce; 3.6 percent are net sellers; and 0.5 percent buy and sell similar quantities of maize during the course of the year. Some of the households in these three categories sell maize grain and buy processed flour. Others are maize traders who also grow their own maize. However, the majority are relatively poor households that are thought to engage in distress sales of grain after harvest to relieve cash constraints (Jayne et al. 2010). These households are often forced to buy back maize grain later in the year, often at higher prices.

More recent data from 2010/11 (IHS3) suggests that the Malawian maize market remains very thin, with only about one-in-six farmers reportedly selling some or all of their maize crop. Maize sellers in the IHS3 sample were asked in which month they sell the bulk of their maize. Figure 3 reports on the timing of these sales. In the months immediately following the harvest (May to August) around two-thirds of households (the cumulative percentage of the first four bars in the chart) sell most of their crop. Overlaid on this graph is the average real maize price trajectory during the past eight seasons. It is evident that farmers tend to sell maize when prices are still heavily suppressed, thus confirming the finding of Jayne et al. (2010). Those that are able to hold onto stocks until February or March are likely to realize better sale prices. We discuss maize price trends and volatility in more detail in the following section.

Figure 3—Timing of crop sales by farmers in Malawi, 2010/11 selling season



Source: Integrated Household Survey 2010/11 (IHS3) (NSO 2012)

To summarize, despite maize being cultivated widely, production is highly concentrated in Malawi's Central region, while the Southern region tends to have a large deficit every year. Only a small percentage of farmers—around five percent—produce more than three metric tons of maize per annum. The vast majority of these "large" farmers are located in the Central region. The result is that very few farmers—about one-in-six— participate in the market as sellers, while only half of those are outright sellers (i.e., they sell but do not buy any maize). The maize market is therefore extremely thin from the supply side, which is often an important contributing factor to price volatility. By contrast, over half of Malawian maize producers are outright buyers of maize. Many of these households tend to buy maize towards the latter end of the marketing season when prices are high. This gives rise to a somewhat counterintuitive conclusion that rural poor farmers in Malawi are adversely affected by food price spikes (Jayne 2012).

Increased storage capacity and utilization thereof through WRS could help facilitate trade from surplus to deficit region, allow households to avoid buy-low-sell-high practices, and reduce price volatility in the market through moderating supply and demand during critical periods of the season. All of these effects should improve food security outcomes. However, a major challenge lies on the supply side of the market. While large-scale farmers could become WRS clients directly, their numbers and hence contribution to national production are limited. Large volumes of maize therefore need to come from smallholder farmers if WRS is to have a meaningful and positive impact on the society at large. Even though many smallholder farmers are unlikely to become direct WRS clients given minimum deposit requirements, they could either store collectively through cooperatives, or could sell to traders who would aggregate and then deposit the grain in a WRS warehouse.

Unfortunately, the present market environment in Malawi is such that few incentives are created for farmers to produce surpluses. A study by Fafchamps (1992) sheds interesting light on this issue. He finds that, despite the existence of rural markets and a general improvement in accessibility to these markets, large proportions of smallholder farmers still do not engage in market transactions as sellers. High transport costs and low productivity in developing countries, he argues, cause markets to be thin and isolated, which in turn explains why prices are volatile and highly correlated with farmers' own agricultural output. For farmers, the best way to protect against price risks is to be self-sufficient in staples as a first priority, and only thereafter allocate land to commercial products, such as surplus food crops or cash crops (Fafchamps 1992). A study in Malawi concurs that lack of confidence in markets leads smallholders to mainly plant low-value food staples, which in turn limits their ability to purchase inputs and adopt improved technologies (Alwang and Siegel 1992). This lack of confidence in markets arguably extends to the Malawian maize market as well. Prices are volatile and generally low—in part due to the subsidization of fertilizer and persistent export bans—and, hence, there is very little incentive to grow more maize than what is required for self-subsistent consumption by the family. Fafchamps (1992) concludes that lower transport costs and higher agricultural productivity will lead to better integrated rural markets, and eventually the rationale for food self-sufficiency will decrease. More farmers, including small farmers, will then allocate land to non-staples or cash crops, thus relying on markets for their staples. Policy should therefore be geared towards reducing transport costs, raising productivity, and establishing more vibrant markets with sufficient volumes and actors. Access to affordable credit or increased off-farm household income are elements in propelling this change in the primary rationale for smallholder crop production in Malawi, as both will allow subsistence farmers to alter their risk preferences.

Price volatility: seasonality versus unpredictability

The previous section raised the issue of price volatility and how unstable prices ultimately create a disincentive to farmers to commercialize their farming. In this section we explore price volatility in Malawi's maize market in more detail. It is well-established that stable prices contribute to economic growth and can be important from a food security point of view as well; hence, one of the goals of government policy should be to reduce price instability. However, as we show in this section, price stabilization efforts in Malawi seemingly have not contributed to price stability. Malawi is not unique in this regard: "*price stabilization* [policies in Africa] *has only occasionally contributed to price stability and in many cases has exacerbated it*" (Jayne 2012, 144).

Considering food markets, and staple food markets in particular, there are essentially two sources of price volatility: a *seasonal component* and an unanticipated or *unpredictable component*. Higher degrees of seasonality are often prevalent in markets characterized by a single harvest season. Seasonality, by nature, also tends to be fairly predictable since seasonal patterns are regular and repeated over time. Seasonal price spreads may increase as a result of market power along the value chain, high transaction or transport costs, and credit constraints among traders (Kaminski et al. 2014). Price seasonality creates the opportunity to engage in temporal arbitrage as long as price differentials are sufficient to compensate for storage and handling costs and the opportunity cost of capital. As more agents engage in temporal arbitrage transactions, seasonal price spreads will decline.

As the name suggests, the unpredictable component of price volatility is due to unexpected or unanticipated variations in prices. Adverse weather shocks, political unrest, unexpected shifts in government policy, and interventions in food markets by governments or international aid agencies are all possible sources of unpredictable price behavior. The contribution of the unpredictable component to overall price volatility can be estimated econometrically using a price prediction model (Chapoto and Jayne 2009; Kaminski et al. 2014). The premise is that economic agents take into account all available information at time *t*, including past prices and production, weather, exchange rates, interest rates, and government behavior, to predict the future price at time $t+1$. The difference between the actual price P_{t+1} and the expected price $E_t(P_{t+1})$ as predicted by the econometric model is known as the forecast error, e_{t+1}, which represents the unpredictable component.

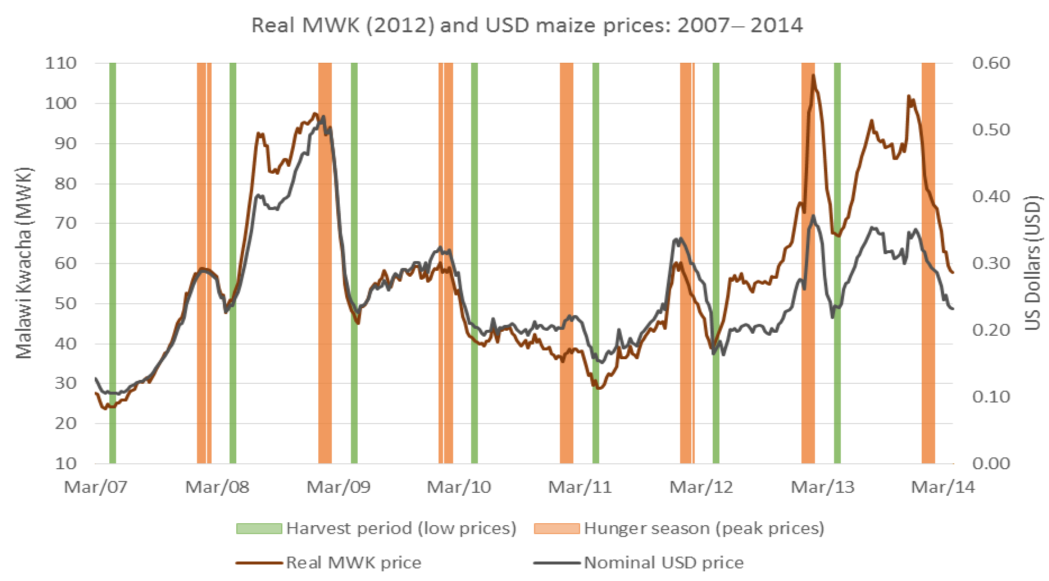
$$P_{t+1} - E_t(P_{t+1}) = e_{t+1}$$

The topic of seasonality was very prevalent in the literature on development economics during the 1990s. However, as developing country markets became more integrated and competitive, and road and storage infrastructure improved, there was the expectation that price seasonality would decline. As a result, the issue of price seasonality has largely disappeared from the development debate, a shift in policy focus Kaminski et al. (2014) believe was premature. These authors set out to measure the contribution of seasonality to overall price volatility in several countries, including Malawi, using a combination of econometric and trigonometric approaches to isolate year-specific seasonal price spreads. Using official government price data for the period 2000 to 2012, they find that seasonal movements in Malawian maize prices explain 40 percent of overall volatility.[3] The balance is due to unpredictable factors. By comparison, only about 20 percent of maize price volatility in Tanzania and Uganda, respectively, is explained by seasonal factors.

After controlling for the unpredictable component of price volatility, maize prices in Malawi are found to be about 50 percent higher at their peak compared to their troughs (Kaminski et al. 2014). By comparison, peak prices in Tanzania and Uganda are only about 30 percent above their troughs. The seasonal price spread for maize in Malawi is also about three times higher than the price spread for white maize on the South African Futures Exchange (SAFEX).

To illustrate the extent of seasonal price movements in Malawi, we conducted an analysis using data from the Agricultural Market Information System (AMIS) (see footnote 3) collected over the period 2007 to 2014. Figure 4 plots average national maize market prices, both in real terms (nominal prices are deflated by the official consumer price index) and US dollar terms. A few observations can be made. First, general price levels tend to fluctuate from one year to the next due production shocks or external factors. A pertinent example is the 2008/09 selling season when peak prices were unpredictably high.[4] This has been attributed to uncertainty in the market over maize supply, which fueled speculative behavior by traders (Dorward and Chirwa 2013). However, there is also significant price volatility within selling seasons, which is attributable, in part, to seasonal factors. As is evident from Figure 4, prices are relatively low at the onset of the harvest season around mid-May, then tend to rise steadily throughout the selling season. In most years, by mid-February, food stocks are low—this is known as the "hunger season"—and prices tend to be at their peak.

Figure 4—Real maize prices trends in Malawi, 2007 to 2014



Source: Authors' calculations based on Agricultural Market Information System (AMIS) data (MoAIWD 2014a).

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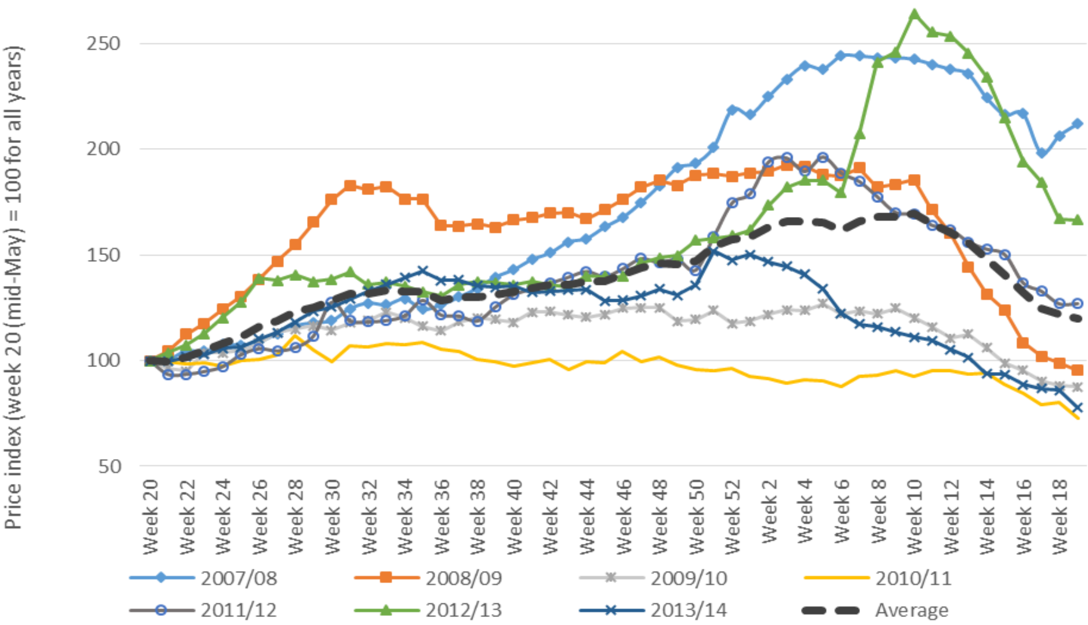
3 Retail market prices from the Agricultural Market Information System (AMIS), which are collected from around 72 rural and urban markets in Malawi by the Ministry of Agriculture, Irrigation and Water Development (MoAIWD).

4 The cropping season for maize starts with planting in late-November to December and harvest takes place between April and May of the following year. The selling season then commences from harvest (April/May) until the following year's harvest. Therefore, the 2013/14 cropping season (November 2013 to May 2014) will be associated with the 2014/15 selling season (May 2014 to April 2015).

There are two notable exceptions to the “normal” intra-seasonal price trends during the period 2007 to 2014. During the 2010/11 selling season, prices remained more or less constant in US Dollar terms and even declined marginally in Malawi Kwacha terms between the harvest and the hunger season, before dropping further at the onset of the May 2011 harvest season. This may have been a continuation of the market correcting itself after experiencing unexceptionally high prices in 2008/09. Another exceptional year was 2013/14 when prices peaked around December 2013 and started to decline through the traditional hunger season period. One possible explanation for this is the distribution of free maize during the presidential election campaign, which may have suppressed maize prices in the lead-up to the elections in May 2014.

In order to better analyze intra-seasonal price fluctuations, we remove inter-annual price levels by constructing a yearly index of real maize prices. Historically, prices have been lowest at or around weeks 19–21 of every year, and therefore we take week 20 (roughly mid-May) as our starting point by assigning a price index value of 100 for that week. Figure 5 plots the yearly prices indexes for 2007/08 to 2013/14 starting at week 20 in the year and ending in week 19 of the following year. It is evident in Figure 5 that prices, on average, are highest during weeks 5–10, which coincides with the hunger season in February.

Figure 5—Real maize price indexes, 2007/08 to 2013/14



Source: Authors’ calculations based on Agricultural Market Information System (AMIS) data (MoAIWD 2014a).

The heavy dashed line represents the average price over the years, and can be interpreted as an expected price given information on historical price movements. Real maize prices can thus be expected to be about 69.3 percent higher during the hunger season (week 10) compared to the preceding harvest season. This estimate is somewhat higher than the 50 percent price spread estimated by Kaminski et al. (2014) who control for unpredictable price movements econometrically. Our analysis is also conducted for a different period (2007–2014) than that analyzed by Kaminski et al. (2014), a period which has been characterized by increased price volatility relative to the period prior to the implementation of the Farm Input Subsidy Program (FISP) (Dorward and Chirwa 2013).

Some degree of price seasonality is necessary to create demand for storage and help even out commodity supply through temporal arbitrage. This is especially true in a country like Malawi where nationally only a small surplus of staple food is produced on average. However, at the same time, severe seasonality may also have negative implications for food security, especially in Malawi where the majority of maize producers are outright buyers rather than sellers of maize. Kaminski et al. (2014) find that household food consumption in Malawi inversely tracks staple prices, which implies that price seasonality impedes households’ attempts at smoothing consumption over the year. The challenge is to find that degree of price seasonality that would encourage seasonal storage and ensure a reliable food supply throughout the selling season without adversely affecting household food security.

What is clear from Figure 4 is that even the normalized price trends vary significantly from one year to the next. As noted previously, 2010/11 stands out as a year in which real prices remained virtually unchanged or may have even declined. In the following year, 2011/12, the year in which ACE issued its first warehouse receipts, prices peaked early (January 2012) but remained about 70 percent above the harvest season price in February. The following year, 2012/13, was exceptional, with prices peaking at the expected time at 164 percent above the harvest season price. Several ACE

WRS clients made significant profits in this year. However, 2013/14 brought disappointment for some WRS clients when prices peaked early and dropped back close to harvest season prices towards the end of the hunger season.

This suggests that, in addition to a high seasonal price spread, there is also a large degree of uncertainty in the way prices move during the course of a year. As noted earlier, up to 60 percent of the overall price volatility in Malawian maize prices is due to unpredictable factors (Kaminski et al. 2014). This implies significant risks to those that demand storage with the objective of engaging in temporal arbitrage. Chapoto and Jayne (2009) conducted a cross-country analysis to better understand what might cause maize prices to be unpredictable in Eastern and Southern Africa. They group several case study countries into two groups. The first group includes countries such as Uganda, South Africa, and Mozambique that have adopted comprehensive staple food market liberalization. Government intervention in staple food markets in these countries is generally limited to regulation, investment in infrastructure, encouragement of crop diversification, and improvement of financial markets. The second group includes countries such as Zambia, Ethiopia, Tanzania, and Malawi where liberalization has been more partial. Governments continue to engage actively in food markets through marketing board activities and discretionary trade policy tools, such as export bans. Governments also directly intervene in external trade or domestic stock releases.

Although interventionist policies in developing countries are ostensibly designed to reduce food price volatility with the intention to protect vulnerable consumers, Chapoto and Jayne (2009) find that these interventions may actually have the opposite effect. Zambia and Malawi, for example, have the highest degree of price unpredictability among the countries studied. This, they argue, is attributed to the fact that that policy interventions are highly discretionary or *ad hoc*, to the extent that they actually have a destabilizing effect on prices (Box 1). Those markets that function more freely, such as South Africa, reveal the most consistent and regular seasonal price patterns where prices are low after harvest and rise gradually over the selling season.

Box 1—Government intervention in the Malawian maize market

The government of Malawi intervenes in the maize market using several tools intended to enhance food security. It subsidizes farm inputs (FISP); announces statutory minimum farm gate prices for key agricultural commodities, including maize; and has banned the export of maize for the past several years. While each of these policies arguably distort the maize market, they are for the most part implemented consistently year to year, meaning that farmers, traders, and processors can plan accordingly. One type of intervention that has been implemented in a more discretionary manner is large, direct purchases of maize by Malawi's National Food Reserve Agency (NFRA) to replenish stocks in its Strategic Grain Reserve (SGR). The NFRA manages storage facilities and has a mandate to improve national food security. In 2013, NFRA received donor funding to purchase 30,000 metric tons of maize, about 0.8 percent of estimated production. Contracts were awarded at a price approximately 23 percent above the prevailing market prices at the time. Procurement started in June shortly after harvest and continued through September 2013. The Agriculture Development and Marketing Corporation (ADMARC), a parastatal agricultural marketing entity, reportedly purchased another 9,000 metric tons for the SGR at an even higher price during the same time period (Moyo and Phiri 2013). At the time of writing, NFRA is in the process of procuring 50,000 metric tons for its 2014/15 intervention. This is equivalent to around 1.2 percent of estimated production, while the price offered is 30 percent above market. In this instance, procurement only started in November 2014, four months later in the marketing season than in 2013. The inconsistent timing, scope and contractual terms linked to maize procurement for the SGR illustrate the highly discretionary nature of government intervention in the maize market, which contributes to maize price unpredictability in Malawi.

Note: Estimates of production shares and contractual price premiums are based on authors' calculations using AMIS (MoAIWD 2014a) and APES (MoAIWD 2014b) data.

Based on the above and other analyses, Jayne (2012) spells out three possible policy options for governments as far as food market interventions are concerned. The first is for the state's role to be confined to promoting efficient market functioning. This can be achieved through developing market rules and regulations, investing in physical infrastructure, providing regulatory oversight and market information, and providing extension services. Price instability can be reduced through the promotion of institutions such as commodity exchanges or the use of forward contracting and futures markets. This option is in the spirit of the Washington Consensus, which is now generally out of favor (Jayne 2012). The second option entails a rules-based approach whereby government relies on markets for most of the direct marketing functions, but it may involve itself in direct marketing operations (e.g., importation of food, management of food reserves or stock releases) following a set of strict rules or pre-commitments that are publicized and non-discretionary. In essence the rules provide government with a mandate to intervene as soon as markets are unable to contain prices within predetermined bounds (Jayne 2012).

The third option provides absolute discretion to the state to intervene in food markets without consideration for any rules. Jayne (2012) believes that most governments in eastern and southern Africa essentially follow this option, which has contributed to highly unpredictable trade policy environments, market uncertainty, and unstable prices. Attempts in sub-Saharan Africa to develop grain commodity exchanges and risk-shifting hedge markets in such environments "*have almost always failed*" (Jayne 2012, 147) owing partly to the fact that markets are often too small for commodity exchanges to operate effectively, often because of parastatal marketing board activities. Price unpredictability also implies high risks for some actors and unfair advantages for others who have information to anticipate state interventions. Thus, although seemingly undesirable from an economic point of view, developing country governments appear to have opted for this approach, presumably because of the political importance of being able to control staple food markets.

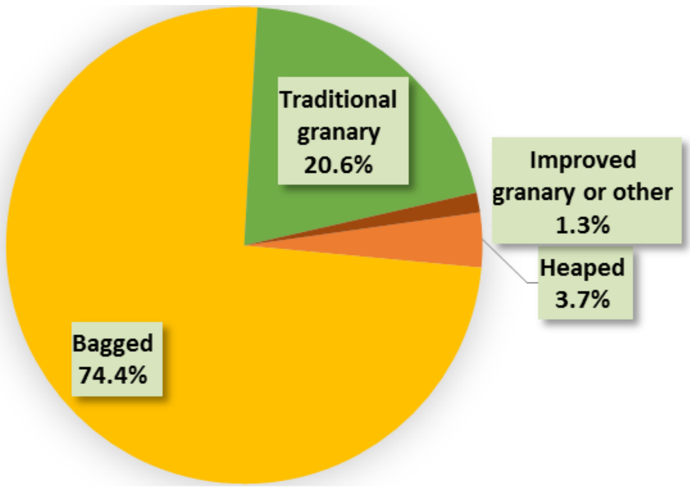
Achieving price stability in underdeveloped and thin staple food markets in developing countries involves a complex set of policy decisions and carefully planned interventions to reduce price seasonality and price unpredictability in the interest of improved food security without alienating those seeking to profit from temporal arbitrage opportunities or creating disincentives to produce for the market. Ideally, interventions should follow strict pre-existing rules and be non-discretionary so as to minimize their effect on price unpredictability. Most important, however, is for government to focus on developing market rules and regulations, investing in physical infrastructure, and providing regulatory oversight and market information. These present the most sustainable long-term solutions to enhancing market efficiency as they will serve to instill confidence among consumers and suppliers that markets will behave predictably so that they can optimize their own behavior with the objective of maximizing utility or profits.

Storage options and post-harvest losses

There are several methods and technologies available for storing food. Some of these are relatively basic while others are more sophisticated requiring specialized knowledge, aggregation, and scale to be practical and profitable (Kitinoja and Kader 2003). In general, the appropriate storage methods will vary by food product, since perishability of the food and its physical properties largely determine the most effective way of storing it. Also, the appropriate storage method may vary by the characteristics of the farmers or traders storing the commodity (e.g. education, experience, and risk preference), as well as economic factors such as storage costs, storage assets owned, and income available for paying for storage services, if they are available. Geographic and infrastructural factors such as distance to the nearest storage facility may also influence the storage methods chosen by farmers and traders.

In some cases, crops can be stored prior to harvest, i.e., in the field. Thus farmers may delay harvest as a storage mechanism, though this may at times come at a cost such as loss of weight or quality of the farm product. In Malawi, crops that are most commonly stored in the field prior to harvest include roots and tubers (e.g. sweet potatoes, cassava, and potatoes) and groundnut, all of which can be stored underground. Grains and other pulses can also be stored pre-harvest if the final product is to be sold or consumed after losing moisture content (e.g. dried maize, rice, wheat and other small grains). While pre-harvest storage is an option for farmers, there is a limit to the duration of this storage method. It generally is shorter than postharvest storage methods.

Figure 6—Storage choice among smallholder farmers



Source: Integrated Household Survey 2010/11 (IHS3) (NSO 2012)

Our interest here is in the variety of post-harvest storage technologies available to farmers and traders and associated post-harvest losses. Storage choices also depend on the nature of the commodity to be stored and the physical and institutional infrastructure that the farmers and traders or brokers have access to. Figure 6 shows the storage choices exercised by maize farmers in Malawi based on the IHS3 data from 2010/11. Only about half of maize producers in the survey sample completed the questions on storage. 20.6 percent of respondents store maize in a traditional granary (*nkhokwe*) outside the house, usually constructed with a combination wooden poles, bamboo or reeds, and mud. 3.7 percent heap the maize, usually inside the house, sometimes covered with a tarpaulin. By far the most common form of storage (74.4 percent) is to bag maize and store it in the house or in a grain storeroom. This choice of storage over the traditional or improved granary is necessitated by the high incidence of theft from external storage facilities in Malawi

(World Bank 2011). Finally, storage in improved facilities, such as corrugated iron granaries, makes up only about 1.3 percent of all storage options. In theory, this would include storage at a third-party storage provider. However, since the survey was conducted prior to the launch of the ACE WRS, the data does not provide any information in this regard.

Among those households reporting to have stored maize, virtually all (99 percent) explained that their main motivation for storing was to ensure a food supply for the household. Only one percent of households reported that they stored with the intention of selling later at a higher price or that they were saving seed for planting in the next cropping season. No household reported choosing a storage method with the intention of preventing post-harvest losses. When considered in combination with the timing of sales (Figure 3), the majority of Malawian smallholder farmers have a food self-sufficiency motivation for storage and are not inclined to think about storage from a temporal arbitrage perspective. It would appear that farmers are pressed to sell as early as possible due to cash requirements, despite the fact that prices might not be as favourable. Changing farmers' mind sets may prove to be a great challenge to WRS operators as they attempt to promote adoption of the WRS among farmers.

LOSSES OF GRAIN IN STORAGE

In addition to offering the potential to sell at a higher price in the future, WRS proponents hold that reduced post-harvest storage losses are an important advantage of their system. We now consider the evidence on post-harvest losses associated with home storage options. Thereafter we examine the implied costs of home storage compared against the cost of storing in a WRS accredited facility.

Evidence on post-harvest losses (PHL) in sub-Saharan Africa is somewhat weak due to differences in calculation methods and assumptions, as well as the sensitivity of PHL estimates to the data used. The African Postharvest Losses Information System (APHLIS) is the custodian of what is perhaps the most comprehensive depository of PHL estimates for sub-Saharan Africa. The APHLIS country narrative for Malawi describes the country's climate as humid sub-tropical in the centre and north and tropical savannah in the south, which explains slight regional differences in PHL estimates reported (APHLIS 2014).

The APHLIS method considers a variety of factors when estimating PHL, including:

- The prevailing weather conditions at the time of harvesting: Malawi is dry during the main harvest period, which means crop losses due to mold are not prevalent.
- The proportion of maize that is marketed within the first three months: marketed maize is unlikely to enter farm storage. Farmers that sell their crop early means that a smaller quantity is lost due to PHL compared to those that sell later.
- The length of the farm storage period: the standard for reporting crop losses associated with farm storage is for storage periods of 7–12 months; for storage of 6 months or less, the loss can be halved.
- The presence of pests, such as the Larger Grain Borer: infestations of this grain storage pest occur frequently in Malawi, causing significant damage to crops in storage.

Storage losses are calculated and reported separately and cumulatively across several stages in the postharvest chain. Estimates for Malawi for 2012 are shown in Table 2. Note that with the exception all the final row, the entries in the table show the share of grain that enters a particular stage in the post-harvest chain that is lost rather than shares of production. Relative losses during harvesting and field drying, as well as farm storage, are the most significant contributors to overall losses. During farm storage alone, around 9.4 percent of stored maize is lost.[5] This estimate assumes grain is stored for 7–12 months. For storage periods of 6 months or less, the loss estimate is typically halved (loss estimates for shorter storage periods are shown in brackets). The APHLIS data for Malawi suggests that the average length of storage among smallholder farmers is 6 to 6½ months. This is understandable considering that harvesting and field drying takes several weeks, and further drying at home may take up to three months before the maize is shelled and stored. At the aggregate, maize losses are approximately 20.3 percent of annual production (or 17.4 percent if maize is stored for 6 months or less). These estimates are at the upper end of the APHLIS range of average grain losses in storage for sub-Saharan Africa of between 10 and 23 percent (APHLIS 2014)

[5] The APHLIS reports losses by region given climatic differences. The estimate shown in this table is the average of the loss factor in the north/center (9.1 percent) and the south (10.4 percent) of Malawi, weighted by the share of grain produced (75.2 percent of maize grain is produced in the north/center).

Table 2—Stages in post-harvest chain and associated storage losses for Malawian smallholder farmers, 2012

	PHL profile (%)	Stored maize (69.3%)		Marketed maize (30.7%)		Aggregate (100%)	
		Incremental loss	Remaining quantity	Incremental loss	Remaining quantity	Incremental loss	Remaining quantity
		-	**69.3**	-	**30.7**	-	**100.0**
Harvesting/field drying	6.4	4.4	64.9	2.0	28.7	6.4	93.6
Platform drying	4.0	2.6	62.3	1.1	27.6	3.7	89.9
Threshing and shelling	1.3	0.8	61.5	0.4	27.2	1.2	88.7
Transport to farm	2.4	1.5	60.0	0.7	26.6	2.1	86.6
Farm storage	9.4 (4.7)	5.7 (2.8)	57.2 (54.3)	-	26.6	5.7 (2.8)	83.7 (80.9)
Transport to market	1.7	-	57.2 (54.3)	0.5	26.1	0.5	83.3 (80.4)
Market storage	2.7	-	57.2 (54.3)	0.7	25.4	0.7	82.6 (79.9)
Cumulative loss (%)		***21.6 (17.5)***		***17.2***		***20.3 (17.4)***	

Source: APHLIS (2014) and authors' calculations.

Note: Farm storage loss numbers in brackets are for storage periods of 6 months or shorter. Farm storage losses do not apply to maize marketed shortly after harvest. Likewise, transport to market and market storage losses only apply to marketed maize and not to home-consumed maize. The cumulative loss is not the sum of individual loss factors, because percentages show losses as a percentage of the maize that enters the next stage in the post-harvest chain, rather than loss as a share of original production.

There are various other estimates of PHL in sub-Saharan Africa. In Malawi, the *Maize Post Harvest Losses Assessment Survey* conducted by the MoAIWD in 2009/10 and 2010/11, with technical assistance from FAO, was used to generate estimates using two methods: a *rapid* and a *conventional* loss assessment (MoAIWD 2011; 2014c). Under the rapid assessment approach, enumerators conducted a visual assessment of cobs or grain to determine the extent of crop losses, while the conventional approach involved laboratory work. The latter is considered to generate more reliable estimates. The rapid loss assessment for 2010/11 yielded maize PHL estimates of 11.0 percent, whereas the conventional approach put the loss at 15.7 percent. Although the sampling methodology employed means the survey cannot be considered nationally representative, the estimates are significantly lower than those of the APHLIS.[6]

Consistent with the APHLIS, farmers in the MoAIWD PHL survey (2011) report that the bulk of the losses occur during harvesting and farm storage. The survey also collected information on losses by storage technology. Consistent with our IHS3 estimates (Figure 6), about two-thirds of households in the PHL survey stored maize grain in bags, whereas a quarter utilized traditional granaries. Aggregate losses for these two storage technologies are reportedly around 5.5 and 5.3 percent, respectively, using the rapid loss assessment method, which is comparable in absolute terms with the APHLIS estimate for shorter periods of storage (compare Table 2). However, the results suggest storage losses are significantly more important in *relative* terms, i.e., approximately half of losses occur during the storage stage. By comparison, the APHLIS data suggests that between one-quarter and one-third of overall losses occur during the storage stage, depending on the length of storage. FAO (2011) reports that maize PHL in sub-Saharan Africa is around 20.5 percent. Consistent with the other estimates reported here, FAO (2011) also finds that losses during harvesting (6 percent) and handling and storage (8 percent) account for 29 and 39 percent of overall losses, respectively.

Kaminski and Christiaensen (2014) are generally sceptical about the high level of PHL reported for sub-Saharan Africa, and question why farmers have seemingly tolerated such high losses in the face of significant hunger and undernourishment. Their own analysis for Malawi, among other countries, uses nationally representative survey data (IHS3) in which respondents self-report PHL. While this approach avoids the sample selection bias often associated with purposively sampled PHL surveys, subjectivity in reporting may also lead to measurement error (Kaminski and Christiaensen 2014). The authors find that only 6.8 percent of maize producers out of a sample of 10,331 report non-zero PHL associated with post-harvest handling and storage. Among these, the average loss, adjusted to reflect an 11-month equivalent is 20.6 percent. Thus, while losses are seemingly significant, only a small percentage of farmers experience losses, which means the national PHLs associated with post-harvest handling and storage is only 1.4 percent of *total* maize grain production. Since only about 60 percent of maize reaches the farm storage stage in the post-harvest chain, a loss estimate that is comparable with those reported in Table 2 is 2.3 percent (1.4/60*100). This is significantly below the estimated 9.4 percent loss reported by APHLIS for longer storage periods.

Even though PHL is usually reported in aggregate across all the stages in the post-harvest chain, most interventions aimed at reducing PHL focus on on-farm storage technologies. As we have shown, this stage in the chain accounts for between one-quarter and half of aggregate losses. As a result, people may have unrealistic expectations of the impact of such interventions on overall storage losses. Various interventions designed to reduce PHL are currently being

[6] In recognition of the shortcomings of the earlier study, the Ministry has committed to prioritize follow-up PHL analysis in the upcoming *Malawi Agricultural Statistics Strategic Master Plan (SMP) Action Plan* (MoAIWD 2014).

implemented or evaluated in Malawi, mostly in collaboration with MoAIWD, and mostly to address PHL that occur during farm storage (APHLIS 2014): (1) use of metal silos and improved grain bags; (2) development of pest-resistant maize varieties; (3) distribution of subsidized storage chemicals under the Farm Input Subsidy Program (FISP); (4) biological pest control; and (5) training of extension staff to provide advice to smallholder farmers on postharvest management of maize.

RELATIVE COSTS OF STORING GRAIN AT HOME OR AT A WRS WAREHOUSE

The remainder of this section is devoted to a rudimentary cost assessment of WRS as a possible alternative storage loss mitigation strategy. Estimated costs and revenues are based on actual costs and expected future prices during the 2014/15 marketing season. We start with the assumption that a particular maize farmer has one metric ton (mt) of maize that he or she wishes either to store for consumption six months later or to sell. We assume the storage season starts in June, i.e., a farmer that stores to consume will extract the maize from storage in December. Storage can either be done at home, which is associated with storage costs such as purchasing bags, pest control chemicals, and building or maintaining home storage facilities. There is also the risk of storage losses. While not an actual direct cost, this can be thought of as the cost that the farmer would have to incur if he or she had to replace the lost maize.[7] Costs under the "home storage" option are compared against the cost of storing the commodity in a WRS with the intention of withdrawing the maize in December after paying all the direct costs to the operator. We include the cost of moving the commodity to and from the storage facility.

Farmers that wish to sell maize can choose to do so immediately in June before moving the commodity into store. This strategy implies no storage costs, but sales revenue may also be lower. Depending on where the market is located, some transport costs may have to be incurred.[8] We use this strategy as the baseline against which we compare other sales strategies. The remaining strategies involve selling either in December or in February. As with the consumption strategy, we assume farmers can choose between home storage at the risk of incurring PHLs and hence sales revenues will be lower, or they can make use of a WRS, which is associated with additional costs. We assume transport costs are similar under both strategies as maize needs to be transported from the homestead to the market or storage facility.

Table 3 reports some of the basic assumptions and departure points for the assessment. The first section of the table shows recorded maize market prices in May 2014 across Malawi's three districts based on AMIS data (MoAIWD 2014a). There was some variation across regions: prices in the more isolated north were generally higher, while prices in the centre, Malawi's surplus region, were lower. The national median price in May was MK76.5 per kilogram. We use this as the basis price for our assessment of several potential strategies that farmers can follow during the 2014/15 marketing season. As explained, transactions can take place in June (move to storage or sell), December (withdraw to consume or sell) or February (withdraw to sell). Expected future nominal prices at these points in time, shown in the second part of the table, are based on historical price movements.[9] We also construct a 95-percent confidence interval around the expected price level based on observed price levels in each particular week over the seven-year period.[10] This provides lower and upper-bound prices at each point in time.

[7] Even if the farmer does not need to replace the lost maize, it is still an opportunity cost in the sense that the farmer would have otherwise been able to sell that maize if it had not been lost in storage.

[8] The cost is either borne by the farmer directly or implicitly when a trader offers a lower farm gate price to compensate for transport costs incurred.

[9] Compare Figure 5, which shows prices in real terms. The inter-annual movements in nominal terms will be much higher than the 69.3 percent peak-trough spread calculated earlier in which the effect of inflation was taken into account.

[10] The confidence interval is estimated using the standard formula $CI = \bar{x} \pm c\frac{s}{\sqrt{n}}$, where $\bar{x}$ is the sample mean (average), s is the standard deviation, n is the sample size (7), and parameter c = 1.96 to obtain a 95-percent confidence interval.

Table 3—Basic assumptions for benefit-cost model of maize storage – prices and storage costs

Actual harvest season maize prices (MK/kg; May 2014)	*25th percentile*	*Median*	*75th percentile*
National	62.3	76.5	94.2
North	67.8	94.3	104.7
Center	53.7	69.4	94.4
South	65.3	75.5	83.8
Projected maize prices (national median nominal prices; MK/kg)	*Lower bound (95% conf. int.)*	*Expected price (average)*	*Upper bound (95% conf. int.)*
June (storage starts)	76.3	82.6	88.5
December (6 months storage)	105.4	126.9	147.0
February (8 months storage)	112.9	151.5	187.8
WRS storage costs (range of supplier prices)	*Min*	*Average*	*Max*
Total handling and bagging (MK/mt)	5,143	6,100	7,000
Handling (MK/mt)	1,023	1,300	1,375
Bags (MK/mt)	2,060	2,500	3,150
Bagging (MK/mt)	2,060	2,300	2,475
Storage fees (MK/month)	1,003	1,339	1,405
Home storage costs	*Value*	*Notes*	
Bags (MK/mt)	2,500	Equivalent to average WRS bag cost	
Chemicals (MK/mt)	2,720	Cost of 2 kg Actellic storage pest control chemical	
Storage fee (MK/month)	685	Based on MK 35,000 storage infrastructure cost payable over 15 years at 25.2% discount rate.	
Other fees/assumptions			
Annual discount rate (%)	25.2	Equivalent to annual CPI inflation during 2010-2014	
Transport costs (MK/mt/km)	55	Estimate provided by ACE	

Sources: Author's calculations based on AMIS data (NSO 2014a), ACE storage and transport costs, pest control costs supplied by Fumigation International Limited, and CPI data (NSO 2014).

We next compare storage-related charges under the two alternative storage options. WRS charges are reported first, and are based on the range of service charges of the various suppliers that ACE uses to provide accredited storage. On average, total bagging and handling costs amount to about MK6,100 per metric ton of maize. This is a once-off charge, applies irrespective of the storage period, and includes handling, bags, and bagging charges. Monthly storage fees range from MK1,003 to MK1,405 per metric ton, with an average of MK1,339.

Our estimates of home storage include the cost of bags, chemicals, and a storage fee based on the cost of infrastructure. For simplicity, we assume that bags cost the same as those provided by the WRS operators (MK2,500 per mt). Pest control fees (Actellic) amount to MK2,720 per mt, which is based on information supplied by Fumigation International Limited in Lilongwe. In reality many farmers probably do not apply chemicals optimally, but the trade-off is likely to be increased losses in storage. We also account for the cost of home storage infrastructure, based on a crude assumption that a small, brick storage facility sufficient for 1–2 metric tons of maize would cost around MK35,000 to build, the cost of which is repayable over a 15-year period at a rate of 25.2 percent (i.e., the average annual inflation rate during the period 2010 to 2014). This is equivalent to MK685 per month or MK7,295 per annum. Unlike the case of WRS storage, we assume the annual cost applies irrespective of the storage period. In reality, some households may sacrifice space in their homes to store maize for a few months every year, but then repurpose that space when maize is no longer stored. For this reason in our assessment below we include cost estimates that both include and exclude the infrastructure cost component.

Table 4 shows the results for the storage scenarios. Cost estimates either exclude or include the cost of storage infrastructure (MK7,295 per annum). We also show costs for a range of storage losses (0 to 10 percent). Since the storage period is only six months it is fair to assume that losses are very unlikely to exceed 5 percent. Storage losses are valued at the future nominal price (December), which is why we also show results for a range of prices (low, average, and high). All costs are discounted to reflect June values. Our results show that, so long as physical infrastructure costs at home are not included in the cost estimate, home storage will generally be more cost-effective that using a WRS warehouse. Even when they are included, home storage costs are still comparable with those of a WRS (MK12,000–18,000) as long as storage losses are low (i.e., in the 0 to 5 percent range) and the storage operators are near the homestead (less than 50km). Transport costs in the WRS scenarios are quite significant, given the assumption that maize has to be transported to *and* from the storage facility. When the facility is 100km or more from the homestead, storage losses of 10 percent are tolerable.

Table 4—Cost of storing one metric ton of maize – home storage versus WRS warehouse storage scenarios, MK

Home storage		Low price scenario	Average price	High price scenario	WRS comparison	
Physical infrastructure cost excluded:						
Storage losses	0% loss	5,220	5,220	5,220	No transport	12,631
	5% loss	9,931	10,889	11,790	50km from facility	17,547
	10% loss	14,641	16,558	18,361	100km from facility	22,462
Physical infrastructure cost included:						
Storage losses	0% loss	12,515	12,515	12,515		
	5% loss	17,226	18,184	19,086		
	10% loss	21,937	23,854	25,656		

Source: WRS model results

We next turn to the various sales scenarios. To recap our assumptions, households can choose to sell their one metric ton in June and incur no storage costs, or they can choose to store with the intention of selling in December or February at a higher expected price, while at the same time incurring higher storage costs. If they choose to store first, storage can either be at home or in a WRS warehouse. There are many similarities between home storage and WRS in several of the cost components. First, irrespective of the date of sale or the storage method, we assume that transport costs are incurred to move the commodity to the market or storage facility. Secondly, once discounted to June prices, bagging and handling costs under a WRS (MK6,100) payable at the end of the storage period are very similar to the cost of bags and pest control at home (MK5,220) payable at the start of the storage period (Table 3). Thirdly, storage fees are marginally lower under a WRS when storing for six months (MK7,180), and only slightly higher when storing for eight months (MK9,221) compared to home storage costs of MK7,295 per annum. As was the case in the storage scenarios, whether we include or exclude the physical infrastructure cost component of home storage has a major bearing on overall costs.

Results of our maize sales scenarios are summarized in Table 5 and are organized as follows: As before, we consider outcomes under low price, average price, and high price scenarios. For each of these we report net revenues, defined as sales revenue minus the sum of post-harvest handling and bagging costs, transport costs, the value of storage losses, storage fees, and physical infrastructure costs, as applicable. Costs of production are not accounted for in this analysis, which means net revenues are not the same as net profits. We also include two columns under each price scenario showing the net revenue gain (or loss) of selling in December or February relative to the default option of selling in June. In the first column, physical infrastructure costs are excluded, while in the second, they are included in the cost calculation for home storage. The results basically show when and to what extent it is worthwhile to engage in temporal arbitrage considering the extra costs associated with storage.

Table 5—Value of storing one metric ton of maize for later sale – home storage versus WRS warehouse storage scenarios

				Low price scenario			Average price scenario			High price scenario		
Month of sale	Storage choice	Storage loss level	Distance to market or storage facility	Net revenue (sales revenue–storage costs), MK	Net revenue gain (loss) relative to June sale, %: Physical infrastructure cost excluded	Net revenue gain (loss) relative to June sale, %: Physical infrastructure cost included	Net revenue (sales revenue–storage costs), MK	Net revenue gain (loss) relative to June sale, %: Physical infrastructure cost excluded	Net revenue gain (loss) relative to June sale, %: Physical infrastructure cost included	Net revenue (sales revenue–storage costs), MK	Net revenue gain (loss) relative to June sale, %: Physical infrastructure cost excluded	Net revenue gain (loss) relative to June sale, %: Physical infrastructure cost included
June	N/A	N/A	None	73,819			80,087			85,982		
			50km	71,069			77,337			83,232		
			100km	68,319			74,587			80,482		
December	Home storage	0% loss	None	81,699	20.6	10.7	100,868	35.1	25.9	118,894	46.8	38.3
			50km	79,241	17.2	7.3	98,410	32.0	22.9	116,436	43.9	35.4
			100km	76,783	13.9	4.0	95,952	28.9	19.8	113,978	41.0	32.6
		5% loss	None	76,988	14.2	4.3	95,198	28.0	18.9	112,323	39.1	30.6
			50km	74,530	10.8	1.0	92,741	24.9	15.8	109,865	36.3	27.8
			100km	72,073	7.5	-2.4	90,283	21.8	12.7	107,408	33.4	24.9
		10% loss	None	72,277	7.8	-2.1	89,529	20.9	11.8	105,753	31.5	23.0
			50km	69,820	4.5	-5.4	87,072	17.8	8.7	103,295	28.6	20.1
			100km	67,362	1.1	-8.7	84,614	14.8	5.7	100,837	25.8	17.3
	WRS	N/A	None	81,583		10.5	100,752		25.8	118,778		38.1
			50km	79,125		7.2	98,294		22.7	116,320		35.3
			100km	76,667		3.9	95,836		19.7	113,862		32.4
February	Home storage	0% loss	None	84,676	24.6	14.7	117,909	56.3	47.2	149,160	82.0	73.5
			50km	82,309	21.4	11.5	115,541	53.4	44.3	146,793	79.2	70.7
			100km	79,942	18.2	8.3	113,174	50.4	41.3	144,425	76.5	68.0
		5% loss	None	79,817	18.0	8.1	111,388	48.2	39.1	141,076	72.6	64.1
			50km	77,449	14.8	4.9	109,020	45.2	36.1	138,709	69.8	61.3
			100km	75,082	11.6	1.7	106,653	42.3	33.2	136,341	67.1	58.6
		10% loss	None	74,957	11.4	1.5	104,866	40.0	30.9	132,992	63.2	54.7
			50km	72,590	8.2	-1.7	102,499	37.1	28.0	130,625	60.4	51.9
			100km	70,222	5.0	-4.9	100,132	34.1	25.0	128,258	57.7	49.2
	WRS	N/A	None	82,719		12.1	115,952		44.8	147,203		71.2
			50km	80,352		8.8	113,584		41.8	144,836		68.4
			100km	77,985		5.6	111,217		38.9	142,468		65.7

Source: WRS model results

Rather than including a detailed discussion of the results of these scenarios, we only focus on the general findings. First, the cost of storage losses in terms of revenue foregone is a significant cost component under the home storage option. Although not explicitly shown in the table, storage losses account for between 25 and 50 percent of total costs, depending on sale date and extent of the losses (5 to 10 percent). Second, home storage generally offers better returns than a WRS as long as storage losses are low (i.e., in the 0 to 5 percent range) and physical infrastructure costs are not included in the cost estimate. Third, when physical infrastructure costs are included, home storage is comparable to that of a WRS for an earlier sale date (December), and yields a better return than does WRS warehouse storage for a later sale date (February). However, this only holds when no storage losses are incurred. Fourth, as soon as storage losses are incurred and physical infrastructure costs are included in the cost of home storage, the WRS approach yields better returns under all scenarios. Finally, the results are generally robust for different price scenarios. Importantly, however, under some of the low price scenarios, home storage yields a negative outcome relative to the June sale option, whereas WRS always yields positive returns.

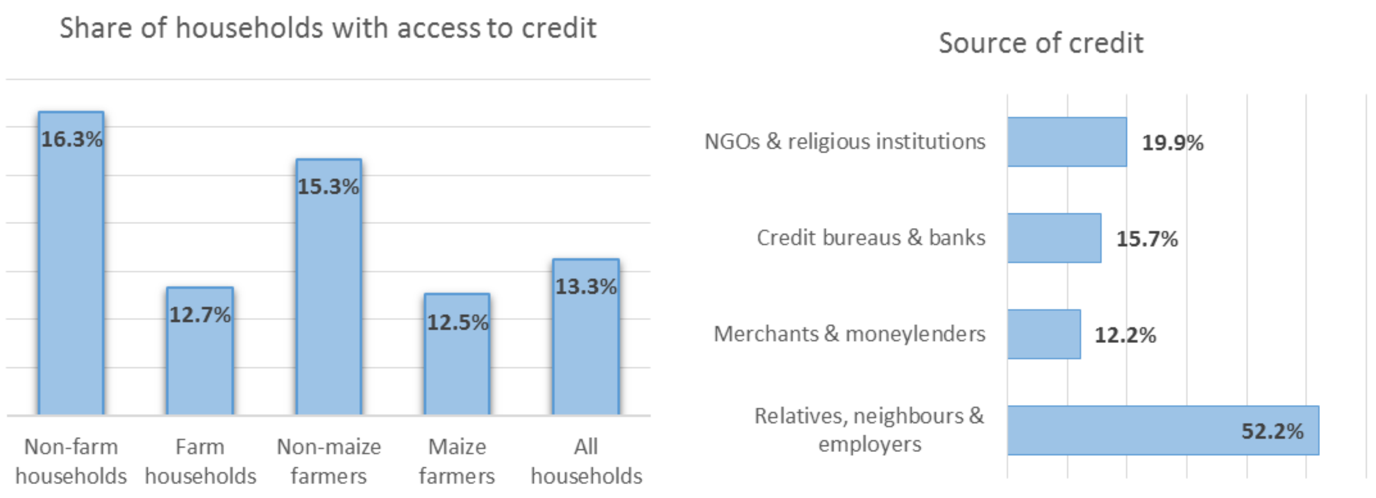
As always with such scenario analysis, results remain sensitive to cost assumptions, and it is hard to generalize about the suitability of one option over another. One would imagine that farmers who build improved home storage facilities and adopt optimal pest control strategies would see their storage losses reduced to very low levels, to the extent that home storage would always yield a better outcome that WRS warehouse storage for them. However, what is not accounted for in the above estimates is the "value of aggregation" that can be gained from collective storage. Since WRS operators aggregate across many sellers, they are often in a position to negotiate better sales prices for WRS clients collectively compared to prices received by individual farmers selling direct to the market or to traders.

Another factor that is not considered in these scenarios is the inherent assumption that farmers have sufficient liquidity to deposit grain for 6 to 8 months. The advantage of a WRS is that credit may be provided the depositor using the stored maize as collateral. However, obtaining credit would add interest as an additional cost component to WRS storage, which is not considered in the above analysis. It would also be difficult to quantify the real or implicit benefit of access to credit without having a better sense of farm-level cash flows throughout the production and marketing seasons and how farmers ultimately utilize the loan supplied through their participation in WRS. The next section briefly describes access to credit in Malawi and its potential benefits.

Access to credit

WRS operators consider access to credit as perhaps one of the greatest advantages of WRS. Access to formal credit at reasonable cost is very limited in developing countries. Malawi is no different with only 13.3 percent of households in the IHS3 (2010/11) reporting to have had access to some form of credit in the recent past (Figure 7). Access varies by household type (see left panel in Figure 7): for example, non-farm households are more likely to access credit (16.3 percent) compared to farm households (12.7 percent). Among farm households, maize farmers have significantly lower access than non-maize farmers. While these estimates in part may reflect demand for credit—for example, non-farm households may be more likely to apply for credit than farm households—it also highlights an access problem for maize farmers in particular.

Figure 7. Household access to credit in Malawi (2010/11)



Source: Integrated Household Survey 2010/11 (IHS3) (NSO 2012)

The right panel of Figure 7 shows the sources of credit for those households that reported to have been able to access credit. Over half of households with access to credit borrow from relatives or neighbours, while one-in-five borrow from NGOs or religious institutions. Although only 12.2 percent of these households rely on credit provided by merchants and moneylenders, this is also typically the most expensive source of credit. Finally, 15.7 percent of households are able to access credit through credit bureaus or banks, which we can assume is mostly formal, collateralized loans charged at reasonable interest rates. However, only 1.9 percent of all farm households (and 3.0 percent of all non-farm households) have access to such loans.

It is difficult to quantify the benefits of access to credit in the same manner that we were able to compare costs and benefits of alternative storage models. However, there is a large body of literature that has looked at the benefits of credit access in terms of how it allows changes in household behaviour. A study in Kenya has shown that liquidity constraints among smallholder farmers often force them to use the market as a “high-interest lender of last resort”, in the sense that they sell maize to relieve cash constraints, often when prices are low, only to buy maize later in the season to supplement food stocks when prices are high (Stephens and Barrett 2011). Another Kenyan study confirmed that timely access to affordable credit influences timing of sales and enables farmers to engage in temporal arbitrage (Burke 2014).

In a related ongoing study, Fink et al. (2014) assess how cash or food constraints might force households to sell *ganyu* labor (piecework) at critical times during the year in Zambia. This they believe leads to under-investment in households’ own plots in terms of land preparation, weeding, or harvesting, which, in turn, causes yields and production to drop in a vicious cycle. Preliminary results from an intervention in which households receive food on a loan basis during the lean season (January to March) shows positive nutritional effects and a significantly reduction in *ganyu* labor supply accompanied by an increase in local *ganyu* wage rates. High repayment rates (in excess of 95 percent) have also been achieved. Evidence on how cash constraints affect household labor supply, however, is somewhat mixed. In Malawi, for example, Dimowa et al. (2010) find that *ganyu* labor is not necessarily a low-return strategy that locks subsistence households into a vicious circle of poverty, while Orr et al. (2009) find no evidence that seasonal food deficits force smallholders to resort to *ganyu* during the critical first six weeks after planting.

In summary, while the storage cost scenario analysis above does not take into account the benefits of access to credit afforded by the WRS, credit benefits appear to be substantial, especially in the case of Malawi where just 1.9 percent of farm households report having access to formal credit. These benefits include helping the farmer to avoid having to sell maize to relieve cash constraints and even allow them to engage in temporal arbitrage, thus increasing farm-level food security and profitability. While evidence on whether or not access to credit would result in farmers investing more time in preparing and tending to one’s own plot rather than performing piecemeal work is mixed, preliminary findings indicate that credit improves nutritional outcomes and reduces the supply of *ganyu* labor.

3. EXAMINING BARRIERS TO WRS ADOPTION BY SMALLHOLDER FARMERS

Overview and methods

This section addresses the following question: given the potential benefits of depositing in the WRS – zero storage losses, access to credit, security, and the possibility to sell later in the marketing season when prices are on average almost 70 percent higher than at harvest time – why are more smallholder farmers (SHF) not adopting this system? While neither WRS operator tracks plot size of depositors, both ACE and AHCX report that very few SHFs have made deposits. In some cases, however, SHFs have come together through farmers’ organizations (FO) to make deposits, but these types of deposits are rare and usually rely on NGO financial and technical assistance or extensive WRS outreach efforts.

In order to understand why farmers are reluctant to adopt the WRS, this study uses findings from the following:

a) focus group discussion (FGD) with farmers from a FO that deposited in a WRS. This FGD was conducted with nine farmers, one of whom chose not to participate in the FO deposit;[11]

b) structured interviews with three WRS field agents whose primary responsibility is to recruit farmers to use the WRS;[12]

c) case study of a FO that deposited in a WRS in 2012-13 but chose not to repeat this experience in 2013-14, even though the deposit generated 35 percent value addition (Concern Worldwide 2013).

While these three data sources do not provide a representative account of farmers’ perspectives on WRS in Malawi, they do complement each other as they include the experiences of farmers who chose to deposit, farmers who

[11] FDG questionnaire is available upon request.
[12] Field agent questionnaire is available upon request.

chose not to do so, and field agents who interact with the farmers as they decide whether or not to deposit in the WRS. As such, they provide a starting point for understanding barriers to increased participation by SHF in WRS.[13]

Findings

The first barrier to adoption of WRS for farmers is that the minimum deposit requirement is too high for most SHFs. While both WRS operators in Malawi report that they are flexible with their minimum deposit requirements, neither is willing to accept deposits of less than one metric ton, as dealing with deposits smaller than this becomes administratively too costly and complicated. One way for farmers to overcome this barrier is to come together and deposit as a FO. This approach, however, creates further challenges. First, unless the FO is quite homogeneous in terms of farmer scale, depositing as a group can create discontent between poorer farmers who prefer to sell sooner and more well-off farmers in the FO who can afford to wait longer for more positive price movements. In addition, the comingling of deposits from multiple farmers within a FO can lead to a downgrading of the deposit unless quality is consistent across farmers.

Second, famers report that it is too expensive to transport their commodity from farm gate to the warehouse.[14] This barrier is a direct result of the limited footprint of the WRS providers in Malawi. And considering that, in most cases, depositors must transport the commodity from farm gate to WRS and then again from WRS to buyer, the costs that arise from the limited existing network of the WRSs become significant. In one case, these costs amounted to 11 percent of the total value of the deposit.

Third, farmers do not trust WRS. This lack of trust arises from multiple sources. Farmers have been cheated in the past by traders who have promised future payment – much like how the WRS operates -- and then defaulted. And in one case in which a FO deposited in a WRS in Malawi, the FO operating the WRS stole part of the deposit. Another potential source of reluctance to trust WRS operators is that the deposit is commoditized and treated as a fungible commodity. In Malawi, families have an existential dependence on maize and the fact that they cannot personally monitor "their own" maize and then subsequently withdraw it for own consumption or sale deters farmers from depositing in the first place.

One of the strongest selling points for WRS is that it enables farmers to borrow up to 70 percent of the value of their deposit. From the farmers' perspective, however, another barrier to adoption is the difficulties faced when trying to access credit. One challenge arises from the fact that, in order to borrow, the farmer must have a government-issued ID. According to our FGD findings, most farmers do not have such an ID. Other farmers report that there were significant delays between when they deposited and when they actually received the loan proceeds. These delays exacerbated cash flow challenges for these farmers. And for farmers that deposit through a FO, the FO is required to have a group account, thus further complicating the process of accessing credit. Alternative models to those employed by ACE and AHCX in Malawi for granting credit to farmers based on their production may prove more suited for SHF in Malawi (Box 2).

A final barrier to adoption is the steep learning curve involved in making WRS work for SHFs. WRS requires that the farmer understands commodity grading, has a basic level of financial literacy, and is able to differentiate between fixed costs (bagging and one-time deduction for losses) and variable costs (storage and finance charges) and then balance these costs against market price movements that are quite unpredictable. Beyond that, WRS requires that the farmer still find a buyer for the commodity, even after accounting for the complexities described above.

[13] One area for future work is to expand the FGDs to additional farmers, including those who have attended WRS sensitization sessions and those who have not.

[14] ACE's quoted transport charge is MK 55/km/MT.

Box 2—Alternative storage models incorporating credit: the example of *warrantage* schemes

Warrantage (or inventory credit) is a form of storage that is based on very similar principles as those of a WRS. A farmer deposits an agricultural commodity in a village or community-based warehouse, that generally has storage capacity no larger than 80 metric tons, that is jointly managed by a farmer organization and financial institution. At the time of deposit, the farmer can borrow a defined proportion of the value of the commodity deposited, up to 80 percent in most cases. The stored commodity can only be accessed again only once the loan has been repaid. The deposit is terminated when the depositor decides to either withdraw or sell to a buyer who collects directly from the warehouse. With warrantage, there is no tradable receipt (see FAO 2012; Coulter 2009; Delavallade and Godlonton 2013).

Warrantage has the potential to address several of the barriers to adoption discussed above. As it is implemented at the community level, farmers are likely to face lower transport costs than under a WRS where storage facilities are far away. Trust in the system could be less of an issue since, since under warrantage, the warehouse is co-managed by the farmer's own farmer organization. Because the financial institution is also involved in managing the warehouse, financial institutions have better control over their risks and it may be easier for farmers to access credit. Finally, as the deposit is not treated as a fungible commodity, the farmer can withdraw his or her own deposit, which is preferable to some farmers.

Since warrantage is currently operating in Kenya, Madagascar, Ghana, Tanzania, Niger, Burkina Faso, Mali, Senegal, and Conakry Guinea, there is scope to deal with challenges raised by the steep learning curve involved in adopting a new storage and credit technology by building on lessons learned from these contexts. Furthermore, evaluations of warrantage in these countries provide evidence that warrantage has both farm-level and macroeconomic benefits. Most notably, a randomized controlled trial in Kenya indicates that warrantage improved farmers' profitability by enabling them to buy grain at lower prices and then sell when prices are higher. In markets where warrantage was introduced, price seasonality was reduced compared to markets without warrantage pilots (Burke 2014). An ongoing evaluation in Burkina Faso will provide further evidence of the impact that warrantage has on food security, dietary diversity, financial and planting decisions, and whether or not warrantage generates spillover effects on neighbors and relatives (Delavallade and Godlonton 2013).

4. CONCLUSIONS AND RECOMMENDATIONS

Warehouse receipt systems have the potential to address a variety of challenges faced by farmers in developing countries, including: high degree of storage losses due to substandard crop storage facilities; lack of access to formal, collateralized credit at reasonable interest rates among both grain traders and smallholder farmers; and the inability of traders or farmers to exploit temporal arbitrage opportunities. This study set out to provide evidence as to whether or not WRS could improve macro- and farm-level food security in Malawi by mitigating these challenges.

First, WRS, through its potential to increase demand for storage, could address high price seasonality driven by high transport costs and thin markets. This lower price seasonality stands to the benefit those that tend to sell low or buy high, with obvious food security benefits via both income and consumption channels. However, the ability of WRS to stimulate demand for storage will be hampered if prices do not follow predictable seasonal patterns. Prices tend to be more unpredictable when markets are thin, or when government involvement through trade policy, international trade, or domestic stock releases is done in an ad hoc manner.

Second, as WRS guarantees the quantity and quality of the commodity stored, WRS could improve food security in Malawi. Widespread adoption of WRS could lead to a reduction in postharvest handling and storage crop losses, currently estimated at between 5 and 15 percent. It is important to recognize, however, that certified storage comes at a cost that farmers may perceive as fairly significant, and potentially higher than the cost of home storage measured at harvest-time prices. Transport costs to and from storage facilities are also significant, thus potentially putting WRS out of reach for many farmers, and especially those that did not necessarily intend to sell some of their commodity at a higher price to recover some of the costs.

The cost scenarios show that for households who choose to store with the intention of withdrawing and consuming their maize are likely to incur very similar costs whether they store at home or in a WRS. This is true as long as storage losses associated with home storage are within a reasonable range (0 to 5 percent) or the WRS storage facility is not too far from the homestead (less than 50km). When the cost of physical infrastructure for home storage is disregarded, or when the WRS storage facility is far from the homestead (100km or more), home storage will always be a less costly option, even when storage losses are relatively high. The sales scenarios also show that home storage offers better returns than a WRS as long as losses are low (i.e., in the 0 to 5 percent range) and physical infrastructure costs are not included in the cost estimate. When physical infrastructure costs are included, home storage is still comparable to that of WRS for an earlier sale date (December), and yields a better return than that of a WRS for a later sale date (February). However, this only holds in the unlikely event that zero storage losses are incurred. As soon as losses are incurred and physical infrastructure costs are included in the cost of home storage, the WRS approach yields better returns under all scenarios.

Not accounted for in our estimates is the “value of aggregation” that can be gained from collective storage and the potential ability of WRS operators to negotiate better sales prices for WRS clients collectively compared to prices received by individual farmers selling direct to the market. Our calculations also do not take into account the potential benefits of access to formal, collateralized loans afforded by a WRS. Currently only around one in fifty households report to have accessed credit through banks or credit bureaus in the past year. Most households reporting to have accessed loans relied on relatives, neighbors, employers or moneylenders, often at exploitative interest rates. Through credit, households can better time the sale of their produce, thus avoiding the corrosive behavior of using the grain market as a lender of last resort.

Finally, survey evidence suggests that the major barriers to adoption of the WRS among smallholders include high minimum deposit quantities; high transport costs, especially for those in remote rural areas located far from storage facilities; lack of trust, given past experiences with unscrupulous traders or the notion that stored commodities are treated as fungible; persistent problems for undocumented farmers in accessing credit facilities; and a steep learning curve as far as understanding the WRS is concerned. Grain traders and larger commercial farmers or farmers groups will probably remain the main clientele of WRSs for some time to come. However, to the extent that WRS enhances market efficiency, promotes transparent price discovery in commodity markets, and reduces price seasonality, such systems may still contribute positively to food security in developing countries.

In addition to providing the findings above, this study has highlighted several areas for further research. First, the analysis of storage losses has illuminated that there is still much to be learned about the magnitude and rate of such losses incurred by smallholder farmers, both of which have implications for the storage cost scenario analysis of WRS adoption. Second, this analysis could benefit from a better understanding of farm-level cash flows throughout the production season. This information, along with an understanding of how farmers utilize credit, could lead to a more accurate quantification of the benefits of access to credit through the WRS. Third, there is still more to be learned on why farmers are not currently adopting WRS. Focus-group discussions could be extended to farmers who have deposited in the past, but subsequently did not deposit again, and to farmers who attended WRS training sessions, but chose not to deposit.

One way to gain a better understanding of these issues would be to pilot a series of interventions designed to address perceived barriers to adoption of WRS and then monitor (a) the effectiveness of each intervention and (b) the impact that adoption of WRS ultimately has at the farm-level. These interventions could include subsidized transport costs, storage costs, and interest rates, as well as a variety of WRS sensitization approaches. The impact evaluation could be done through a randomized controlled trial (RCT) that would track the household from a baseline series of measures through to the end of the evaluation. This RCT would monitor cash flow, post-harvest losses, profit and losses from adoption, and the degree to which each intervention addressed the perceived barriers of adoption. Since it would include a control group, the RCT would more accurately detect impact of alternative approaches. In doing so, it would inform government and development partners on which types of interventions could improve food security at the household level. It could also provide important lessons for current WRS operators on how their models could be adapted to facilitate farmer uptake and thereby increase demand for their product.

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