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Post-harvest losses in Sub-Saharan Africa measurement concepts and economic assessment of reduction strategies

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Abstract

Post-harvest loss (PHL) is a major source of inefficiency in the agricultural value chain in Sub-Saharan Africa (SSA). It wastes productive resources, reduces economic agents' income, and aggravates the problem of insufficient consumption of adequate, nutritious and safe food. Addressing the problem of PHL therefore has to be an important part of any strategic approach for improving food security in the region. As a first step, the extent and nature of the problem has to be more precisely investigated, as differences in available estimates of PHL vary widely. On the policy level, interventions have traditionally focused on the adoption of technical solutions by farmers, which is primarily suited to address the quantitative loss aspect. However, to reduce the equally common losses through reduced quality, it is also relevant to understand to what extent buyers are willing to compensate farmers for the costs involved with adopting new technologies to supply crops of superior quality.

The objective of this thesis is to assess strategies for reducing PHL in SSA focusing on (i) measurement concepts of losses and the implication for reliable estimates (ii) analyzing the determinants, extent and economic benefits of technology use in PHL reduction and (iii) assessing marketers' (intermediary buyers) aversion to loss. The approaches applied in achieving the objective of this thesis involve a detailed methodological review of studies providing post-harvest loss estimates; empirical analysis of the use, determinants and economic benefits of advanced technology use in PHL reduction; and empirical assessment of marketers' aversion to loss. Each empirical analysis uses both descriptive and regression frameworks based on data from farmers and marketers obtained in 2015. The result on measurement approaches shows that problems associated with obtaining consistent PHL estimates for SSA include, insufficient micro-level assessments, different estimation methods, and varying temporal and spatial extrapolations applied in the estimation process. Results for the use of advanced PHL reduction technologies show that incentives are inadequate and that buyer power is crucial in the decision to use these technologies. The assessment of aversion to loss shows that marketers' aversion is more evident where grades and standards are clearly defined. The findings highlight the need for updated micro-level studies in order to obtain reliable and consistent estimates for the region, while addressing the institutional development of markets to make PHL reduction efforts profitable for economic agents in SSA.

Keywords: Post-harvest loss, Assessment methods, Technology use, Loss aversion

Zusammenfassung

Nacherntеverluste sind eine der Hauptursachen für Ineffizienzen in der Agrar-Wertschöpfungskette in Subsahara-Afrika. Sie führen zur Verschwendung produktiver Ressourcen, Einkommensminderungen und verstärken das Problem unzureichenden Konsums von adäquaten und sicheren Lebensmitteln. Die Verringerung von Nachernteverlusten ist daher ein wichtiger Bestandteil jedes strategischen Ansatzes zur Verbesserung der Ernährungssicherheit in der Region. Hierzu ist ein verbessertes Verständnis der Art und des Umfangs des Problems erforderlich, zumal die vorhandenen Schätzungen von Nachernteverlusten stark variieren. Einschlägige Politikmaßnahmen basieren traditionell auf der Umsetzung technischer Lösungen mit dem Ziel, quantitative Verluste zu verringern. Allerdings geht mit dem quantitativen Verlust meist auch eine Qualitätsverringerung des Ernteguts einher. Um Verluste durch Qualitätsverringerung zu begrenzen, ist es daher wichtig, zu verstehen, inwiefern Käufer bereit sind, Landwirte für die Kosten zu kompensieren, die diesen durch die Verwendung neuer Technologien für die Herstellung qualitativ hochwertiger Produkte entstehen.

Das Ziel dieser Arbeit ist die Untersuchung von Strategien für die Verringerung von Nachernteverlusten in Subsahara-Afrika. Behandelt werden (i) Messverfahren für Verluste und deren Auswirkungen auf zuverlässige Schätzungen, (ii) die Analyse der Faktoren und das Ausmaß wirtschaftlicher Vorteile durch die Nutzung von Technologien für die Reduktion von Nachernteverlusten und (iii) die Untersuchung der Verlustaversion von Händlern (Zwischenkäufern). Die Herangehensweise umfasst einen detaillierten methodologischen Literaturüberblick einschließlich einer Zusammenstellung von Schätzungen für Nachernteverluste. Darauf aufbauend folgt eine empirische Analyse der Nutzung, Determinanten und wirtschaftlichen Vorteile fortgeschrittener Technologien zur Reduktion von Nachernteverlusten, ebenso wie eine empirische Untersuchung der Verlustaversion von Händlern. Jede der empirischen Untersuchungen ist auf deskriptiven und Regressionsmethoden aufgebaut und nutzt Umfrageergebnisse unter Landwirten und Händlern aus dem Jahr 2015. Die Ergebnisse bei den Messverfahren zeigen Probleme bei der Beschaffung konsistenter Nachernteverlustschätzungen auf, d.h. unzureichende Untersuchungen auf der Mikro-Ebene, Unterschiede zwischen Schätzverfahren sowie variierende zeitliche und räumliche Hochrechnungsmethoden in den Schätzverfahren. Die Untersuchung der Anwendung fortschrittlicher Technologien zur Verlustminderung zeigt, dass vorhandene Anreize unzulänglich sind und die Marktmacht der Käufer ausschlaggebend für die Entscheidung ist, diese Technologien seitens der Landwirte anzuwenden. Eine Abneigung der Händler gegen Verluste wird vor allem dann deutlich, wenn klar definierte Standards und Güteklassen angeboten werden. Die Erkenntnisse unterstreichen den Bedarf an aktuellen Studien auf der Mikro-Ebene, um zuverlässige und konsistente Schätzungen für die Region zu erhalten. Gleichzeitig wird die Wichtigkeit einer institutionellen Weiterentwicklung der regionalen Märkte deutlich, um die Rentabilität der Verringerung von Nachernteverlusten für die Marktteilnehmer in Subsahara-Afrika zu verbessern.

Suchworte: Nachernteverluste, Untersuchungsmethoden, Technologieverwendung, Verlustaversion

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Abbreviations

APHLIS	African Postharvest Losses Information System
ATE	Average Treatment Effect
ECOQUAL	Economic Community of West African States Quality Policy
ECOWAS	Economic Community of West African States
EUR	Euro
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
FBS	Food Balance Sheet
GH¢	Ghana cedi
GSA	Ghana Standards Authority
MLE	Maximum likelihood Estimation
NGO	Non-Governmental Organization
PH	Post-harvest
PHL	Post-harvest Loss
PHLR	Post-harvest Loss Reduction
SSA	Sub-Saharan Africa
USD	United States Dollar
VM	Variability Measure
WAQSP	West Africa Quality System Program
WTP	Willingness to Pay

Chapter 1

Introduction and overview of the thesis*

Post-harvest loss (PHL) of food biomass in Sub-Saharan Africa (SSA) is a current challenge and topic of interest in the development and food security debate because food insecurity is still a widespread issue on the continent. It is usually due to agricultural processes or technical limitations and represents potential consumables which are not finally consumed (Lipinski et al. 2013; Sheahan and Barrett 2017). Losses can either be quantity- or quality-related, and its importance depends on the aspect in focus. Both quality and quantity losses result in wasted productive resources and reduction of farmers' potential income. Food quality loss also affects the level of food safety and the extent of nutrient uptake, while quantity loss further reduces the already low availability and stability of food calorie consumption.

Available estimates of PHL put the value of food biomass lost or wasted globally to be about one-third of annual production (FAO 2011). In SSA, the 2013 loss estimate for cereals is 35% and 25% higher than the 2005 and 2007 estimates, respectively, implying that losses are increasing (FAOSTAT). The worth of these cereal losses were estimated at four billion dollars annually for the period 2005-2007 (Hodges et al. 2011; World Bank 2011), and may be currently higher given the increase in losses. The quantity of cereal lost constitutes slightly more than 10% of SSA's annual production from 2009-2011, or about 26% of SSA's annual cereals imports, on average, between 2009 and 2013. Scarcity of cropland as well as import dependency makes such losses crucial, as the region's population is projected to increase by 110% in 2050 relative to its population in 2011

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(Moomaw et al. 2012). PHL, if not addressed, will further waste future acreage brought into production, and aggravate the current problem of unsatisfactory levels of consumption of adequate, nutritious and safe food. Hence, while increasing productivity on existing farmlands and expanding acreage of production it seems economically sensible to also more aggressively focus on post-harvest loss reduction (PHLR) to meet the food needs of the growing population.

The starting point for the successful reduction of PHL is the knowledge of critical crops, sub-regions and points in the value chain. This will facilitate the design of effective interventions. Few studies and databases (Affognon et al. 2015; APHLIS database; FAO 2011; FAO's Food Balance Sheet) attempt to quantify loss, however, estimates provided either vary considerably among sources or are limited to few crops, making it difficult to conclude on adequate intervention strategies across crops and sub-regions. On the other hand, most interventions for PHLR discussed in the literature focus on the introduction of technologies and the education of farmers on best post-harvest practices (Sheahan and Barrett 2017; World Bank 2011). The focus on off-farm factors as a strategy for PHLR is limited; yet the availability of PHLR technologies and training of farmers is not sufficient to ensure sustainable PHLR in SSA. Off-farm factors like the nature of markets are also important to ensure that farmers are incentivized to employ strategies or technologies introduced (Hodges and Stathers 2013; World Bank 2011). Therefore, in addition to introducing PHLR technologies a more aggressive approach to addressing PHL requires a focus on other pertinent discourses which include: (1) having accurate periodic estimates for effective measurement of progress in PHLR, (2) the adoption of interventions for PHLR, and (3) market readiness for PHLR of agricultural produce. As to (1), there is wide variation in PHL estimates between sources even for similar periods, which calls for a discussion on how more consistent estimates can be achieved. As to (2) the scarce literature on adoption and effective use of PHLR strategies among farmers provides limited empirical evidence on the economic benefits of adopting

PHLR technologies and the effects of buyers' market power vis à vis farmers. Yet, such market conditions and adequate returns from PHLR are crucial for ensuring a sustainable approach to PHLR. Finally regarding (3), beyond farm-level interventions, off-farm interventions discussed in the literature include physical infrastructure improvement (such as transportation, electricity and storage facilities) and availability of financial products such as insurance and credit (Kadjo et al. 2016; Sheahan and Barrett 2017). Literature on market readiness as an off-farm PHLR intervention is scarce, especially for domestic markets, which serve the majority of the regional population. There is thus a need to address the above-mentioned gaps in further addressing PHLR.

1.1 Research questions and thesis structure

1.1.1 Research questions

The objective of this thesis is to examine measurement concepts for PHL in Sub-Saharan Africa and assess strategies for reduction. In contributing to existing research, the thesis answers the following questions:

(1) *How are post-harvest loss estimates for Sub-Saharan Africa obtained?*

Curbing PHL first requires reliable and consistent estimates; such estimates indicate for which crops and at which points along the value chain interventions are needed to curb losses, and consequently increase food availability and accessibility in SSA. Yet, estimates differ substantially between sources even for similar periods; hence, it is necessary to examine how estimates are obtained and the reason for the differences.

(2) *Do farmers utilize and benefit economically from advanced technologies for post-harvest loss reduction?*

One approach to sustainably curbing PHL is the consistent use of loss reducing technologies. However, this approach can only be successful if farmers expect sufficient returns from adopting these technologies (Hodges and Stathers 2013). Some agricultural markets in SSA also exhibit collusion among buyers (marketers) (Britwum 2013; Langyintuo 2010), with likely impacts on price determination to the disadvantage of farmers. Along with examining the general determinants and extent of farmers' use of technologies or advanced methods of PHLR, it is likely important to consider also the effect of the process of price determination on the use of PHLR technologies. Of equal importance is the need for further evidence on whether net returns and prices between PHLR technology users and non-user actually differ.

(3) *Are marketers averse to quality loss in supplies?*

Although most PHLR technologies curb losses by first reducing deterioration and physical damage to agricultural produce, a number of markets in SSA directly accessible to farmers are still weakly regulated regarding quality control and prevention of collusion among buyers (marketers). This creates the risk of low returns to farmers who use PHLR technologies. Farmers' widespread expectation of insufficient rewards for the supply of quality produce in these markets (Hodges and Stathers 2013) suggests that they observe low or non-existent value and price premiums for the supply of quality produce. Given the absence of standardized quality grades in these rather informal markets, it is necessary to empirically assess quality-consciousness among buyers (marketers) and compare results for different institutional settings.

1.1.2 Structure of the thesis

Hereafter, this introductory section describes the methodology and data sources, and summarizes the key results for the three main sections of the thesis (chapters 2 -4). The final part of this section presents a general conclusion of the thesis and avenues for future research.

Each of the chapters 2-4 focus on a separate research question and can be read independently. Based on an extensive literature review, chapter 2 answers research question 1 by providing an overview on how different sources of PHL data for SSA obtain estimates, and by highlighting how more consistent estimates may be achieved. Chapter 3 addresses research question 2 with a brief overview on available technologies for PHLR, an empirical investigation of the effect of the price determination process on farmers' adoption of PHLR technologies, and resulting differences in net returns and prices between users and non-users of PHLR technologies. Finally, chapter 4 focuses on research question 3 by assessing marketers' valuation of quality loss reduction under different market scenarios –a weakly regulated market without standard grades versus a market with defined grades.

1.2 Methodology and data sources

To answer research question 1, a detailed methodological review of the most recent database and empirical studies assessing PHL in SSA is conducted. Two database procedures, two empirical studies assessing region wide PHL and 48 micro-level studies are reviewed. Given the dynamic nature of PHL and the need to assess recent estimation techniques, studies reviewed cover the period between 2005 and 2015. Methodologies of reports and studies are examined based on the type of estimates provided – aggregated (for region-wide estimates) or micro-level – and the basis for most SSA PHL estimates is discussed.

Research question 2 is investigated based on data collected from a 2015 survey of 296 maize farmers in the Brong Ahafo region of Ghana.[1] More details on the survey and variable description can be found in the corresponding chapter. This research question is investigated in three parts: (1) *Are advanced technologies for post-harvest loss reduction utilized by farmers?* (2) *What are the determinants of the use of advanced technologies for post-harvest loss reduction?* (3) *Is the use of advanced technologies for post-harvest loss reduction economically beneficial for farmers?* For the first part, the post-harvest activities focused on are storage and drying activities, given their importance in maize PHLR (Hodges et al. 2011; Magan and Aldred 2007); PHLR methods utilized in these activities were assessed descriptively. Given the utilization results from the first part, the second and third parts focus only on storage activity. The determinants of the use of advanced technologies in storage is assessed by maximum likelihood estimation (MLE) of a variant of Heckman's (1979) sample selection model, in which both the first and second stages are binary choice models of the decision to store and the decision to use advanced technologies in storage, respectively. The use of the two-stage model is necessary because the sub-sample of users of advanced technologies is drawn from a sub-sample of farmers who store maize, resulting in potentially biased coefficient estimates of a stand-alone analysis on the decision to use advanced technologies. Finally, in the third part, treatment-effect regression adjustments are used to assess the difference in net returns and prices between users and non-users of advanced technologies.

Research question 3 is addressed using data from a 2015 survey of 288 maize marketers in the Brong Ahafo region of Ghana. The corresponding chapter discusses details on the survey and the description of variables. Given the absence of standard grades and the weak regulations in the markets studied, we assess marketers' aversion to quality loss based on

[1] The study area is based on the selected area in Ghana by the BiomassWeb project

two market scenarios: *an informal market scenario* depicting the current state of the markets studied (i.e., without standard grades, and hence some form of information asymmetry), and *a hypothesized grade scenario* depicting the existence of standard grades. The *hypothesized grade scenario* builds on the underlying concept of the discount schedules employed in Compton et al. (1998), Jones et al. (2016) and Kadjo et al. (2016), but differs from these previous studies based on the scope of attributes covered in the assessment of quality loss. While the discount schedules previously used in the literature focus on limited quality loss attributes, the hypothesized grade used in this study considers all attributes that could possibly constitute quality loss. This allows for the assessment of the value for quality loss reduction (or aversion to quality loss) as a whole and not just the value for the reduction of a specific quality loss attribute. Using purchase responses provided by marketers, the assessment of aversion to quality loss under the *informal market scenario* descriptively analyses the acceptance of *poor grains* and the comparison of purchase prices for both *good* and *poor grains*. In the *hypothesized grade scenario*, respondents provide amounts they are willing to pay (WTP) over different grades, which is used to assess their aversion to quality loss, determinants of the premium offered for quality loss reduction, and their acceptance of *poor grains* in comparison to the *informal market scenario*. Aversion to quality loss is assessed as differences in potential premiums offered. Given the repeated WTP values over different grades for each respondent and the invariant nature of other data provided by respondents, the random effect model is used to asses both aversion to quality loss and the determinants of aversion.

1.3 Summary and main findings

The key findings of the main chapters' 2-4 s are summarized independently as follows:

Research question 1: The primary components for computing PHL estimates for SSA are micro-level studies, but their scarcity and consequential unavailability as data sources results in the use of differing assumptions in region-wide PHL studies and databases to offset missing data.

Few sources provide region-wide PHL estimates. For all these sources, micro-level studies are crucial elements in the computation process. The process of *deriving estimates* is common, and comprises directly or indirectly reliance on micro-level studies to provide data for developing loss profiles, conversion factors, or consolidation of estimates. These micro-level data supplied stem from scientific studies, sample surveys and administrative records.

A number of criteria are required for these micro-level data to be usable; these include the use of credible methods and the provision of actual data along with variability measures (VM), or means of estimating the VM. Approaches which have been used in recent micro-level PHL assessments are either based on *actual assessment*, *rapid assessment, subjective assessment*, *simulation*, *trials,* or a combination of two or more of these approaches. The most used approach in studies reviewed is *subjective assessment,* which is based on guesstimates or self-reporting. In addition, a number of reporting issues were observed in some reviewed studies including a lack of thorough documentation of procedures, a respondent-based format of reporting loss estimates instead of a PHL-estimate-based format (i.e. some studies reported estimates either as averages and ranges across respondents, or based on the proportion of respondents reporting each loss magnitude), and reporting of means without VMs or the possibility of computation. Some of these issues particularly occur among studies employing the subjective assessment approach, thereby reducing their credibility and further aggravating the already existing problem of scarce micro-level PHL studies for sources aiming to provide updated and reliable national and region-wide PHL estimates.

To cope with the scarcity and consequential unavailability of studies assessing micro-level PHL, region-wide studies and databases providing PHL estimates use strategies such as the reliance on back-dated micro-level PHL assessments, on assumptions, and data sharing between regions. The likely consequences of these coping strategies are: i) micro-level estimates being outdated as data sources for current region-wide estimates and thus the likelihood of region-wide estimates not reflecting current losses; ii) provision of probable losses rather than actual losses given the use of data sharing; and iii) a bias in estimates and differing estimates between studies providing region-wide estimates caused by varying assumptions across these studies.

Research question 2: For PHL activities where the use of advanced PHLR technologies is generally observed, buyer power in price determination reduces the likelihood of the use of advanced PHLR technologies. Net returns between users and non-users do not differ significantly.

The use of advanced PHLR technologies is shown in Figure 1.1. While the use of advanced PHLR technologies for drying activities is not common, the use is observed in storage activities. Of respondents who store maize, about 56% use advanced technologies, with a majority of them using fumigants. The use of hermetic technology (silos and hermetic bag) and biological control, which are considered safer for food, are either very low or not observed.

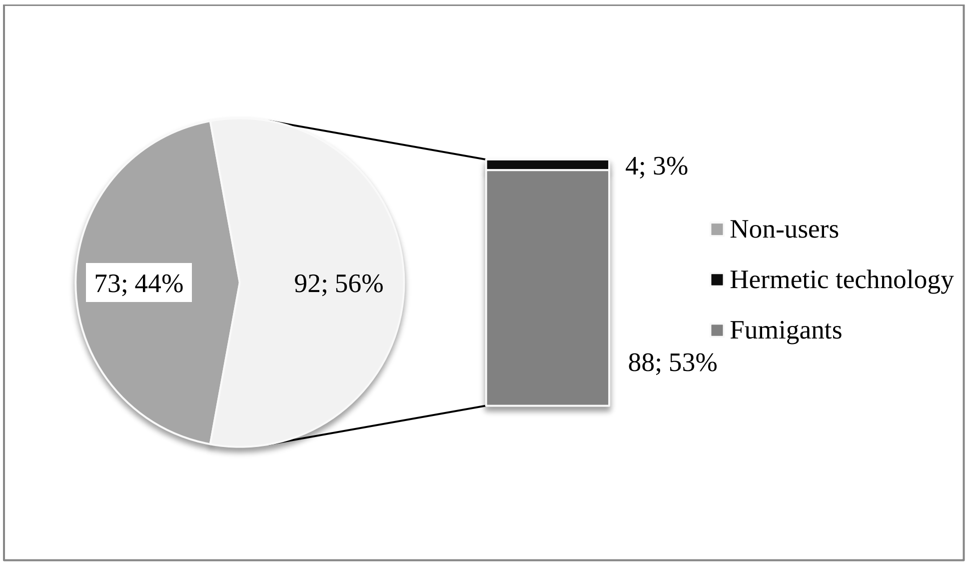

Figure 1. 1 Use of advanced PHLR technologies in storage

For storage activities, test results show that the decision to use advanced PHLR technologies is not nested in the decision to store. This implies that prior to the decision to store, farmers decide on the use or non-use of advanced methods, should they decide to store. Key determinants of the decision to use advanced methods include the process of price determination and storage trainings. Although having prices determined by marketers associations or buyers is not significant in the decision to store, it significantly decreases the probability of farmer’s use of advanced PHLR technologies compared with a situation when prices are determined by bilateral negotiations or a form of contractual agreement. Prices being determined by buyers with market power can increase price uncertainty, especially when the criterion used by buyers in such price determination is subjective, which can erode the producers’ motivation to improve grain quality. In addition, storage training by either extension agents or NGOs increases the probability of farmers’ use of advanced PHLR technologies compared with when farmers have no storage training. These activity-specific trainings expose farmers to new information, serve as practical guides on the appropriate use of these advanced technologies, and highlight the benefits of use; hence, farmers’ expectations are heightened.

Although the use of advanced PHLR technologies in storage gives farmers the opportunity to sell their maize at significantly higher prices than non-users, the average net returns for users of these technologies is not significantly different from non-users. This implies that at present, the economic benefit of engaging in the use of advanced technologies or activities aimed at reducing post-harvest loss in storage is negligible, and that output prices are not sufficiently high to earn users significantly distinct financial rewards from non-users of advanced methods.

Research question 3: Where standard grades are lacking in markets, marketers seem not to be quality conscious, but with clearly defined grades, marketers are evidently averse to quality loss, offering substantially higher premiums for quality loss reduction.

In the *informal market scenario*, 44% of respondents indicated acceptance and purchase of poor grains. However, when clearly defined grades are used in the *hypothesized grade scenario*, respondents who indicated acceptability of a low grade similar to what constitutes poor grains in the *informal market scenario* increased to above 80% of respondents (Figure 1.2). First, this suggests that assessment of what constitutes quality loss is *individual* and *criteria-specific* in these markets, and secondly, it suggests a high possibility of underreporting tolerance for poor grain where no objective grading system exists.

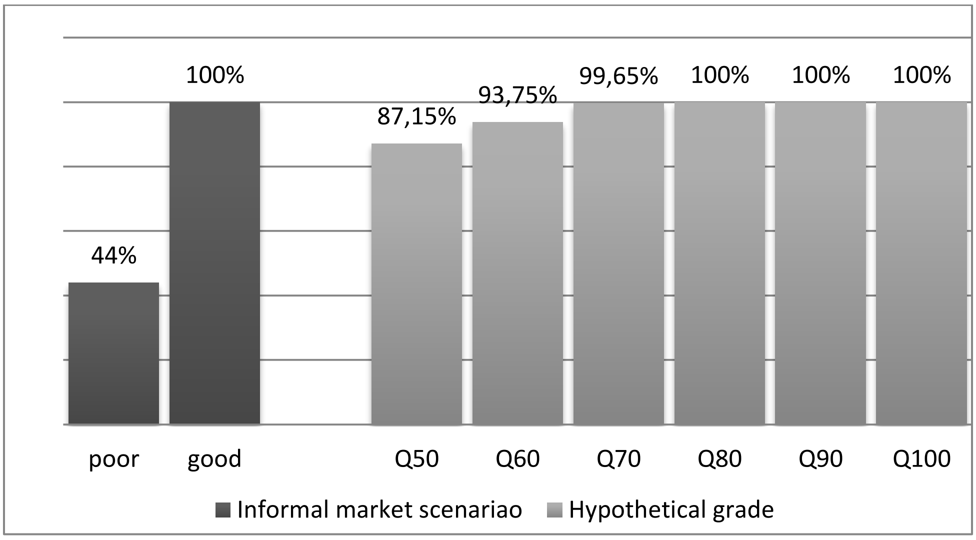

Figure 1. 2 Grain acceptability

Also, in the *informal market scenario*, purchase prices of good grains and poor grains overlap, and do not differ distinctly. In peak periods (shortly after harvest), purchase prices for good grains and poor grains range from GH¢40 – GH¢200 and from GH¢40 – GH¢180, respectively. Similarly, in off peak periods, both good and poor grains can equally be purchased for GH¢80 – GH¢160. This price overlap either implies a conflict between the ‘perception of quality’ and ‘real quality’ of grains in these weakly-regulated markets, or it implies that in some cases the prices for good and poor quality grains do not differ in these markets. Both implications reflect the complexity of estimating incentives for the supply of grains with reduced quality loss in these markets.

With clearly defined grades, the majority of marketers are evidently averse to physical losses. Potential premiums for better grains are substantial, even for a slight reduction in physical losses. In relative terms, potential premiums for the higher quality levels are between 50% to 148% times more than premiums for a lower grade. Marketers who strategically interact to determine prices and participate in the marketers’ associations are willing to offer significantly higher premiums for reduced losses than those who do not collaborate, particularly for the higher quality levels. Contrary to expectations, this suggests that these unions can be instrumental in ensuring rewards for loss reduction in supplies.

1.4 Conclusion and future research

The objective of this thesis is to investigate the strategies for PHLR in SSA. Tackling PHL requires estimates on regular basis, which, despite being available, differ considerably between sources. Also, a sustainable approach to PHLR will require that economic agents are adequately rewarded for reduction methods employed. Hence, strategies for PHLR range from providing reliable periodic estimates to ensuring market readiness for produce with reduced losses.

The objective is separated into three research questions on (1) the methods of obtaining PHL estimates for SSA, (2) the extent to which advanced technologies for PHLR are used among farmers, the determinants of use and the net returns associated with use, and (3) marketers' value for PHLR. These research questions have been addressed in the three subsequent chapters, using suitable methodologies. For questions (2) and (3), a case study from maize post-harvest activities in Ghana was used.

The key elements for obtaining PHL estimates for SSA are micro-level studies, which measure losses at specific points in the value chain. The scarcity, methodologies and reporting of these micro-level studies result in the reliance of PHL computing studies on backdated micro-level studies, and extrapolations in the form of assumptions and data sharing among regions. How these assumptions and data sharing are structured differs between computing sources; hence the differing estimates provided.

The extent of use of advanced PHLR methods is activity-specific. While the use of advanced PHLR methods is not observed in maize drying activities, it is used considerably in maize storage activities. Technologies considered to increase food safety are the least used among farmers. The decision on use or non-use of advanced PHLR technology is a prior decision before engagement in the specific PHL activity, and important determinants of use include the process of output price determination and participation in the relevant post-harvest activity-specific training. Also, although output prices received by users and non-users of advanced PHLR technologies differ substantially and net returns from the use of advanced PHLR technologies are positive, this net return does not substantially differ from net returns from the non-use of advanced PHLR technologies.

Marketers' value for PHLR is dependent on the institutional infrastructures characterizing markets. When markets are weakly regulated with respect to quality, quality judgement is individual-specific, and this gives rise to price ranges that do not reflect the actual quality of the grains being purchased; however, with clearly defined grades in markets, potential premiums for reduced losses are substantial, with participation in marketer associations positively influencing these potential premiums.

In summary, the implications of the thesis' results are as follows:

- In order to obtain reliable PHL estimates for SSA and reflect its dynamic nature, there is a need for updated and accessible micro-level PHL assessments, which use appropriate methodologies, assumptions and reporting.
- For a wholesome PHLR, there is a need for advocacy and training for the use of advanced PHLR technologies in other PHL activities for which the use of these technologies is lacking.
- Any advocacy for the use of an advanced method for PHLR should not be restricted to only farmers involved in the post-harvest activity under consideration, but to all farmers, as this may be important for future decisions.
- A sustainable approach to achieving PHLR requires addressing the uncertainty of farmers' output price for better quality, which is induced by alliances among marketers, mapping out strategies that can ensure that output prices are adequately high to earn farmers sufficient rewards for employing advanced PHLR technologies,

and providing institutional infrastructures in markets, such as clearly defined grades and standards.

A number of areas are open for future research. First is the investigation of market driven approaches that can improve farmers' output prices for better quality produce in agricultural markets in SSA –such as contracts between suppliers and buyers, and strong farmers associations. Of particular interest is how contracts can be structured to make them equally attractive to both buyers (marketers) and suppliers of agricultural produce, especially in regions where contracts may be difficult to be enforced. In addition, in regions where strong farmers associations are missing, how can such associations be strengthened in order to countervail buyers' power and give farmers a better bargaining position? A second research focus which can be beneficial to PHLR is how best to introduce institutional infrastructure in markets – is it more beneficial and effective to improve farmers' accessibility to markets with already existing standards and better rewards than enforcing standards in existing informal markets? If enforcing standards in existing informal markets is an option, how can a sustainable acceptability of this infrastructure be ensured in these markets without resistance from strong intermediary buyers (marketers)? Finally, although our result show substantial premiums for PHLR where institutional infrastructure exists, there is need for further investigation on the sufficiency of these premiums as financial rewards for farmers' investments in PHLR reduction, especially when integrated PHLR approaches are employed being neither PHL activity-specific nor PHL cause-specific.

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Chapter 2

How are post-harvest loss estimates for Sub-Saharan Africa obtained?

Abstract

Reliable and consistent post-harvest loss (PHL) estimates are required to identify where interventions are needed to curb losses, and thus improve food availability in Sub-Saharan Africa (SSA). However, estimates differ considerably between sources, making the extent of loss uncertain. This article reviews how recent SSA PHL estimates for crops are obtained; highlighting the importance, scarcity and *consequential* unavailability of micro-level studies, and identifying how improving these studies can help provide more reliable and updated loss estimates for SSA. Resolving both problems of scarcity and *consequential* unavailability, and addressing the dynamic nature of PHL, will require a balance in micro-level studies, and an improvement in documenting procedures and statistical reporting in future PHL research.

Keywords: Assessment methods, Micro-level, Post-harvest loss, Region-wide, Sub-Saharan Africa.

2.1 Introduction

Post-harvest loss (PHL) is an important element of the food security discourse in developing regions like Sub-Saharan Africa (SSA) and is considered a major efficiency problem of food production chains in these regions (Hodges et al. 2011). Occurring between production and distribution, PHL is fortuitous and mostly due to technical reasons ranging from poor handling of produce to the lack of appropriate post-harvest technologies, thereby differing from 'waste' typically found at retail and consumption stages due to negligence or a conscious decision to discard household or personal food (Lipinski et al. 2013).

To address this problem and enhance food security in developing regions, consistent and reliable estimates of PHL are required, as they are important in identifying priority areas for both private and public interventions. However, loss estimates provided for SSA vary considerably between sources. For example, loss estimates differ between the Food and Agricultural Organization's (FAO) food balance sheet (FBS) and the African Postharvest Loss Information System (APHLIS) databases. Table 2.1 exemplifies the stark differences between maize PHL estimates of FBS and APHLIS. The tonnes of maize lost in 2011 for Ethiopia, Burkina Faso, Kenya and Zimbabwe estimated by APHLIS are 2.74 – 3.21 times higher than those reported by the FBS of FAO, and 1.86 – 8.98 and 2.03 – 12.05 times higher in 2012 and 2013 respectively; while the tonne of maize loss estimated for Nigeria by APHLIS are 58.15, 54.6 and 61.73 times lower in 2011, 2012 and 2013 respectively. Some 2013 estimates of loss proportion from FBS (2.2 percent for Kenya and 5.0 percent for Ethiopia) do not sound alarming, while the corresponding 25.9 and 17.8 percent loss figure reported by APHLIS is high enough to justify interventions to address the PHL problem.The focal question is: how are these and other loss estimates obtained, and how can more reliable estimates be obtained?

Table 2. 1 Exemplary differences between maize PHL estimates between FBS and APHLIS.[2]

		PHL in t (FAOSTAT)	PHL in t (APHLIS)	FAOSTAT's PHL (% of annual production)[a]	APHLIS PHL (% of annual production)[b]
2011	Burkina Faso	76000	208745	7.1	19.4
	Ethiopia	304000	975517	5.0	17.8
	Kenya	73000	584459	2.2	18
	Zimbabwe	96000	295267	6.6	17.5
	Ghana	267000	302703	15.9	18
	Nigeria	1026000	17645	11.2	20.3
2012	Burkina Faso	147000	273550	9.4	17.6
	Ethiopia	308000	1144558	5.0	17.8
	Kenya	76000	682593	2.1	18.1
	Zimbabwe	77000	230842	8.0	19.3
	Ghana	325000	318514	16.7	18
	Nigeria	1052000	19266	11.2	19.9
2013	Burkina Faso	151000	307238	9.5	19.4
	Ethiopia	334000	1095778	5.0	17.8
	Kenya	74000	891963	2.2	25.9
	Zimbabwe	71000	177708	8.9	18.7
	Nigeria	1162000	18823	11.2	20

[a] % calculated from FAOSTAT production and loss data; [b] % as reported in APHLIS

To this end, the objective of this article is to highlight and discuss how PHL estimates are obtained in and for SSA. First, the role of micro-level studies in obtaining region-wide PHL estimates is discussed in Section 2.2. The article then discusses how some recent estimates in these micro-level studies (for the period 2005 – 2015) have been obtained (Section 2.3). Section 2.4 discusses steps region-wide sources have taken to supplement data. Section 2.5 highlights potential ways of improving estimates for SSA. We conclude in Section 2.6.

[2]Figures quoted are from APHLIS and FAO databases, last accessed 26 May 2017

2.2 The role of micro-level studies in obtaining region-wide PHL estimates

Only few sources try to estimate region-wide losses. Of these, two are databases (FAO-FBS and APHLIS) and two are specific studies (Affognon et al. 2015; FAO 2011). While the studies provide one-time loss estimates for specific crops or crop categories, both data bases provide periodic estimates. The one-time estimates are either solely for SSA (Affognon et al. 2015), or for different world regions including SSA (FAO 2011). FBS provides national estimates for quantity loss, which are aggregated to regional levels, while APHLIS provides provincial estimates which are also aggregated to national and regional levels. Estimates provided in FBS are for both primary and derived commodities of different crop types lost at all stages between production and distribution; particularly storage, transportation and processing (FAO 2001). This implies that FBS has a wider coverage than APHLIS estimates which are currently for cereal crops and also specifically for primary commodities. With such lesser coverage of the value chain, it will be expected that estimates for specific crops should be lower in APHLIS than FBS. However, APHLIS still has higher loss values for some countries as illustrated in Table 2.1. Of the four sources, APHLIS, Affognon et al. 2015 and FAO 2011 are more detailed in the outline of procedures used in providing PHL estimates.

Although each source uses a different method for computing region-wide and national PHL estimates, in all the sources, the process of *deriving estimates* is common and comprises directly or indirectly relying on micro-level studies as crucial data sources in providing statistics during computation. This highlights the role of micro-level studies as crucial elements in providing estimates for SSA. The micro-level studies are either used in developing loss profiles or conversion factors, or in consolidating estimates. For instance, APHLIS relies on a postharvest loss profile and seasonal data to derive estimates. The loss profile is a predetermined set of expected loss figures at each link in the chain derived from scientific studies

–i.e. actual estimation and informed guesstimates (Hodges and Stathers 2013), while the seasonal data is supplied by a network of local experts and tries to cover factors that may affect losses on a seasonal or annual basis (APHLIS 2014). Some steps are taken to avoid overestimation in APHLIS. First, emphasis is placed on the term 'dry matter' in the context of quantity loss. This implies that for micro-level studies to be usable in APHLIS computations, they must also adhere to assessing loss strictly for dry matter. Secondly, provincial losses along the chain are assessed as cumulative loss[3] from production instead of fixed proportions.

Conversely, FBS estimates are not cumulative, but fixed proportions of quantity supplied (FAO n.d). Again, this would imply that if the statistics used in computation are updated periodically, then the use of fixed proportions in contrast to a cumulative based assessment should result in higher estimates in FBS than APHLIS; however, Table 2.1 shows that this is not always the case. The statistics provided for FBS computations are obtained from different sources, and based on sample surveys, administrative records and best estimates obtained from each country (FAO 2001), however, it is not clear if they are carried over periodically or updated regularly. The processing losses used in FBS computations are typically obtained from manufacturing surveys (FAO 2001) and considered in the assessment of extraction and conversion rates as shown in FAO's total conversion factors for agricultural commodities. Manufacturing surveys, where they exist, are more likely to focus on industrial establishments of a certain size. This poses a challenge for actually capturing PHL occurring at small scale processors, as most agricultural processing is happening at small scale farms and enterprises in SSA, and is less likely to be captured in such manufacturing surveys when they are available.

[3] According to Hodges (2013), 'cumulative' implies that the final loss is based on separate measurements occurring at each stage in the chain, in which each measurement considers the result from preceding loss estimate in the chain.

Similar to the databases, Affognon et al. (2015) and FAO (2011) also derived estimates. Besides previous studies, other sources of data used for computation in FAO (2011) also included national authorities, expert assessments and databases like FBS. Such reliance on some other sources apart from scientific studies highlights the problem of scarce and qualitatively poor PHL data, especially when disaggregated by regions in SSA. The judgement of the quality of data from micro-level assessment stems from expected criteria for usability which are not met. Of the sources estimating region-wide losses, only Affognon et al. (2015) provides a synopsis of criteria for usability of micro-level assessments. These criteria include the use of credible methods and the provision of actual data along with variability measures (VM) (or means of estimating the VM). After filtering by these criteria, the problem of scarce data was further aggravated in Affognon et al. (2015); only 15% of the initially selected micro-level studies were used to consolidate estimates. This portrays the importance of these criteria in current micro-level assessments in order to ensure updated and reliable estimates for SSA. A crucial question is, ‘what methodologies have been used in recent micro-level studies for PHL estimation, and how appropriate has the statistical reporting been?’ The aspect of chosen methodologies becomes more pertinent when other aspects of PHL are in focus, such as assessing resulting monetary loss, or food safety and health issues.

2.3 Recent micro-level studies: methodologies and reporting

2.3.1 Methodologies employed

As shown in Figure 2.1, approaches which have been used in recent micro-level PHL assessment [4] can be classified under the field assessment and

[4] 48 studies of micro-level assessment were reviewed. Selection was based on accessibility and period of publication, with a focus on the period 2005 – 2015 (see Appendix 2.1 for a list of reviewed studies). First, Google Scholar search engine was used to search out micro-level studies. Thereafter, databases were also searched; these include AgriKnowledge,

experimental approach. The field assessment approach involves economic agents in assessing PHL, while the experimental approach assesses PHL based on designed experiments and excludes economic agents in the whole process of loss assessment.

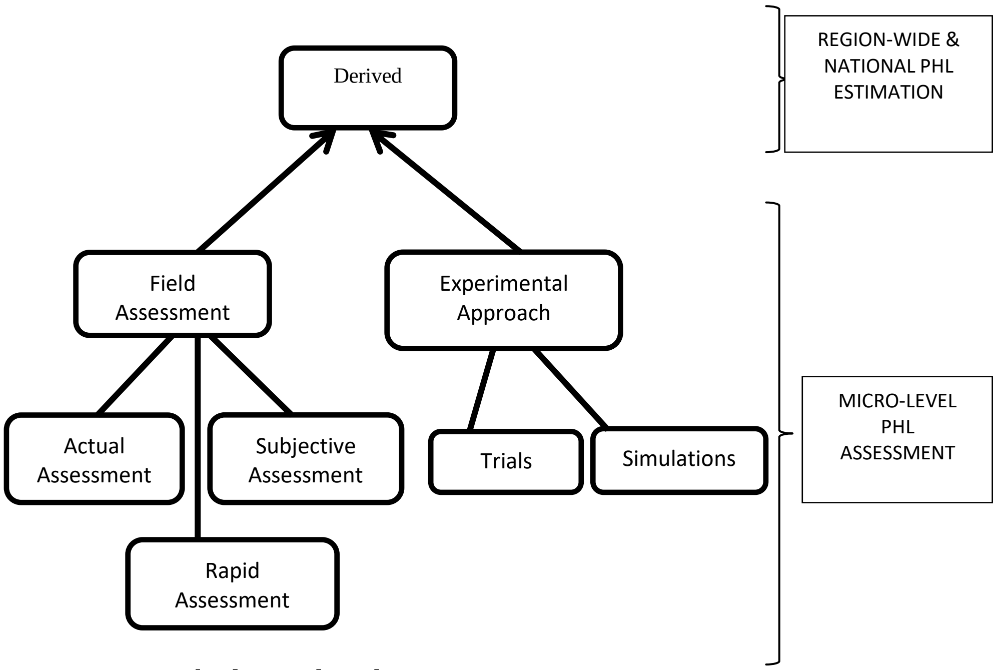

Figure 2. 1 Methods employed in PHL assessment

Of the sub-categories under the field assessment approach, *actual assessment* is less prone to measurement error. It involves taking samples of produce directly from selected economic agents along the chain, and estimating defined losses based on specified techniques, either from the physical sciences or as described in the literature (Compton et al. 1998; Harris and Lindblad 1978; Proctor and Rowley 1983; Reed 1987). Thus, economic agents only supply the samples of produce needed from their stock, but are not involved in the estimation process; PHL is estimated independent of these agents and results are usually extrapolated. Despite the fact that this approach may be less prone to error than some other approaches, only a limited number of reviewed micro-level assessments

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AGRIS, EconLit, eldis, Harvest Plus, IBSS, IDEAS, PubMed, and some journals listed under Agricultural and Biological Sciences in Scopus. Keywords used in the search are 'crop post harvest loss Africa'.

employed this approach. This may be due to the tremendous financial and time resource it requires, and consequently the infeasiblity of applying it to a large sample size of economic agents. A major setback with the use of this approach (and others which exclude economic agents in the estimation process) is the consideration of physical damage/ alterations as an outright measure of quantity loss. This may be misleading due to differences between what is technically considered as PHL (particularly quality loss) and what economic agents consider as important constituents of quality loss. It can lead to overestimation of monetary loss and underestimation of the likely consumption of unsafe or poor quality food. Monetary loss is often estimated by considering qualitative loss as outright loss and valuing this loss based on a general price level, thereby ignoring the existence of lower value markets, which is of particular importance in developing regions like SSA. To avoid the possibility of overestimation, some studies using this approach (Kitinoja and Alhassan 2012; Vayssieres et al. 2008) adopted a similar idea discussed in Pantenius and Krall (1993), by either estimating physical losses with respect to inconsumable and unmarketable produce, or by presuming that a damaged produce corresponded to an estimated percentage yield loss and not an outright loss. Such assumption of a yield loss reflects the existence of lower value and informal markets in SSA, in which economic agents sell poor quality and damaged produce.

Table 2.2 shows that the least used approach in reviewed studies is the *rapid assessment approach.* Yet, this is an approach suggested by APHLIS for micro-level assessments (Hodges 2013) trying to create a balance between precision and resource use, thereby addressing the resource constraint of employing actual assessment especially for a wider coverage of loss assessment, while taking into consideration losses that are really important to economic agents. The various procedures which have been developed under this approach (see Compton and Sherington 1999; Compton et al. 1992; Jago et al. 1993; Wright and Golob 1999) are carefully designed to incorporate simplicity and suitability for rapid surveys. These procedures employ certain techniques from the actual assessment approach to provide initial loss estimates from smaller samples, which is then calibarated against a devloped scale that reflects different classes of damaged produce and their relative uses (as defined by economic agents). For example in Utono (2013), a maize sample with greater than 85% damage was not suitable for home consumption, but used as animal feed. To finally estimate losses, economic agents are interviewed on a larger scale, using charts and samples which represent the scales. This approach estimates losses from the perspective of quality deterioration, recording quantity loss as only unmarketable produce (i.e., the extreme of deteriorated produce). The interaction with economic agents and classification into scales allows for the assessment of other aspects of PHL besides quantity loss; for instance, the assessment of the amount of deteriorated produce which is still absorbed in the food and feed value chains, or assessing monetary loss more accurately as the discounted value of each loss level on the scale. With a spotlight on food security, assessing these different aspects of PHL is crucial, as they reflect the effect on food availability, food and feed quality, and economic agents' income (which is vital for food accessibility).

Subjective assessment (i.e., guesstimates or self-reporting) is the most used approach for PHL estimation in reviewed studies. Although this approach has been highlighted as equally probable in revealing losses that are of importance to farmers (Kaminski and Christiaensen 2014) and also emphasizes where cultural values begin to interact with the concept of PHL[5], a major drawback with it is the high possibility of imprecision due to recall bias. Precision is usually a function of the duration of recall period, the type of estimate being assessed and the design features of the survey[6]

[5] One example is the case of old harvested yams, which shrink in weight and are generally considered to have lost value, yet they are culturally valued and priced more than freshly harvested yam in some parts of Africa.

[6] Design features include, but are not limited to: method of data collection, nature of respondent, characteristics of the interviewer, and specifics of cross section or longitudinal design.

(Beegle et al. 2012; Bound et al. 2001). The possible direction of error in agricultural data due to the use of this approach is uncertain. For example in a study to assess the reliability of recall, Beegle et al. (2012) found evidence of recall bias in agricultural data provided, with over reporting in one country and under reporting in another. Such uncertainties in expected outcome make it difficult to provide a standard outline for tackling recall bias due to the use of this approach. On the other hand, Kaminski and Christiaensen (2014) observed substantially lower PHL estimates with the use of this approach in comparison to FAO estimates, highlighting that the difference in estimates reflects farmers' perception of PHL.

Table 2. 2 Summary of reviewed micro-level studies profile and use

SUB-CATEGORY	WHAT IS SAMPLED?	BASIS FOR ESTIMATION	USE IN REVIEWED STUDIES [cd]	VARIABILITY MEASURES (VM) REPORTED [c]
Actual assessment	Economic agents [a] and Produce	Sampled produce	12	Clearly reported in 1 study, VM reported but not clearly specified in 3 studies, VM not reported but can be computed in 2 studies.
Rapid assessment	Produce [b] and Economic agents	Loss class visually identified by economic agents	1	Not reported
Subjective assessment	Economic agents	Loss estimates recalled by economic agents	25	Clearly reported in 2 studies.
Simulation	Produce	Sampled produce	12	Clearly reported in 1 study, VM reported but not clearly specified in 2 studies, VM not reported but can be computed in 1 study.
Trials	Produce	Sampled produce	6	Clearly reported in 2 studies, VM reported but not clearly specified in 1 study, VM not reported but can be computed in 1 study

[a]Sampling economic agents is only a means to sampling produce.
[b]Sampled produce is used to develop visual scale for loss classes.
[c] Of 48 micro-level studies reviewed; including counts for studies that combined approaches.

As a buffer, few of the reviewed studies using this approach combined it with other approaches. Such combination is advantageous for two reasons. First, it allows for comparison of estimates obtained from the different approaches. Secondly, aspects of PHL which may have otherwise been overlooked with the use of only one approach are highlighted by these combinations.

Other approaches used in reviewed studies are s*imulations* and *trials*, which are more experimental in nature. Both involve the use of estimation techniques similar to those used in the actual assessment approach; however unlike actual assessment both approaches do not involve obtaining produce from economic agents, but are based on designed experiments. While simulations are usually set up to imitate real scenarios in the post-harvest system, trials are primarily designed in controlled environments to either modify natural processes and assess possible outcomes, or assess the effectiveness of interventions and treatments along the post-harvest system. This means that for simulations, the precision of PHL estimates is dependent on the extent of similarity of scenarios and environmental parameters in the experiments to those experienced by agents. Typical examples under the simulation approach imitate the storage process done by economic agents in order to assess storage loss (Rugumamu 2009) or assess transportation losses by imitating similar transportation conditions (Aba et al. 2012). Examples under the trials approach include introducing insects into grains to estimate loss (Isah et al. 2012) or comparing the effectiveness of an improved technology with traditional methods (Baoua et al. 2012; Njoroge et al. 2014) . Estimates from these experimental approaches can only be used with caution, as the extent of precision in reflecting actual losses experienced by economic agents is dependent on the experimental design and the assumption behind such experiments.

2.3.2 Reporting

A number of reporting issues were observed in reviewed studies. First, some lacked thorough documentation of procedures for both the sampling and estimation phases of loss assessment, particularly occurring among studies which employed the subjective assessment approach, thereby reducing their credibility. Furthermore, with this approach, some studies reported estimates either as averages and ranges across respondents, or based on the proportion of respondents reporting each loss magnitude. Such reporting is respondent focused, not PHL estimate focused making the actual magnitude of losses unclear. Also, one criterion for the inclusion of micro-level studies in region wide computation is the reporting of variability measures (VMs) alongside estimates, or at least providing data from which these measures can be computed. This is important for two reasons: first, some region-wide computation techniques used to consolidate estimates from micro-level assessments may require these measures (see Affognon et al. 2015); secondly, outliers in data have profound effect on means and a different summary statistic may best reflect a randomly selected loss value, hence a VM such as the standard deviation, along with other summary statistics, will show the distribution of estimates and indicate if the reported summary statistic is the best representation of PHL estimates. Despite this, most of the reviewed micro-level studies do not discuss or provide statistics that portray the distribution of data. In all, over 55% of the reviewed studies reported means without VMs or the possibility of computation. Of those with VMs, some did not indicate which was being reported –standard deviation or standard error. Such lapses increase the probability of exclusion of these as data sources for reliable and updated region-wide computations, resulting in *consequential* unavailability of micro-level reports, which further aggravates the problem of scarce updated micro-level PHL assessments for sources which try to provide updated and reliable region-wide estimates.

2.4 Supplementing for scarce and unusable data in region-wide PHL computations

Given the scarcity and consequential unavailability of studies assessing micro-level PHL, the pertinent question is: how have region-wide studies and databases coped? One way is the reliance on back-dated micro-level PHL assessments to provide region-wide estimates; for example, of the used studies in Affognon et al. (2015), about 50% date back to over a decade. The consequence of this is a lag in micro-level estimates used in computing current region-wide estimates; hence an oversight of the possible dynamic nature of PHL and the likelihood of region-wide estimates not reflecting current losses. By way of illustration and based on studies used in consolidating estimates in Affognon et al. (2015), Table 2.3 shows variations which may occur in PHL estimates even between shorter periods.

Table 2. 3 Examples of varying PHL estimates between periods

***Referenced Studies**	***Crop**	***Country**	***(A) % PHL without interventions**	**Δ in A (% point)**	***(B) % PHL with interventions**	**Δ in B (% point)**
Affognon et al. (2000)	Maize	Benin	33.5	0.31↓	2.1	2.33↑
Meikle et al. (2002)			23 .0		7.0	
Schneider et al. (2004)			18.7	0.19↓	3.0	0.57↓
Komen et al. (2006)		Kenya	7.6	a^1	3.9	a^1
Mutambuki & Ngatia (2006)			29.1	a^2	19.3	a^2
Mutambuki & Ngatia (2012)			20.6	1.71↑ ^{c} 0.29↓^{d}	9.7	1.49↑ ^{c} 0.50↓^{d}
Rees et al. (2003)	Sweet potato	Tanzania	35.8	0.87↑	32.5	0.27↓
Tomlins et al. (2007)			66.9		23.7	

*Source: Affognon et al. (2015)

^{c} In comparison with a^1. ^{d} In comparison with a^2. ↑implies increase in PHL estimate between periods of comparison. ↓ implies decrease in PHL estimate between periods of comparison.

Another coping strategy employed in region-wide estimation is the reliance on extrapolation. Such extrapolations are crucial in the reliability of estimates, and if clearly reported also provide information on the context in which estimates from these sources can be cited. For the databases, the basis for the extrapolations and the assumptions adopted are more clearly outlined in APHLIS compared to FBS. In APHLIS, overestimation of losses in the APHLIS database is avoided by the assumption of a standardized storage loss and a constant household consumption pattern over a nine month period

(APHLIS 2014). Both assumptions are necessary due to the absence of reliable micro-level panel surveys assessing PHL in the region. In FAO (2011), similarities between regions were assumed where data was absent, however, the extent of similarities considered are unclear, particularly which type of similarities are considered –climatic conditions, infrastructure, consumption patterns or postharvest technological advancement. Data sharing, for areas with similar climate, also occurred in APHLIS. Consequently, some estimates provided may likely not reflect actual losses of areas under consideration, but rather reflect probable losses. Furthermore, beyond climatic factors, there are other drivers of PHL like infrastructural and technological development which may differ between countries and regions and can influence estimates. Each of these factors will lead to different outcomes; for instance the extent of loss in regions with similar climatic conditions but varying postharvest technological advancement is likely to differ. Hence, assumptions made based on climatic factors alone may not be sufficient to conclude on similarity of regions.

Although data supplementation through back-dated studies, data sharing and assumptions has led to a continuous supply of PHL estimates for SSA, they also increase the probability of bias in estimates. An instance is the use of loss figures from the FBS to approximate loss percentages during post-harvest handling and storage stages in the food supply chain in FAO (2011); loss percentages for the processing and packaging stages were obtained separately. However, as highlighted in the FBS procedure (i.e., FAO 2001), processing loss obtained from manufacturing surveys, when available, also make up the loss figure; hence, exclusively restricting loss figures from FBS to the post-harvest handling and storage stages increases the probability of overestimation. In light of the effect of these data supplementing strategies, the central question is: how can more reliable and updated PHL estimates for SSA be obtained?

2.5 Towards more reliable PHL estimates for SSA

Evidently, the fundamental element for reliable and updated region-wide PHL estimates is current and usable micro-level assessments, which serve as data inputs. As such, the departure point for consistent and updated PHL estimates requires reliable and adequate micro-level studies and reports. This article suggests two takeaways for obtaining more reliable PHL estimates.

First, is the need for continuous and accessible micro-level PHL assessments, which can bridge the already existing lag to reflect the possible differences in PHL over periods. Accessible micro-level studies are quite scarce, both regionally and over time. For example, when constrained by the period 2005 – 2015, a limited number of micro-level studies (articles) were accessible for this review. Affognon et al. (2015) also reports a substantial amount of unpublished PHL research, with a limited number of articles published in peer review journals, even for a wider time frame. Accessible reports of more frequent investigations are crucial in improving periodic estimates, as regular repetition of PHL measurement would provide a basis for comparing estimates over time and across improved strategies. PHL is not expected to be static; changing environmental conditions occur over time, while technological and infrastructural factors may also improve. The scarcity of studies is further aggravated by the great variety of crops for which losses can be measured, and by disaggregating by sub-regions. A regular focus on crop varieties, which are either important as staple covering about 80% of the calorie supply or as affordable sources of essential nutrients, is important for food security. Despite the importance of some legumes as major sources of affordable protein, and root/tubers as major staples in SSA, only 6.7% and 11% of reviewed studies focused on these, respectively. Of about 44% studies, which focused on fruits and vegetables, 50% assessed losses in tomatoes, while other studies focused on some other fruits and vegetables. Also, of studies reviewed, most were conducted in West (51%) and East (47%) Africa; other regions were inadequately represented. This representative imbalance in micro-level loss assessment reports makes it difficult to provide reliable periodic region-wide estimates by agricultural commodities, value chain level and countries, as FAO and APHLIS attempt to do; and it is a major cause for reliance on supplementing strategies as earlier discussed. Solving this requires continuous and balanced micro-level research across commodities, value chain levels and countries.

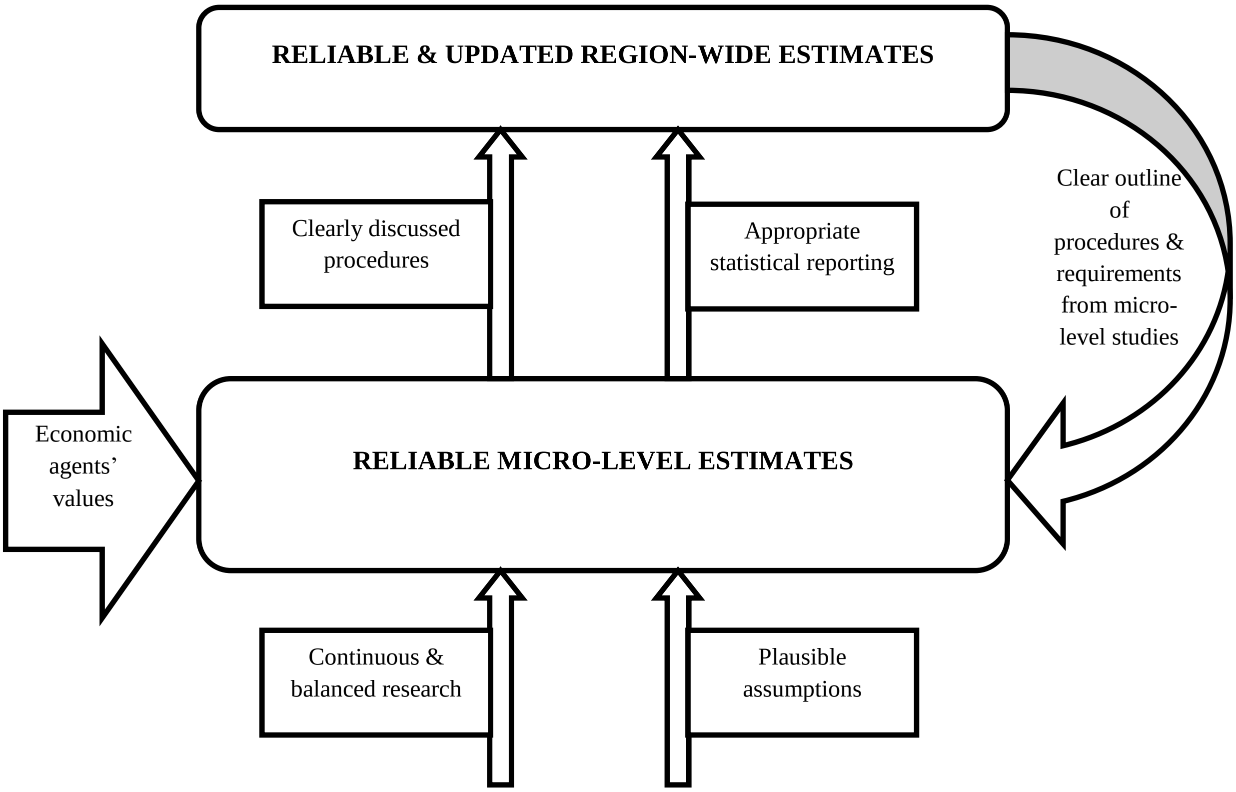

Figure 2. 2 Obtaining more reliable SSA PHL estimates

Secondly, and perhaps even more crucial, is the need for *suitable* micro-level assessments. Achieving this will require appropriate methodologies, assumptions and reporting in these studies. A major observation is that of recent micro-level studies reviewed, most are based on guesstimates. Also observed in most reviewed micro-level studies, especially those employing actual assessment, is the count of damaged produce as outright quantity loss. This can lead to a bias in estimates, especially when further assessing other aspects of PHL. One way of addressing this in micro-level studies is by combining loss assessment approaches, particularly approaches which involve interaction with the economic agents at the estimation phase and those which do not. Combining approaches also allows for comparison of estimates across approaches, which is important in assessing the tendency of bias in micro-level approaches. Irrespective of the approach being employed, thorough documentation of valid procedures for both the sampling and estimation phases of loss assessment, and proper reporting of statistics, is also required for micro-level studies to be reliable. Apart from contributing to reliable and updated national and region-wide PHL estimates, they also ensure that resources spent on such micro-level assessments are not wasted. Appropriate statistical reporting increases the probability of use, since researchers in micro-level studies cannot tell prior which statistical method will be used to synthesize estimates for regional losses, and what measures or summary statistic will be required.

2.6 Conclusion

Addressing food security in SSA requires tackling all aspects of PHL, and this in turn necessitates reliable periodic estimates, which reflect current losses and help in the assessment of progress made in PHL reduction. Despite the amount of emphasis on post-harvest loss reduction, reliable and updated PHL for the region is still a problem. A crucial element in the solution to this problem is reliable and continuous micro-level PHL assessments. Although one attributable reason for the inadequacy of micro-level assessments may be the lack of investment in this field (Affognon et al. 2015; Chaboud and Daviron 2017), this factor can only be responsible for the sparse availability of balanced micro-level studies, but not for methodological and reporting issues.

This article suggests three takeaways from the review. First, despite the advantage of subjective assessment, its prevalence as a method in more recent micro-level assessments implies that if estimates from such studies are used for region-wide computation, then updated region-wide estimates will have the nature of guesses. Tackling this (and setbacks from other methods) will require combining approaches in other studies. Secondly, poor methodologies and reporting in micro-level assessments result in unusable studies for obtaining updated and reliable region-wide PHL estimates, wasted resources, and further aggravates the problem of scarce PHL studies. The consequence is a continued reliance on assumptions and back-dated micro-level studies for region-wide PHL computations. Resolution requires increased awareness for PHL research on the importance of justifiable and appropriate methods and reporting as well as a clear outline by region-wide estimates detailing the requirements for usable micro-level studies. Finally, continuous and balanced micro-level PHL research, and policies which encourage this are required to have updated and reliable periodic loss estimates across commodities and countries.

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2.8 Appendix

A.2.1: List of reviewed studies for micro-level post-harvest loss assessments

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Chapter 3

Do Maize Farmers Utilize and Benefit Economically from Advanced Technologies for Post-harvest Loss Reduction? A Case Study from Ghana

Abstract.

Post-harvest loss reduction among farmers in Sub-Saharan Africa necessitates the continuous use of effective loss reduction strategies or advanced technologies in post-harvest activities; but this also requires that these advanced methods are economically beneficial to ensure sustained use. This study first assesses the determinants and extent of use of advanced post-harvest methods among maize farmers, and then proceeds to assess the economic benefit that accrues to farmers who use these methods in comparison to non-users. The analysis is based on survey data from farmers in Ghana. A two-stage regression model was used to assess the determinants of using advanced methods conditional on participation in the post-harvest activity under consideration, while treatment effect regression adjustment was used to assess the difference in outcomes between users and non-users. The results suggest that training and buyer power are important factors supporting and discouraging the use advanced methods or technologies in storage. The average economic benefits between users and non-users, however, do not significantly differ. These findings highlight the need to address issues that improve the economic benefits accruing to farmers to ensure sustained use of post-harvest loss reduction methods.

Keywords: Farmers; Ghana; Maize; Post-harvest loss reduction; Technology use

3.1 Introduction

Reducing post-harvest loss (PHL) in Sub-Saharan Africa (SSA) has been a discourse of interest for over a decade. PHL estimates in some cases are over 10% of annual production, and conventional post-harvest handling methods do not prevent losses effectively. For maize in Ghana, the most recent estimates show that PHL was in the range of 279 – 325 thousand tonnes between 2012 and 2013 (FAOSTAT and APHLIS database), with over 70% occurring before exchange between producers and buyers (APHLIS database). To curb such losses in maize and other grains, a number of advanced post-harvest loss reduction (PHLR) methods have been developed. For storage, these include synthetic fumigants/ pesticides, biological control and hermetic-based technologies; while advanced drying methods include solar and rotary dryers, among others. Although there is scarce discussion in the literature on the use and effectiveness of advanced drying methods, a number of studies have highlighted the effects of advanced methods employed in grain storage.

The use of synthetic fumigants/insecticides is a method widely adopted by farmers in Africa (Kimenju and De Groote 2010; Kumar and Kalita 2017). The effectiveness of this method varies according to the literature. In some cases, its efficacy on storage insects has been noted to be limited; with no significant difference in profits and grain damage when compared with untreated grains (Meikle et al. 2002), while in other cases, it is observed to be quite effective (Meikle et al. 2002; Mutambuki and Ngatia 2006, 2012). Snags such as health hazards from toxic residues, high costs and the development of genetic resistance by storage pests are associated with synthetic fumigants and insecticides (Kumar and Kalita 2017; Shaaya et al. 1997; Tapondjou et al. 2002), which may account for the observed insignificant differences in damage and profits, and further raises questions about the sustainability of this storage method. Other storage methods centred on the use of biological control and hermetic technology are less susceptible to toxic residues and ineffectiveness on resistant pests; while the hermetic technology relies on the physiological principle of insect suffocating to reduce losses (Baoua et al. 2013; Murdock and Baoua 2014; Navarro et al. 1994; Tefera et al. 2011), biological control relies on the use of plant based insect repellent or grain protectants which are not toxic for humans. In some trials, Kumar et al. (2007), Shaaya et al. (1997) and Tapondjou et al. (2002) reported significant effects of plant extracts as biological storage control for pests and microorganisms. Also, methods under the hermetic-based technology have been observed to maintain or improve viability and germination rates of seeds, minimize grain damage, reduce moisture content, reduce contamination of aflatoxins and prolong grain storage periods which is expected to result in better prices during off-peak periods (Baoua et al. 2013; Baoua et al. 2014; De Groote et al. 2013; Gitonga et al. 2013; Ndegwa et al. 2016; Njoroge et al. 2014; Vales et al. 2014). Averted monetary loss for farmers has also been reported (Njoroge et al. 2014), and based on a randomized trial experiment, profits were assessed to be higher when compared with conventional methods (Ndegwa et al. 2016). The continuous use of advanced PHLR methods could therefore drastically reduce or eliminate PHL and its resulting effects among farmers in SSA.

Inadequate rewards to farmers and the condition of markets in SSA can hamper the sustained use of advanced PHLR methods. As Hodges and Stathers (2013) note, farmers often find financial rewards insufficient and investing in technology for better quality grains worthless. Such obstacles to adoption can be aggravated by the structure of the market, particularly where buyers (marketers) can easily collude, which give them an edge over farmers and influences farmer-buyer interactions. The effect of such resulting farmer-buyer interactions on farmer’s use of agricultural technologies in SSA is barely discussed in the empirical literature. So in addition to understanding the extent and effects of use of technologies, it is also important to assess the effect of farmer-buyer interactions on the use of advanced PHLR methods, and consequently PHLR.

The aim of this study is to assess the use of advanced PHLR methods among farmers, and the consequence of buyer-power on farmers' decision to use these methods. The study also analyses the impact of advanced method use on net returns of farmers. The focus is on maize storage and drying as these are important activities in the context of maize PHL. Most technology adoption and utilization studies in SSA focus on agricultural production and pre-harvest technologies; hence, in addition to providing empirical evidence on the effect of buyers' strategic-interaction on farmers PHLR method use, this study also contributes to the literature by providing evidence on the extent and impact of utilization of advanced PHLR methods. The extent of use reflects how well these PHLR methods have permeated communities after being introduced, while the impact of use and the consequence of buyer-power on technology-use are important in designing policies that will sustain existing and future PHLR methods and in turn promote PHLR.

In the following section, we present a review on the determinants of technology use. Section 3.3 provides the analytical framework for this study. Section 3.4 presents the survey and data description, Section 3.5 discusses the results, while conclusion and policy implications are discussed in section 3.6.

3.2 Agricultural technology use and determinants

The adoption and utilization of agricultural technologies have been discussed extensively in the literature, especially for production and pre-harvest technologies. Key determinants in the literature can be classified into personal characteristics like education and household size (Abdulai and Huffman 2014; Dafale et al. 2011; Gachango et al. 2014; Lawal and Oluyole 2008; Mwebaze and Mugisha 2011; Nejatian et al. 2016; Odendo et al. 2017; Sidibé 2005; Tenge et al. 2004; Tessema et al. 2016); economic factors such as income and crop diversification, value or quantity of produce, and assets (Abdulai and Huffman 2014; Amsalu and de Graaff 2007; Anley et al. 2007; Dinar et al. 2017; Gachango et al. 2014; Gitonga et al. 2013; Isgin et al. 2008; Jara-Rojas et al. 2012; Kassie et al. 2013; Mwebaze and Mugisha 2011; Nejatian et al. 2016; Odendo et al. 2017; Tenge et al. 2004; Tessema et al. 2016); and social and institutional factors such as information and training, credit, association membership, trading relationship with buyers and access to market (Ainembabazi et al. 2017; Chavai et al. 2015; Dinar et al. 2017; Gachango et al. 2014; Jara-Rojas et al. 2012; Kassie et al. 2013; Kijima and Sserunkuuma 2013; Lawal and Oluyole 2008; Murage et al. 2015; Mwebaze and Mugisha 2011; Nejatian et al. 2016; Noltze et al. 2012; Ranawat and Ram 2015; Sidibé 2005; Tessema et al. 2016).

The focus of farmer-buyer relationship in the literature has been on the number of traders (marketers) in farmer networks as a form of social capital which can induce technology use (Kassie et al. 2013). However, some agricultural markets in SSA exhibit a case of 'short term' non-binding mergers among buyers (marketers), which is aided by strong and well organized associations. Such collaborations are more evident during interactions with authorities and other trade unions, or during transactions with farmers, and give marketers an edge. For example, in Ghana, strong marketer associations have been connected with inducing the conduct of agricultural markets in favor of members by increasing the likelihood of tacit or explicit strategic interactions among members; hence, members collude to fix prices and exercise market power in transactions with farmers, the latter who are relatively poorly organized (Britwum 2013; Langyintuo 2010; Lyon 2003; Robbins 2000; Robinson and Kolavalli 2010). Where formal and enforced contracting exists, such that suppliers (farmers) jointly contract with buyers, then buyer power may be beneficial as suppliers can confidently engage in innovations or product improvement due to the sharing of up-front cost or an assurance of sufficient rewards; however, this is not always realistic and suppliers may bear the bulk of the cost and risk of innovation or product improvement (Inderst and Mazzarotto 2008). Although buyer power can lead to underinvesting in innovations or reduce product improvement among suppliers (European Commission 1999 as cited in Inderst and Mazzarotto 2008, p.15; Federal Trade Commission 2001 as cited in Inderst and Mazzarotto, 2008, p.15; Koehler and Rammer 2012; Weiss and Wittkopp 2005), it can also be beneficial depending on the nature of buyer power. Where buyer power is a result of few, large buyers in the market, this can incentivize producers to innovate (Inderst and Wey 2007; Kai et al. 2013). However, a case of mergers or consolidated buyers, in which a limited sourcing strategy is employed and some suppliers can be ignored based on buyers' criteria, can dis-incentivize innovation or product improvement among suppliers (Inderst and Shaffer 2007; Koehler and Rammer 2012), especially when the buyer criterion is largely hinged on a ceiling price. Hence, the effect of buyer power is not clear-cut and can be double-edged.

3.3 Analytical framework

3.3.1 The decision on use of advanced PHLR strategies

We consider a farmer's profit maximization decisions subject to a given production function. For maize production and post-harvest activities, farmers utilize inputs which comprise post-harvest management strategy, $\boldsymbol{a}$, and other inputs $\boldsymbol{i}$. While he chooses the level of inputs $\boldsymbol{i}$ to use, $\boldsymbol{a}$ is fixed exogenously at this stage. Alternatives under $\boldsymbol{a}$ can be broadly classified into the use (a_u) or non-use (a_n) of advanced post-harvest methods. Given his choice of optimal level of inputs and output, the farmer's indirect profit function is given as $\pi = (\boldsymbol{p}, \boldsymbol{c}, a)$, where $\boldsymbol{c}$ is a vector of input prices and $\boldsymbol{p}$ is a vector of output prices. PHLR depends on $\boldsymbol{a}$ utilized, and with the different strategies, different PHL magnitudes are expected. For activities like storage and drying, an effective post-harvest management strategy can induce profit by minimizing or mitigating quality loss and deterioration, and consequently quantity loss; an extreme case of deteriorated produce can result in quantity loss (i.e. produce becomes unmarketable) and affect the quantity supplied.

In considering the choice of a_i, profit maximization will result in choosing the alternative that provides higher expected profit. Hence, if the expected difference between π_{an} and π_{au} (i.e. $\pi_{au} - \pi_{an}$) is represented as a_i^*, then the farmer will only choose a_u over a_n if $a_i^* > 0$ is expected. It follows that this preference for a_u will be sustained for the farmer if the expectation is fulfilled. Although a_i^* is not observed for each agent, the use or non-use of advanced methods is observed along with farmers' production variables and personal characteristics x'_{ai}; therefore, a_i^* can be transformed into a dummy a_i, such that $a_i = a_u = 1$ (i.e. use of advanced method) if $a_i^* > 0$ and $a_i = a_n = 0$ (non-use) if $a_i^* \leq 0$. The farmer's decision to use advanced post-harvest methods is then represented by eq. 1; such that the probability of use can be inferred from x'_{ai}.

$$a_i^* = x'_{ai}\beta_a + \varepsilon_{ai} \tag{3.1}$$
$$a_i = 1 \text{ if } a_i^* > 0, \text{and } a_i = 0 \text{ if } a_i^* \leq 0$$

In principle, an economic agent should be involved in a particular post-harvest (PH) activity before he considers utilizing an advanced PHLR strategy associated with this activity. Given that our sample is drawn from a wider population and not restricted to respondents involved in the PH activities under consideration, the observation of non-use of an advanced method in a specific PH activity may occur for two reasons in the sample – the first is the non-involvement in such activity, and the second is the actual choice of non-use of an advanced method given an involvement in the PH activity. Hence, from the total sample *N*, we observe three sets of respondents; the first set *K* are not involved in the PH activity under consideration, the next set *M–K* are involved in the PH activity but do not use advanced methods and the final set *N–M* use advanced methods in the PH activity under consideration. To resolve this, we model the farmer's decision on the use of advanced method in a PH activity following a two-stage process[7]; with the first stage being the decision to be involved in the PH activity and the second stage to use advanced methods in the PH activity.

To model this, we adopt a variant of Heckman's (1979) sample selection model, in which both the first and second stages are binary choice models, with the second stage being conditional upon the first. Equation (3.1) provides the specification of the second stage decision and can be transformed to:

$$P\,\{a_i^* > 0|s_i = 1\} = P\,\{x'_{ai}\beta_a + \varepsilon_{ai} > 0|s_i = 1\} \qquad (3.2)$$

With P signifying probability, s_i denoting involvement in the PH activity under consideration, x'_{ai} denoting a vector of exogenous variables (agents' personal characteristics and production variables), $ß_a$ denoting a vector of coefficients, and ε_{ai} denoting the unobservable error term.

The specification for the first stage decision, which describes if a person is involved in the PH activity, can be represented as:

$$s_i^* = x'_{si}\beta_s + \varepsilon_{si} \qquad (3.3)$$

a_i^* is only relevant for farmers who are involved in the PH activity under consideration. Consequently, a_i is only observed if farmer i participates in the PH activity and $s_i = 1$. Given the nature of our sample and the fact that both decisions from equations (3.1) and (3.3) are closely related post-harvest decisions, the error terms in both equations might contain some common unobserved factors and the case of correlated error terms (i.e. corr (ε_{si} , ε_{ai}) = $\rho \neq 0$) is suspect. If such correlation occurs, then coefficient estimates of eq. 1 from a stand-alone analysis will be biased. Therefore,

[7] It is also possible to model farmers' use of advanced method in a PH activity as a single decision in which the options will be 1) not store 2) store without using advanced methods, and 3) store using advanced methods; however, this will first require a justification that the decision is not a two stage decision. In modelling farmers' decision as a two stage decision, we jointly determine if the decision is a single or two stage decision while examining the determinants of use of advanced methods.

both equations (3.1) and (3.3) are jointly estimated using the maximum likelihood method.

Following from equation (3.2), the joint likelihood function of both equations is given as

$$L = \prod_{i=1}^{K} [\,1 - P\,(s_i = 1)] \times \prod_{i=K+1}^{M} [\,P\,(s_i = 1)1 - P\,(a_i^* > 0|s_i = 1)] \times \prod_{i=M+1}^{N} [\,P\,(s_i = 1)P\,(a_i^* > 0|s_i = 1)] \tag{3.4}$$

And the log-likelihood function, which follows from equations (3.1) and (3.3), is given as:

$$\log L = \sum_{i=1}^{K} \log(1 - F(x'_{si}\beta_s) + \sum_{i=K+1}^{M} \log(F_2(x'_{si}\beta_s, -x'_{ai}\beta_a; -\rho) + \sum_{i=M+1}^{N} \log(F_2(x'_{si}\beta_s, x'_{ai}\beta_a; \rho) \tag{3.5}$$

Where F is the cumulative standard normal distribution and F_2 is the cumulative bivariate normal distribution (see heckprobit StataCorp; Van de Ven and Van Praag 1981). The first part of equations (3.4) and (3.5) captures the effect of x'_{si} on the probability of being involved in the PH activity, while the second and third parts capture the joint effect of x'_{ai} on the probabilities of being involved in the activity and using advanced PHLR methods. For identification purpose, it is necessary to impose at least one justifiable exclusion restriction when estimating equation (3.1), such that fewer variables appear in x'_{ai} than x'_{si}. With the maximum likelihood method, coefficients ($ß_a$) obtained for the decision to use advanced PHLR method in the PH activity are marginal effects of the explanatory variables and can be interpreted as not being conditional upon the activity selection, i.e. as if the decision on use/ non-use of advanced method was observed for the whole sample (see Verbeek 2012, p.252).

3.3.2 Use of advanced PH methods and differences in net-returns and prices

Given each farmer's consideration of the expected net returns in his post-harvest decisions and the decision on the use of advanced methods, it follows that the problem of self-selection may exist such that the net returns and the choice of alternatives are correlated. Models used in impact evaluation, especially where self-selection occurs, are the Propensity Score Matching (PSM) method and the Endogenous Switching Regression (ESR) model. The objective of the PSM is to match individual observations from an observational data set, such that imbalance in other covariates which influence outcomes between the treated and control groups will be reduced. This requires that the data set is approximated as close as possible to a completely randomized experiment; however, this leads to excessive pruning of the data and consequently increases imbalance rather than reducing it (King and Nielsen 2016). On the other hand, the ESR model proposed by Lokshin and Sajaia (2004) is a two-stage model in which the first stage estimates the choice under consideration (in this case, the decision to use advanced PHLR methods) and the second stage estimates the impact on the outcome (net return). ESR provides more efficient estimates by correcting for both the unobservable and observable factors that may account for possible correlation between the decision to use advanced PHLR methods and the net returns. The structure of ESR requires that at least one independent variable in the first stage is excluded in the second stage regression. However, in our model specification, no independent variable in the decision to use advanced PHLR methods (which is first analysed with the two-stage Heckman model, as explained in Section 3.1) is conceptually justified for exclusion in the assessment of the impact on net returns. Given the lack of justification for an exclusion restriction required by the ESR model, we employ a treatment effect regression adjustment to assess the impact of the use of advanced PHLR methods. The impact from the treatment regression adjustment is reported as the difference-in-means conditional on observed variables (***x***). Following Wooldridge (2010) and Linden et al. (2016), this difference-in-means can be represented as:

$$ATE\,(\mathrm{x}) = \mathrm{E}\,(\,z_1 - z_0 \mid \mathrm{x}) \;\equiv \mathrm{E}\,(z_1 - z_0 \mid \mathrm{x},\, a = 1) \qquad (3.6)$$

Where ATE denotes the average treatment effect which is the estimated difference, ***z*** denotes net return for the different alternatives, ***a*** denotes the use of advanced methods, and ***x*** denotes the variables which could influence *a*.

We also assess the difference in output prices between the different alternatives. We do not assume output prices to be fully exogenous, we expect that certain factors ***w*** can influence difference in prices (these factors are presented in the footnote of Table 3.6); hence, we first directly estimate the difference-in-means between prices from basic statistics (E ($p_1 - p_0$)) and then compare results with difference-in-means estimates obtained from a Poisson regression after controlling for factors ***w*** (i.e. E ($p_1 - p_0 \mid$ w)).

3.4 Survey and data description

The data for this study is from a 2015 survey of randomly selected maize farmers from 13 communities in Techiman north, Techiman Municipal and Nkoranza south districts of the Brong-Ahafo region, which is an important region for maize production in Ghana. The choice of survey communities ensures representation of communities in each cardinal direction[8] within each district. A total of 303 farmers participate in the in-person interviews

[8] Given (i) the lack of sub-districts in each district (ii) the inability to sample assemblers from all communities in each district and (iii) the need to ensure that all parts of each district were represented in the selection of communities for the study, each district was sectioned into clusters that can constitute either Northern, Southern, Eastern or Western communities of the district.

which is based on a structured questionnaire[9]; due to incomplete responses only 296 of the observations are used for analysis. The questionnaire focuses on details of maize production, post-harvest activities, socioeconomic and other contextual details. To assess the nature of farmer-buyer relationship, respondents are asked how their output prices are determined, which we term 'price decision'.

Table 3.1 and 3.2 present summary statistics of variables used in the study. Table 3.1 shows that respondents do not use any form of advanced method for the post-harvest activity 'drying'. For respondents who do not dry maize on stalks in farms, drying is mainly carried out either by spreading produce on bare cement floor or on tarpaulins placed on the floor. Perhaps this explains the scarcity of literature on the use and effectiveness of advanced drying methods among African farmers.

Table 3. 1 Methods used in storage and drying activities

Methods in drying	**Respondents (Percentage)**
Advanced Methods	Nil (0.00[b])
Other Methods	
• On cement floor	21 (7.09[b])
• On tarpaulin spread on floor	61 (20.61[b])
• On raised platforms	1 (0.34[b])
Users of other methods	*83 (28.04[c])*
No specified Method (In field drying)	*213 (71.96[b])*
Methods in storage	***Respondents (Percentage)***
Advanced Methods	
• Cribs with fumigants	31 (19.14[a])
• Bagged with fumigants	64 (38.89[a])
• Silo (Hermetic drum)	1 (0.62[a])
• Hermetic bag	3 (1.85[a])
Users of advanced PHLR methods	*91 (56.17[a])[c]*
Other Methods	
• Cribs without fumigants	85 (52.47[a])
• Bagged without fumigants	24 (14.81[a])
Users of other methods	*71 (43.83[a])[c]*
Total number of storing Respondents	*162 (54.73[b])*
Non-storing Respondents	*134 (45.27[b])*

[a] Of respondents who store; [b] Of total respondents; [c] Respondents are only counted once irrespective of number of methods used

[9] A sample of questions related to this study, which enumerators asked maize farmers during in-person interviews is provided in Appendix 3.2 of this chapter.

The result differs for storage; over 50% of those who store use advanced PHLR methods, which largely constitutes of the use of fumigants. The use of hermetic technology (silos and hermetic bag) is very low – only 4 respondents indicate using this method, and there is no record of the use of biological control in storage.

Given the results on the use of advanced methods in storage and drying activities, we henceforth focus our discussion and analysis on decisions in storage activity only. The average net return over all respondents is GH¢ 423.22 per acre, the average yield is 630 kg per acre, and on average farmers sell their maize at GH¢ 111.95 per bag (i.e., GH¢ 1.12 per kg). As previously discussed, the existence of buyer power among marketers in SSA agricultural markets can be triggered by poorly organized farmers or the lack of a form of contractual agreement. Table 3.2 shows that up to 43.24% of respondents indicate that their maize prices are determined by organised marketers, while only 19.59% and 9.80% claim to be members of a farmers' association and have a form of contract with buyers, respectively. When disaggregated by groups (Table 3.3), the proportion of respondents who indicate that prices are determined by organised marketers are considerably higher among non-users of advanced methods in storage (59.15%) than users (31.87%), while the proportion of participants in farmers' associations and those having contracts are slightly higher among users (27.47% and 15.49%, respectively) than non-users (14.08% and 8.45% , respectively).

Table 3. 2 Description and Summary Statistics of Variables

Variable	**Description**	**Sample Mean (std. dev.)[e]/ Percentage of respondents [f]**
Net returns per acre	Revenue minus production and storage input and hired labour costs per acre (GH¢)	423.22 (423.42)
Farming experience	Number of years a farmer has been farming	18.93 (11.94)
Schooling	1 if farmer at least attained primary education, 0 otherwise	66.21
Household size	Number of people in household	5.10 (2.10)
Storage training from ext. agent/NGO	1 if farmer received training on storage activity from extension agents or a Non-Governmental Organization, 0 otherwise	78.38
Value of assets	Total value of assets (GH¢)	7949.99 (69577.23)
Membership in farmers' group	1 if farmer is a member of farmers' group, 0 otherwise	19.59
Off-farm paid employment	1 if farmer has an off-farm paid employment, 0 otherwise	61.49
Diversification of crops	1 if farmer plants other crops, 0 otherwise	77.70
Contract with buyers	1 if farmer has a contract with buyers, 0 otherwise	9.80
Price (GHc)	Average price farmers sells maize (GH¢)	111.95 (21.65)
Access to credit	1 if farmer is not liquidity constrained, 0 otherwise	31.42
Use of local variety	1 if farmer cultivates local variety, 0 otherwise	86.15
Use of coloured variety	1 if farmer cultivates yellow variety, 0 otherwise	18.92
Location	1 if farmer is located in Techiman, 0 otherwise	47.64
Price decision	1 if farmer indicated that maize price is determined by marketers' association or buyers, 0 otherwise	43.24
Output	Maize quantity produced (bags/acre)[d]	6.30 (3.79)

Notes: GH¢ is Ghana cedis. Exchange rate at 4th quarter 2015: ≈ 4.15 GH¢ = 1 EUR = 1.15 USD.
[d] One bag is equivalent to 100kg; [e] Only for continuous and count variables; [f] For categorical variables

Table 3. 3 Differences between groups of farmers –based on Summary statistics

Variable	ADVANCED METHODS IN STORAGE		
	Mean (std. dev.) [e] / % [f] for Users of Advanced Methods in Storage	**Mean (std. dev.)[e] / % [f] for Non-users in Storage**	**Diff. [e h]**
Net returns per acre (GH¢)	408.21 (383.89)	377.86 (486.72)	30.35
Farming experience (years)	22.26 (11.99)	19.11 (12.16)	3.15**
Schooling	60.44	71.83	-
Household size	6.00 (2.10)	4.70 (1.77)	1.30***
Storage training from ext. agent/NGO	86.81	81.69	-
Value of assets (GHc)	22806.18 (124571.4)	1923.37 (5303.29)	20914.55*
Membership in farmers' group	27.47	14.08	-
Off-farm paid employment	69.23	59.15	-
Diversification of crops	82.42	74.65	-
Contract with buyers	15.49	8.45	-
Price (GH¢)	120.52 (22.31)	107.89 (20.24)	12.63***
Access to credit	38.46	19.72	-
Use of local variety	82.42	84.51	-
Use of coloured variety	24.18	12.68	-
Location	48.35	36.62	-
Price decisions	31.87	59.15	-
Maize output (bags/acre)[d]	6.38 (3.55)	6.31 (4.13)	0.07
Number of observations	*91*	*71*	

Note: GH¢ is Ghana cedis. Exchange rate at 4th quarter 2015: ≈ 4.15 GH¢ = 1 EUR = 1.15 USD.

***, **, and * indicate the level of significance at $P < 0.01$, 0.05, and 0.1, respectively

[d] One bag is equivalent to 100kg; [e] Only for continuous and count variables; [f] For categorical variables

[h] Test of significance are one-tailed tests and the t-statistics employed to show the difference between groups is computed as $t = (y_1 - y_0)/\sqrt{((var(y_1)/n_1) + (var(y_0)/n_0))}$, where 1 signifies the use of advanced method and 0, the non-use; n_1 is the number of respondents using advanced methods and n_0 are non-users, conditional on storing; y_1 and y_0 are sample means; and degree of freedom is given as $n_1 + n_0 - 2$.

3.5 Results and discussion

3.5.1 Storage and the use of advanced method in storage

Table 3.4 presents the results of factors influencing storage and advanced method use decisions. The values under stage 1 are the marginal effects of the explanatory variables on the probability of storage. Values in the second stage are unconditional marginal effects of explanatory variables on the use of advanced methods in storage.

For identification, the exclusion restriction is imposed on the variable indicating crop diversification, which is conceptually irrelevant for the second stage decision; the availability of other income generating crops can affect the decision to store maize since farmers may need quick cash during the harvest period, but may not affect the decision on what to do in storage. Although the structure of the data suggests dependent decisions and the nesting of the second stage decision in the first, the test for independent decisions shows no correlation between ε_{si} and ε_{ai}. Hence, both decisions can be considered as independent, with the decision on the use of advanced methods not being nested in the decision to store. This implies that prior to the decision to store, farmers already decide on the use or non-use of advanced methods, should they decide to store. Therefore, any advocacy for the use of an advanced method for PHLR should not be restricted to farmers involved in storage, but to all farmers, as this may be important for future decisions.

The result shows that our variable of interest – price decision – is significant in the decision to use advanced methods in storage. The coefficient in the first stage is negative but not significant. This implies that having prices determined by a marketers association or buyers has no significant influence on the probability of farmers' choice to store maize, all other factors being constant. However, prices being determined by marketers significantly decrease the probability of farmers' use of an advanced method by about 83 percentage point ($P < 0.01$) compared with the case of prices determined by bilateral negotiations or a form of contractual agreement.

Table 3. 4 Maximum likelihood estimation results –marginal effects of variables that influence probability of storing maize and the use of advanced methods in storage.

Explanatory Variables	Stage 1		Stage 2	
	Storage decision		Use of adv. method in storage	
	Probit Estimator		Probit Estimator	
	ME	(Std. error)	UME	(Std. error)
Farming experience	0.013683*	(0.007570)	0.003767	(0.011123)
Schooling	-0.091752	(0.172070)	-0.352289	(0.247274)
Household size	0.055910	(0.042339)	0.175766***	(0.059915)
Storage training from ext. agent/NGO	0.556275***	(0.198584)	0.764391**	(0.305362)
Value of assets	0.000054**	(0.000021)	0.000023*	(0.000013)
Membership in farmers' group	0.14947	(0.228686)	0.317015	(0.315585)
Off-farm paid employment	0.290048*	(0.167533)	0.184396	(0.269523)
Diversification of crops [g]	0.176856	(0.201829)	-	-
Contract with buyers	-0.207503	(0.255599)	-0.060788	(0.350905)
Coloured variety	0.060651	(0.211875)	0.543260*	(0.319978)
local variety	0.198621	(0.249077)	-0.237582	(0.356061)
Access to credit	-0.110156	(0.176957)	0.364546	(0.287011)
Location	-0.334169	(0.204620)	-0.303659	(0.309303)
Price decision	-0.110077	(0.179772)	-0.829511***	(0.297026)
Output	0.004057	(0.020732)	0.007215	(0.031321)
Constant	-0.816160***	(0.383783)	-1.676334*	(0.867592)
Sample size (*N*)	296			
Uncensored observation	162			
Log likelihood	-271.09			
Prob>chi^2	0.0005			
$\rho_{\varepsilon si\ \varepsilon ai}$	0.2933			
Wald test of independent equations χ^2 (1)	0.19 (P = 0.6659)			

Notes: ***, **, and * indicate the level of significance at $P < 0.01$, 0.05 and 0.1, respectively
[g] exclusion restriction for second stage decision.

Prices being determined by strong buyers can increase price uncertainty, especially when the criteria used in such price determination is subjective; hence producers (farmers) who experience this may not consider it beneficial to further expend cost on improving grain quality. This empirical finding shows that buyer power in SSA agricultural markets can reduce farmers' probability of engaging in product improvement or the use of advanced methods for PHLR. Such a negative effect of buyer power based on empirical evidence is also reported by Koehler and Rammer (2012).

Regarding other determinants of the use of advanced method in storage, our results show that training in storage, household size, assets, and the cultivation of yellow maize positively influence the decision to use these methods. For storage training, the coefficient is positive and significant in both the decision to store and use advanced method in storage. Storage training by either extension agents or NGOs increases the probability of farmers' use of advanced methods by 76 percentage point ($P < 0.05$) compared with farmers having no storage training. Apart from exposing farmers to new information, such activity-specific trainings also serve as practical guides on the appropriate use of the advanced methods in storage and highlight the benefits of use; hence, farmers' expectations are heightened. A similar effect of training and information on the adoption and use of agricultural technologies is observed in Murage et al. (2015), Mwebaze and Mugisha (2011) and Noltze et al. (2012). Household size also increases the probability of farmers' use of advanced method, but has no effect on the decision to store. On average, an additional household member increases the probability of using an advanced method by about 18 percentage point ($P < 0.01$). Household size is linked to the availability of surplus labor for farmers; this is particularly important for post-harvest activities like storage, considering the labor requirement for inserting or using fumigants (the most used advanced method) on bagged maize.

Mwebaze and Mugisha (2011) also observe a similar effect of household size on the use of improved methods in post-harvest activities.

The effect of assets, which is a proxy for households' wealth, is also significant for both the decision to use advanced methods and the decision to store. Wealth is observed to positively influence technology adoption and use decision (Jara-Rojas et al. 2012; Kassie et al. 2013). In this study, each additional GH¢ 10000 value of asset increases the probability of use of advanced method by 23 percentage point ($P < 0.1$). Other variables, such as farming experience and off-farm paid employment, influence the decision to store, but do not have a simultaneous significant effect on the decision to use advanced methods in storage.

3.5.2 Differences in net returns and prices

Table 3.5 and Table 3.6 present results of the difference in net returns and prices from the regression adjustments. These differences in outcomes are presented as ATE's. The results show that on average, the net returns for those who use advanced methods is higher by GH¢ 27.92 than for non-users; however, this is not significantly different ($P = 0.682$). Conversely, the use of advanced methods in storage gives farmers the opportunity to sell their maize at significantly higher prices of GH¢ 10.99 ($P < 0.01$) compared to non-users. This result is similar to the basic statistic results (Table 3.3).

Both the basic statistic and ATE results imply that at present, it is on average not beneficial for farmers to engage in the use of advanced methods or activities aimed at reducing post-harvest loss in storage. Although farmers' output prices significantly differ between groups, the result suggests that output prices resulting from the use of advanced methods are not sufficiently high enough to earn users significantly distinct financial rewards from non-users of advanced methods. This may account for the low use and non-use of the more recent hermetic based technologies and advanced drying methods (Table 3.1); as farmers are yet to enjoy adequate rewards for the use of previously introduced in-storage technologies. This finding corroborates farmers' observation of insufficient financial rewards in supplying better quality grain, which is an offshoot of the adoption of improved technology (Hodges and Stathers 2013).

Table 3. 5 Difference in net returns–Treatment effect regression adjustment results

Explanatory Variables	Use of adv. method in storage	
	Use	Non-use
Farming experience	3.650*** (1.384)	-1.111 (2.871)
Schooling	4.919 (35.236)	51.344 (64.335)
Household size	30.839*** (8.059)	47.012*** (14.757)
Storage training from ext. agent/NGO	49.277 (63.573)	-92.354 (62.837)
Value of assets	-0.000034 (0.000069)	-0.006 (0.004)
Membership in farmers' group	-2.938 (45.355)	-51.546 (113.040)
Off-farm paid employment	32.415 (39.689)	17.212 (44.747)
Contract with buyers	93.455 (51.526)	-143.168 (196.517)
Access to credit	-58.926 (43.675)	-5.675 (52.562)
Location	38.016 (37.418)	97.615 (99.693)
Colored variety	13.264 (41.208)	-87.025 (67.213)
Local variety	74.751 (52.663)	-40.317 (68.035)
Price decision	-41.974 (34.057)	-91.826 (77.177)
Output	93.688*** (5.877)	102.026*** (6.723)
Constant	-580.522*** (142.199)	-342.622** (156.014)
Means	377.571 (33.997)	349.654 (71.922)
Number of observations	162	
Average Treatment Effect (ATE)	27.92	

Notes: ***, **, and * indicate the level of significance at $P < 0.01$, 0.05 and 0.1, respectively. Values in parenthesis are standard errors

GH¢ is Ghana cedis. Exchange rate at 4th quarter 2015: ≈ 4.15 GH¢ = 1 EUR = 1.15 USD

Table 3. 6 Difference in prices –Treatment effect regression adjustment results

	Mean Price
Users of advanced PHLR method in storage	120.07
Non-users of advanced PHLR method in storage	109.07
Average Treatment Effect (ATE)	10.99***
Number of observations	162

Notes: ** and * indicate the level of significance at $P < 0.05$ and 0.1, respectively. Outcome model is Poisson. Controlled variables are membership in farmers' association, contract with buyers, location, price decisions and maize varieties. GH¢ is Ghana Cedis. Exchange rate at 4th quarter 2015: ≈ 4.15 GH¢ = 1 EUR = 1.15 USD.

3.6 Conclusion and policy implication

Continuous use of effective post-harvest strategies or technologies that reduce post-harvest loss is important for sustainable PHLR. However, economic agents have to receive sufficient financial rewards from such strategies or technologies to choose them over less appropriate alternatives. In this study, we use survey data to assess maize farmers' use of advanced methods for post-harvest loss reduction; of particular interest is the effect of price determination on farmers' decision. Furthermore, we assess if the choice of such methods is on average more beneficial to users in comparison with non-users.

Findings show non-use of advanced technologies in drying activities and a low use of safer advanced methods in storage activities. Results from the determinants of use show that when prices are decided by buyers who collaborate, farmers are less likely to use advanced methods in storage. This suggests that the extent of buyer power in African agricultural commodity markets has a role to play in farmers' perception of economic benefits in deciding to use these methods, and can hamper quality improvement or PHLR. Also, participating in trainings specific to storage activities positively influences the use of advanced methods in storage. Both findings highlight the importance of activity-specific training and addressing issues that heighten price uncertainty in order to increase the extent of use of advanced PHLR methods.

Of significant relevance is the insufficient reward that accrues to farmers who use advanced methods in storage. Although output prices differ between users and non-users, we find that such price differences are not high enough to induce significantly different net returns between both categories of farmers; hence the use of advanced PHLR methods currently seems not economically beneficial. This implies that it is not economically sensible to introduce new and more effective PHLR technologies or encourage farmers to adopt already existing ones until sufficient rewards can be guaranteed. Farmers' cohesiveness and direct access to new and competing markets can possibly result in better rewards.

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3.8 Appendix

A 3.2: Sample of questions asked by enumerators during in-person interviews with maize farmers.

DEMOGRAPHIC AND SOCIO-ECONOMIC CHARACTERISTICS

	Questionnaire ID:	
1	Region:	
2	Community:	
3	District:	
4	Sex: ________	
5	Age:________(years)	
6	Type of Education	No formal=0, Koranic=1, Adult literacy training = 2, Primary=3, Secondary =4, Tertiary=5, MSLC =6.
7	Number of Years of Education	
8	Did you receive any formal agricultural training?	Yes = 1; No = 0
9	How long have you been farming (years)?	
10	How would you describe the scale of your operations?	Commercial/industrial production = 1 ( ); Small scale commercial/Smallholding = 2 ( ) Community project /cooperative = 3 ( ); Others = 4 (specify) ________________
11	Are you a member of any farmers association?	Yes = 1; No = 0
12	If yes, which one(s)?	Maize farmers association = 1 ( ); General farmers association = 2 ( ); Others (specify) ________________________
13	How long have you been a member of these associations?	

Kindly fill the table below on other sources of income you have received in the last 12 months.

Categorized income sources	Frequency of income [1]=Once a year [2]=Every 6 months [3]=Every 3 months [4]=Monthly [5]=Weekly	Amount per time
Livestock/fish sales		
Petty trading		
Paid employment		
Remittances		
Rent income		
Hunting/wild food gathering		
Traditional medicine		
Other1 (specify)		
Other2 (specify)		
Other3 (specify)		

Kindly fill the table below on other sources of credit for your farming activities in the last 12 months.

Source of credit [1]= farmers association/other social groups [2]=money lender [3]= Bank [4]=Friends/relatives [5]= Govt; [6]= Others (specify)	No. of times	Total Amount	Repayment schedule [1]=Once a year [2]=Every 6 months [3]=Every 3 months [4]=Monthly [5]=Weekly	Interest

Please provide us with some information on the members which make up your household.

No	Household Members	Status in the household (1=husband, 2=wife, 3=son, 4=daughter, 5=relative)	Age (years)	Education (1=none, 2=Arabic, 3=primary, 4=secondary, 5=tertiary, 6= MSLC)	Years of Education	Income earner/ [1]= agric income [2]=non-agric income [3]=No income
	Males					
	Females					

PRODUCTION

Please answer the following questions on your farm lands.

Plot	size	Tenure [1]= owned [2]= rented [3]= leased [4]= borrowed [5]= shared/ communual [6]= others (specify)	Current use [1]= cultivated [2]= Fallow	System [1]=mixed cropping [2]= sole cropping	Crops grown
1					
2					
3					
4					
5					
6					
7					
8					
9					

3.8 Appendix

Please fill the table below on the crops you cultivated in the last 12 months on your farm land.

Crops cultivated	Years of experience in cultivating crops	Season of cultivation [1] = Rainy [2] = Dry	Percentage of total cultivated farmland area allocated to crop (average over rainy and dry season)	Number of harvests	Average Quantity harvested per harvest (in bags or basins)	Amount sold per unit harvest (e.g GHC 10 per bag)

Please supply information about the quantity of input used in maize production in the last planting season.

Input	Quantity used [kg]	Amount paid for purchase (*Cedis*) (e.g GHC 10 per bag)	Transport charge for input (Cedi)
Maize seeds(in cup)			
fertilizer [1 bag ≡ 50 kg]			
Herbicides (lts)			
Insecticides (lts)			
Manure (kg/cart) [1 bag ≡ 50 kg]			
Others: 2			
Others: 3			

Please fill the following with respect to your physical farm assets

Asset	Quantity owned	Total Value (Cedi)	Life span (years)
Motor vehicle			
Motor cycle			
Bicycle			
Tractor			
Tricycle			
Tractor plough			
Tractor harrow			
Wheel barrow			
Knapsack sprayer			
Private well			
Private borehole			
Water pump			
Farm house			
Water tanks			
Generator			
Mobile Phones			
Fixed phone			
Others:			
i.			
ii.			

3.8 Appendix

Fill the table on maize varieties produced

Plot	Variety [1]=Yellow (improved) [2]=Yellow (local) [3]=White (improved) [4]=White (local)	Reasons for growing the variety	Proportion to maize cultivated on plot

MAIZE SALES DECISION

What proportion of maize produced do you use for

i	food	
ii	sale	
iii	For producing own animal feed	
iv	Others	

Please fill the table below

<table>
<tr><td rowspan="2">a</td><td rowspan="2">Do you have a contract to supply maize to with any of your customers?</td><td>Codes</td><td>Response</td></tr>
<tr><td>[1]=Yes
[2]=No</td><td></td></tr>
<tr><td rowspan="4">b</td><td>If yes to (a) above,</td><td></td><td></td></tr>
<tr><td>i) with who?</td><td>[1]=Fellow farmer
[2]=Marketer
[3]=Processor/processing companies/ feed millers
[4]= Creditors
[5]= Others(specify)</td><td></td></tr>
<tr><td>ii)For how long?</td><td></td><td></td></tr>
<tr><td>iii) Frequency of supply</td><td>[1]=Once a year
[2]=Every 6 months
[3]=Every 3 months
[4]=Monthly
[5]=Weekly</td><td></td></tr>
<tr><td>c</td><td>Who makes the decision on quantities to be produced and sold?</td><td>[1]=Based on expected demand
[2]=Farmers group/ association
[3]=Marketers group/ association
[4]=Based on contracts
[5]=Others (specify)</td><td></td></tr>
<tr><td>d</td><td>Who makes the decision on the prices you sell at?</td><td>[1]=Farmers group/ association
[3]=Marketers group/ association
[4]=Based on contracts
[6]=Based on bargaining
[5]=Others (specify)</td><td></td></tr>
</table>

3.8 Appendix

MAIZE POST HARVEST OPERATIONS AND ACTIVITIES

Please supply information about maize post-harvest operations and hired labour for various maize post-harvest operations in maize

Operation	Carried out [1] = Yes [2] = No	Hired labour						Family labour			
		Number of hired labour		No. of days	Labour cost/day	Cost (if contract)		Number of family labour		No. of days	If you were to pay cash, how much would you pay for each of the operations per day?
		Male	Female					Male	Female		
Transportation to homestead											
De-husking											
Preparation for storage											
Shelling											
Grading/ sorting											
Bagging/ packaging											
Drying											
Transporting to market											

3.8 Appendix

Please fill the table below on maize loss reduction methods/ technologies for each post-harvest activity

STORAGE

Loss reduction Methods/ technologies*	(Awareness) Do you know this method/ technology/? [1]=Yes [0]=No If yes, since when? (year)	Source of knowledge	(Utilization) Do you currently use this method/ technology/? [1]=Yes [0]=No	Have you ever used this method/ technology? [1]=Yes [0]=No	Major reason for non-use (if never used)	Acquisition cost (if used)	Operation cost (if used)	Any other cost incurred from use	Year you adopted the method/ technology	Magnitude of loss relating to harvest with method or technology (e.g ½, ¼, of harvest)	Year you stopped using the technology (if no more in use)	Major reason for stopping adoption
1.												
2.												
3.												

DRYING

Loss reduction Methods/ technologies*	(Awareness) Do you know this method/ technology/? [1]=Yes [0]=No If yes, since when? (year)	Source of knowledge	(Utilization) Do you currently use this method/ technology/? [1]=Yes [0]=No	Have you ever used this method/ technology? [1]=Yes [0]=No	**Major reason for non-use (if never used)	Acquisition cost (if used)	Operation cost (if used)	Any other cost incurred from use	Year you adopted the method/ technology	Magnitude of loss relating to harvest with method or technology (e.g ½, ¼, of harvest)	Year you stopped using the technology (if no more in use)	Major reason for stopping adoption
1.												
2.												
3.												

*List of technologies or methods are based on farmers' responses during pre-survey focal group discussions

Please fill the table below on trainings you have received for maize loss reduction methods/ technologies for each marketing activity

Activity	Training [1]=Yes [2]= No	Number of trainings	Trainers [1]= Ext. agents (MoFA) [2]=IITA [3]=NGO [4]=Others (specify)	Technolog(ies)/ Method(s) trained on	Focus of training [1]=Introduction to method/ technology [2]=Details on procedures and benefits
Storage					
Transportation					
Shelling					
Grading/ sorting					
Drying					
Bagging/packaging					

Chapter 4

Are Maize Marketers Averse to Quality Loss in Supplies? A Case Study from Ghana*

Abstract

To ensure sustainable post-harvest loss reduction, markets that are averse to quality loss and provide incentives for farmers to supply high quality produce are crucial. Such markets will be averse to quality loss, offering distinct prices and substantial rewards to farmers for the supply of quality produce. Farmers in sub-Saharan Africa (SSA), where informal markets exist, have often assessed the rewards for the supply of quality produce as inadequate. Hence, this study investigates if intermediary buyers are actually indifferent to quality loss in supplies based on two scenarios –*the informal market scenario* and *a hypothesized grade scenario*. The analysis builds on survey data from marketers in two informal maize markets in Ghana. For the hypothesized grade scenario, random effect regression was used to examine the influence of marketer-specific characteristics on premiums offered to farmers over different quality levels. The findings suggest that although informal markets seem not to adequately value loss reduction, investing in institutional infrastructures, such as grades and standards can change this. Furthermore, interaction among marketers and association participation positively influences the value marketers place on quality loss reduction. The result highlights the importance of standard grading systems and collaborating with market groups in minimizing quality loss.

JEL classifications: D81, L15, Q13

Keywords: Ghana; Informal markets; Maize; Marketers; Quality loss aversion

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4.1 Introduction

Markets and post-harvest systems that are averse to quality loss are crucial for a sustainable and integrated approach to post-harvest loss (PHL) reduction in sub-Saharan Africa (SSA). While providing safe and nutritious grains to consumers and improving grain flows in national and regional markets, such markets will offer distinct premiums for quality grades, which is important for providing suitable incentives and adequate rewards to farmers, (Hodges 2014; Hodges and Stathers 2013; Zorya et al. 2011). Policies have been designed to improve quality-awareness in markets of some regions in SSA. For instance, in West Africa, one aim of the Economic Community of West African States' (ECOWAS) quality policy (ECOQUAL) and its implementation framework—the West Africa Quality System Program (WAQSP), is to provide standard goods and services and protect buyers in member countries by strengthening standardization, quality assurance and awareness (ECOWAS 2013; Ghana Standards Authority [GSA] 2015). In Ghana, the legislative framework on food standards includes the Standards Authority Act, which established the GSA to propagate standards that ensure a safe and quality-oriented food production and management system (Ghana Ministry of Health 2013).

Such policies should improve the demand for and supply of quality, however a number of markets in SSA are still unregulated in this regard. Farmers who supply to these markets require some form of certainty of rewards that accrue from employing PHL reduction strategies. These farmers have often assessed investments in the production of good quality produce as unattractive due to insufficient rewards (Hodges and Stathers 2013), indicating that price premiums offered are either low or non-existent; hence, markets are not considered as valuing quality loss reduction. In Ghana, such markets for maize, which are directly accessible to farmers, also reflect price movements in other downstream markets (Abdulai 2000; Badiane and Shively 1998), thereby serving as an acceptable mirror of market reactions and price tolerance for quality loss reduction along the maize supply chain. The absence of standardized quality grades in these rather informal markets makes the assessment of guaranteed premiums for quality loss reduction difficult. Yet, such guaranteed premiums are necessary for two reasons; first, they enable farmers to fully understand the potential rewards for produce with reduced quality loss, which in turn is crucial for cost-benefit analysis of appropriate and effective investments in PHL reduction and for planning; and second, their levels suggest if further policies aimed at ensuring better premiums for the supply of quality produce are required in these markets.

Most studies which assess the value that accrues to reduced physical alterations or damage in products, focus on the points of exchange between marketers (intermediary buyers) and consumers; either from the marketers' angle (Amegbeto et al. 2008; Faye et al. 2004; Vandeplas and Minten 2015) or from the consumers' angle (Langyintuo et al. 2004; Mishili et al. 2009, 2011). Due to the margins that exist between the farmer-marketer exchange and the marketer-consumer exchange, such estimates do not reflect the rewards that can accrue to farmers for reducing physical alterations or damage. For maize, however, although the literature is sparse, more studies have focused on the exchange between farmers and marketers or traders (Compton et al. 1998; Jones et al. 2016; Kadjo et al. 2016). Using discount schedules (or quality grades), these studies observed significant discounts for damaged grains. The focus of loss assessed in these studies is limited to specific physical alterations—i.e., insect damage and mold; however, in making purchase decisions, marketers face an array of attributes constituting physical alterations asides insect damage and molds—these may include impurities, discoloration, germination, shriveled and broken grains. Hoffmann and Gatobu (2014) considered several quality loss attributes in their assessment, which included debris, weevils, discolored and broken grains; but the study focused on farmers as consumers and their value for reduced physical damage in self-produced maize in comparison to the market-bought maize.

This study builds on and contributes to the previous literature in three ways. First, along with simulating a grading system during the survey, we assess prices marketers pay for grains with varying losses to reflect the current markets reaction to quality loss reduction (i.e. where clearly defined grades are absent). Second, no aspect of physical alteration and damage was excluded during the assessment; this is of particular importance in assessing the value placed on loss reduction and provides descriptive evidence of the complexity of quality assessment and the resulting price overlaps in informal markets. Finally, the study provides empirical evidence on marketers' aversion to quality loss in these markets under different institutional settings.

In the following section, we describe the nature of these relatively informal markets. Thereafter, we present the conceptual framework and hypotheses for the study in section 4.3. Section 4.4 describes the methodology, while section 4.5 discusses results. The final section concludes and offers policy recommendations.

4.2 The nature of informal markets

Informal markets in SSA are of immense importance; while they serve as a socialization space for most economic agents along the value chain by creating avenues for social interaction and social capital formation (Vermaak 2017), they also offer economic benefits in the region. Farmers easily can access these markets as they face low entry barriers; hence, most of the food in Africa is sold in informal markets—for some foods, this constitutes over 70% of the market share (Gómez and Ricketts 2013; Grace et al. 2015; Robinson and Humphrey 2015). Given the ease of access of small scale farmers and traders (vendors) to these markets, they are considered as an important means of survival for traders on one hand, and a main source of food supply to consumers in both urban and rural areas on the other, especially low-income consumers (Ferreira-Tiryaki 2008; Resnick

2017; Roesel and Grace 2014). This implies that informal markets have an important role to play in food security in the region.

Various factors characterize informal markets. First, defined standards and grades are lacking, resulting in a subjective (i.e., individual and criteria specific) grading system. Hence, decisions made about the extent of quality loss and the prices to offer relate solely to the physical[10] alteration aspects of quality loss. This results in a complex relationship between price and quality (Hodges 2012). For instance, some studies have observed discounts for physical damage in markets, while others have observed even higher prices (Amegbeto et al. 2008; Faye et al. 2004; Kadjo et al. 2015; Langyintuo et al. 2003, 2004; Mishili et al. 2009, 2011; Vandeplas and Minten 2015). For maize markets of this type, the supply of grains with various degrees of physical alteration results in marketers incurring additional transaction costs. These costs consist of search costs (to locate suppliers with tolerable loss levels) and inspection costs (to determine the perceived level of loss), and equals the opportunity costs of the resources (time and effort) employed. Furthermore, the large number of smallholder suppliers increases such costs and complicates tracing supplies to suppliers. Despite these costs, marketers still face uncertain conditions due to the following reasons. First, finding suppliers offering products with acceptable level(s) of physical alteration (or no alteration) is not guaranteed. Second, marketers are constrained by time and effort, and more thorough quality inspections at the point of purchase will require more of these resources. Consequently, marketers may take samples from bagged grains, at best, and may not obtain full certainty about the total quality of a certain grain delivery at the point of purchase, or the extent to which poor grains have been mixed with good grains. Hence, marketers face the risk of not finding desired grain quality to

[10] Physical alteration aspects of quality loss differ from nutritional loss and toxicity aspects, and ensue from impurities, discoloration, infestation, mould growth, germination, defects and other aspects that are evident. In the literature, physical loss is considered as also constituting volume shrinkage or weight loss. However, we exclude this aspect of physical loss and mainly consider aspects highlighted here.

purchase and/or discovering after purchase that purchased grains are of lesser quality than initially perceived.

Another characteristic of informal markets is the lack of regulations or effective oversight to curb collusion and anticompetitive practices of associations formed by economic agents. In Ghana, such associations are common among marketers of similar agricultural produce; and although participation in organized activities is optional, compulsory membership is often required for marketers to trade in certain open markets. These associations are usually gateways through which commodity-specific information, including quality awareness, is communicated to marketers by either government agencies or other external institutions. They are considered instrumental in reducing the risks and uncertainties associated with deterioration of agricultural produce, and also serve as a form of social capital—providing social relations, access to information and informal credit based on trust, and unequivocal negotiation with government officials and other trade associations (Clark 1997; Lyon 2003; Robinson and Kolavalli 2010). Conversely, the likelihood of tacit or explicit collusion among members of such associations is high. For instance, these associations are also considered as a cartel exercising market power in transactions and members have been linked with collaborating to fix prices (including purchase prices), controlling quantity supplied as well as having exploitative credit relations with farmers, and influencing the conduct of the market in favor of members; farmers, in contrast, are relatively poorly organized (Britwum 2013; Langyintuo 2010; Lyon 2003; Robbins 2000; Robinson and Kolavalli 2010).

4.3 Conceptual framework

Based on this description of informal markets, the principle of expected utility maximization and the theory of risk aversion, we derive a framework to assess maize marketers' aversion to quality loss, and a theoretical hypothesis about the potential behavior of marketers and the effect of strategic interaction. Concepts from Jones-Lee (1974), Nicholson and Snyder (2012), and Goldberg and Roosen (2007) are adapted and modified to the context of quality loss aversion, based on the risks discussed in Section 4.2.

The fundamental assumption of the expected utility maximization model is that individuals faced with a gamble involving a number of uncertain conditions will choose the option that maximizes the expected value of the gamble. Therefore, individuals tend to avoid risky situations, including arbitrary risks (fair gambles or zero-mean risks), and prefer to pay premiums equivalent to the expected value of the risk instead (Menezes and Hanson 1970; Nicholson and Snyder 2012). Hence in our framework, we assess aversion to supply risks based on additional amounts or premiums marketers will offer for the supply of good quality, and marketers can choose either to reduce or eliminate such risk.

4.3.1 Premium for quality loss reduction

For an initial situation A, in which the probability of obtaining a lower quality of maize than desired in the market is h, and the expected outcome resulting from obtaining this lower quality is I_L (otherwise, the expected outcome from obtaining grains with equal or higher quality than desired is I_G),[11] then the expected utility of this uncertain situation for a marketer with a von Neumann –Morgenstern utility function is given in Eq. (4.1). Where $U(I_L)$ and $U(I_G)$ are utilities derived from the respective outcomes:

$$EU[A] = h\,U(I_L) + (1- h)\,U(I_G)\,. \tag{4.1}$$

In an alternative situation B where a marketer can be assured of a certain quality, he can choose to pay a premium p to reduce or avert h; then his valuation for the supply of the desired grain quality is inherent in p. If he can reduce h by an amount s by paying p, such that $0 \leq s \leq h$, then his new

[11] Given that all marketers face similar market environments, we assume similar risk probabilities except for marketers currently employing some risk reduction measure (e.g., contract with farmers).

probability of obtaining a lower quality than desired is h_0 (i.e. $h_0 = h\text{–}s$). Hence, p is a function of the extent of risk reduction, s, which he chooses, given the supply risk he faces (i.e., $p = f\,(s|h)$) and his expected utility for situation B is given as

$$EU[B] \;=\; (h_0)\,U(I_L - p) \;+\; (1\!-\,h_0)\,U(I_G - p). \qquad (4.2)$$

He will choose to pay a premium p, such that, in the worst case, he is indifferent between situation A and situation B. As such, Eq. (4.2) is his certainty equivalent of situation A. When s is up to h (i.e., $h_0 = 0$), then the risk is fully eliminated, and the supply of the particular quality is totally guaranteed. If, for such a full guarantee of a certain quality, a marketer offers a zero premium, then the certainty equivalent will be

$$EU[B] \;=\; U(I_G), \qquad (4.3)$$

and, by equating Eq. (4.1) to Eq. (4.3), we have

$$U(I_L) \;=\; U(I_G). \qquad (4.4)$$

Hence, premium p is an observable element which expresses the unobservable difference between the expected utilities (i.e. ΔU), such that $p > 0$ if $\Delta U > 0$, and $p = 0$ otherwise. Equation (4.4) implies that when the premium offered to eliminate uncertainty of quality supply or to ensure the supply of a specific quality level is zero, then the marketer is indifferent between obtaining grains below this level and grains of this level.[12] We formulate this result in our first hypothesis.

Hypothesis 1*: Marketers are averse to quality loss and offer premiums > 0 to ensure the supply of grains of specific quality, except they are indifferent to outcomes from quality loss reduction.*

[12] It is important to note that this does not suggest that the outcome obtained by the marketer is generally the same irrespective of the quality level, but only holds if the marketer offers no premium to reduce the supply risk he faces (or to ensure that he obtains a higher quality).

4.3.2 Current risk reduction measures and premiums

If p is offered to reduce h by s, then the marketer's indifference between situation A and B is shown in Eq. (4.5) which results from equating Eqs. (4.1) and (4.2):

$$h\,U(I_L) + (1- h)U(I_G) = (h - s)U(I_L - p) + (1- h + s)\,U(I_G - p) \quad (4.5)$$

The total differential of Eq. (4.5) as regards *h* and *s*, is positive and given in Eq. (4.6) (Goldberg and Roosen 2007; Jones-Lee 1974). Equation (4.6) represents the change in premium offered in response to a change in the risk of obtaining a lower quality than desired, indicating that premium offered is increasing in the risk reduction induced by *s*.

$$\frac{dp}{ds} = \frac{U(I_G - p) - U(I_L - p)}{(1-h+s)U'(I_G) - (h-s)U'(I_L)} > 0 \quad (4.6)$$

If prior to paying p, it is also possible to engage in any other risk-reduction activity (e.g., contract with farmers), then h reduces to h_1 (i.e., $h_1 < h$). Given that as s increases it tends toward h (i.e. $0 \leq s \leq h$) and that premium offered is increasing with s (Eq. 4.6), then premium offered at h_1 will be less than premium offered at h. We summarize this proposition as follows:

Hypothesis 2*: Marketers who already employ specific methods that reduce the risk of obtaining poor quality grains will offer lower premiums than those who do not*.

4.3.3 Marketers association, strategic interaction and premiums

As discussed in Section 4.2, there are two contrary sides to the existence of marketers' associations in the study area. First, these associations serve as social capital for marketers and are also a gateway for quality sensitization campaigns or information. In general, social capital has been identified as an important influence in promoting the adoption of innovations and facilitating information exchange among economic agents; while serving as a substitute where formal and legal institutions are lacking (Ahlerup et al. 2009; Lyon 2000; van Rijn et al. 2012). Hence, regarding the supply of quality grains, participation in joint activities can increase the likelihood of marketers' involvement in quality awareness campaigns and their offering of higher premiums for reduced quality.

Hypothesis 3*: Marketers who participate in the association will offer higher premiums for reduced quality loss than those who do not.*

Second, with the absence of appropriate regulations, buyer power and price fixing is induced by these associations. Since such buyer power is not countervailed by suppliers, it substantially enhances marketers' bargaining position while weakening that of suppliers. Hence, we expect marketers' involvement in such strategic interaction to have a negative influence on the additional amounts they are willing to pay to ensure quality loss reduction.

Hypothesis 4*: Marketers who strategically interact with other marketers will offer lower premiums for reduced quality loss than those who do not.*

4.4 Survey description and methods

4.4.1 Survey of marketers

The data for this study is from a 2015 survey of maize marketers in Techiman and Nkoranza maize markets, and assemblers[13] in 13 communities in Techiman north, Techiman Municipal, and Nkoranza south districts of the Brong-Ahafo region, which is an important region for maize marketing in Ghana. The Techiman maize market is one of the major maize markets in Ghana which supplies both domestic and international buyers

[13] Assemblers are community-based marketers, who purchase grains solely from farmers within communities, and either sell in markets or directly to final consumers. They are vital to farmers, particularly for the sale of small quantities of produce.

(from other West African countries), while the maize markets in Nkoranza supplies mostly local and city buyers within Ghana. In each district, we consider the cardinal directions important for stratification in selecting communities from which assemblers are sampled; while marketers in the maize markets are randomly selected. In total, 233 marketers and 61 assemblers are interviewed in an in-person survey using a structured questionnaire.[14] A total of 288 of the observations are useable, achieving a response rate of about 98%. The focus of the questionnaire is on details of maize marketing, socioeconomic and other contextual details. First, a section reflects the *informal market scenario* and collects data on marketers' current purchase pattern, particularly purchase prices and the perception of the quality(ies) purchased. A subsequent section involves the use of a *hypothesized grade scenario* and an open-ended stated preference method to elicit the value marketers place on reduction of quality loss in maize grains supplied. In both scenarios, we base quality loss assessment solely on physical alterations and damage because marketers are familiar with this.

4.4.2 Assessing the value for loss reduction under the informal market scenario

A ranked scale is used in assessing marketers' perception of the quality of grains purchased, i.e., < 30% loss, up to 30% loss, between 30% and 50% loss, and > 50%. In this case, enumerators provide no objective explanation as to what physical loss should comprise of. Hence, the decision of what constitutes loss is individually specific and subjective, reflecting what currently occurs. For each quality class indicated, marketers also provide purchase prices. Post-survey, the scale is collapsed into *good grains* and *poor grains*, with < 30% loss and up to 30% loss constituting *good grains*, and between 30% and 50% loss and > 50% loss constituting *poor grains*.

[14] A sample of questions related to this study, which enumerators asked maize marketers during in-person interviews is provided in Appendix 4.2 of this chapter.

Acceptance of *poor grains* and the comparison of purchase prices for both *good* and *poor grains* is analyzed descriptively.

4.4.3 Modeling aversion to quality loss under the hypothesized grade scenario

The data

In the second scenario, a hypothesized objective grading system is employed. The grade focuses on moderate and lower levels of physical losses –ranging from Q_{50} to Q_{100}. Each level reflects the quantity of good quality grains that can be sorted from a 100 kg bag.[15] For example, a Q_{50} level on the scale will imply that, if sorted, a 100 kg bag will yield 50 kg of quality grains and 50 kg of extrinsically defected grains and impurities, also, Q_{80} quality will yield 80 kg of quality grains and 20 kg of extrinsically defected grains and impurities. We do not assume choices to be mutually exclusive; hence, depending on preferences, marketers can choose to purchase grains with various levels of physical loss. Consequently, the only difference between this *hypothesized grade scenario* and the *informal market scenario* is the grading system. Marketers' WTP for each level on the scale is assessed, resulting in a repeated measure of WTP for each respondent.

Post-survey, we first define marketers' threshold for physical losses by the WTP value; a stated zero-amount implies that grains under consideration have no value to respondents, while an amount greater than zero implies acceptability. Next, we derive premiums across respondents for each grade level. For this, Q_{50} is used as a proxy for grains with higher levels of physical losses, and premiums for other levels on the scale (Q_{60} – Q_{100}) are obtained by deducting the WTP for Q_{50} maize grains from that of the quality level under consideration (i.e., $p_q = \text{WTP } Q_q - \text{WTP } Q_{50}$; where

[15] To ensure full understanding, these objective grades were illustrated to marketers using familiar materials during in-person interviews. For example, in an illustration of $Q_{80,}$ marketers were clearly shown that while this meant 80kg of good grains, it also implied that physical losses were up to 20kg (i.e., 20%).

p_q is the potential premium for quality q and WTP Q_q is the amount marketers are WTP for maize grains of quality q, with q = 60, 70, 80, 90, 100). Different marketers might have different payment levels for unobserved reasons; therefore, by deducting (from the base Q_{50}) we eliminate the variation in payment levels resulting from these other reasons and aim to explain only the difference resulting from the reduction of quality loss.

In order to test *Hypothesis 2 – 4,* data is also collected on purchase contracts, collusion on purchase prices and participation in the union (association). Purchase contract reflects the employment of a current risk reduction measure, and takes the value of 1 if the marketer indicates having a purchase contract with suppliers and 0 otherwise. Only 39.24% of respondents employ this risk reduction strategy (Table 4.1b). Collusion on purchase prices and participation in the union are proxies used to assess the conflicting aspects of marketers' interaction, which is induced by the existence of associations. Collusion on purchase prices is used as proxy to assess the extent of strategic interaction among marketers; this takes the value of 1 if the marketer indicated that his/her purchase prices decision is based on collaboration with other marketers and 0 otherwise. Marketers' participation in the association is also assessed and takes the value of 1 if the marketer participates in activities and 0 otherwise. Table 4.1b shows that slightly above half of marketers participate in the association activities and only about 39.24% of the marketers indicate collaborating with other marketers on purchase price. This result further reflects an attempt by marketers to collude as suggested in the literature.

Table 4.1a Summary of data

Variable (Unit/ Description)	Used statistic	Figures
Informal Market Grading Scenario (*Purchase*)		
Poor grain purchase (Respondents who indicated purchasing grains with higher physical loses)	% of total respondents	44.44
Good grain purchase (Respondents who indicated purchasing grains with lower physical loses)	% of total respondents	100
Reported purchase price for poor grains (peak [a]) (GH¢/100kg)	Min; Max; Mean [c] (Est. std. [c])	40; 180; 110.84 (23.33)
Reported purchase price for good grain (peak [a]) (GH¢/100kg)	Min; Max; Mean [c] (Est. std. [c])	40; 200; 123.62 (26.67)
Reported purchase price for poor grains (off-peak) (GH¢/100kg)	Min; Max; Mean [c] (Est. std. [c])	60; 160; 108.7 (16.67)
Reported purchase price for good grain (off-peak) (GH¢/100kg)	Min; Max; Mean [c] (Est. std. [c])	80; 190; 132.32 (18.33)
Hypothesized grade scenario (*Grain acceptability*)		
Acceptability of Q_{50} (= 1 if respondents WTP> 0 GH¢ for Q_{50}, 0 otherwise)	% of total respondents	87.15
Acceptability of Q_{60} (= 1 if respondents WTP> 0 GH¢ for Q_{60}, 0 otherwise)	% of total respondents	93.75
Acceptability of Q_{70} (= 1 if respondents WTP> 0 GH¢ for Q_{70}, 0 otherwise)	% of total respondents	99.65
Acceptability of Q_{80} (= 1 if respondents WTP> 0 GH¢ for Q_{80}, 0 otherwise)	% of total respondents	100
Acceptability of Q_{90} (= 1 if respondents WTP> 0 GH¢ for Q_{90}, 0 otherwise)	% of total respondents	100
Acceptability of Q_{100} (= 1 if respondents WTP> 0 GH¢ for Q_{100}, 0 otherwise)	% of total respondents	100
Sample size (*N*)	288	

Note: Exchange rate at 4th quarter 2015: ≈ 4.15 GH¢ = 1 EUR = 1.15 USD.
[a] Due to lack of records, prices are self-reported by marketers and in most cases provided as ranges.
[b] Periods of increased supply.
[c] Mean over all respondents is estimated based on mid-range of prices reported by each respondent.

Table 4. 1b Variables in the regression model

Variable (Unit/ Description)	Used statistic	Figures
Dependent Variable (Premiums over the reference quality Q_{50})		
Premium for Q_{60} (GH¢/100kg)	% Indifferent; Min. [a]; Max [a]; Mean [a] (Std. [a])	10.07; 5; 120; 24.81 (23.48)
Premium for Q_{70} (GH¢/100kg)	% Indifferent; Min. [a]; Max [a]; Mean [a] (Std. [a])	0.35; 5; 140; 46.83 (33.34)
Premium for Q_{80} (GH¢/100kg)	% Indifferent; Min. [a]; Max [a]; Mean [a] (Std. [a])	0; 10; 145; 57.38 (32.19)
Premium for Q_{90} (GH¢/100kg)	% Indifferent; Min. [a]; Max [a]; Mean [a] (Std. [a])	0; 10; 170; 64.79 (31.00)
Premium for Q_{100} (GH¢/100kg)	% Indifferent; Min. [a]; Max [a]; Mean [a] (Std. [a])	0; 10; 185; 75.43 (30.88)
Explanatory Variables		
Location (= 1 if marketer trades in Techiman maize market, 0 if in Nkoranza)	% of 1	50.69
Marketer type (= 1 if not an assembler, 0 if an assembler)	% of 1	79.86
Purchase collusion (=1 if purchase prices are based on collaborative agreement, 0 if not)	% of 1	39.24
Participation in association (=1 if marketer participates is active in marketing association, 0 if not)	% of 1	51.74
Purchase contract (= 1 if marketer has a purchase contract with supplier, 0 if not)	% of 1	38.19
Poor grain purchase (= 1 if marketer indicates purchasing poor quality alongside good quality, 0 if not)	% of 1	44.44
Maximum inventory of maize (tons)	Min; Max; Mean (Std.)	0.4; 900; 40.10 (88.66)
Marketing experience (years)	Min; Max; Mean (Std.)	0; 50; 14.79 (8.56)
Sample size (*N*)	288	

Note: Dependent variable is the pooled premium over $Q_{60} – Q_{100}$.'% Indifferent' refers to respondents who offer Premium = 0 over the reference Q_{50}. Exchange rate at 4th quarter 2015: ≈ 4.15 GH¢ = 1 EUR = 1.15 USD.
[a] Values are for marketers with premium > 0.

The estimation method

We use a random effect model to test our hypothesis outlined in Section 4.3 and explain the effect of additional variables on premium for reduction of quality loss in supplies. In the model, the dependent variable (p_{iq}) is the premium offered by individuals i over quality levels as defined above. Given that the decision to pay for the different quality levels is not mutually exclusive; the resulting effect is a repeated measurement of the dependent variable across respondents, similar as in a panel data set. The consequence is a potential correlation among responses, which need only be corrected in the dependent variable. Models typically used to estimate data with a panel structure are the fixed effect and random effect models. Since the explanatory variables in this case are invariant with quality levels, the fixed effect model is inappropriate as it prevents identifying these effects. The random effect model is a more suitable alternative to correct for the violation of the independence of observation in the dependent variable, while recognizing the level invariant nature of the explanatory variables.

Considering the invariant nature of the explanatory variables, the model for our estimation can be represented as:

$$p_{iq} = ß_0 + \mathrm{x}'_i ß + \alpha_i + \varepsilon_{iq} , \qquad (4.7)$$

where $\alpha_i + \varepsilon_{iq}$ is treated as the error term consisting of two components. The second component, ε_{iq}, varies with quality levels, while the first component α_i is individual-specific and does not vary over quality levels; this may include unobservable factors like marketers' preferences, aptitude, or business skills. β_0 is the intercept term and β is a (Kx1) vector of unknown parameters. x'_i is a K –dimensional row vector of explanatory variables which constitutes: (1) a set of dummy variables Q_{iq} distinguishing the quality levels corresponding to p_{iq}, (2) proxies to depict interaction among marketers (i.e., (a) participation in marketers association and (b) colluding on purchase prices. See Table 4.1b for variables description), (3) additional explanatory variables (variables description and basis for inclusion in the model are presented in Tables 4.1b and Appendix 4.1, respectively), and (4) cross-terms between dummies that depict marketers' interaction (Set 2) and the quality level dummies $Q_{70,...,}$ Q_{100} (Set 1); which allows for the analysis of the extent to which the effects of interaction among marketers differs for different quality levels.

The inclusion of dummy variables Q_{iq} allows estimating to what extent premiums, p_q, differ for each quality level. Specifically, we omit the dummy Q_{60} (i.e., the premium offered for going from Q_{50} to Q_{60}), making this our reference situation in the model. The effect of the dummy Q_{70}, for example, then provides to what extent premium p_{70} differs over p_{60}. In this setup, the test of significance for the dummy variables provides a direct test of the significant difference of premiums from the reference situation (Q_{60}). Additionally, we conduct Wald tests to determine if there are significant differences between the other premiums (e.g., between p_{80} and $p_{70,}$ or p_{90} and p_{100}).

4.5 Results and discussion

4.5.1 Grain acceptance and prices

Table 4.1a shows that in the *informal market scenario*, 44% of respondents indicate acceptance and purchase of poor quality grains. This seems to imply that more respondents have high threshold levels. However, in the *hypothesized grade scenario*, the acceptability of a low grade of Q_{50} is quite high (87.15%), implying a low threshold level. Since the Q_{50} and Q_{60} levels under the *hypothesized grade scenario* are similar to poor grains under the *informal market scenario,* the result suggests a high possibility of underreporting tolerance for poor grain where no objective grading system exists.

Table 4.1a further shows that in the *informal market scenario*, purchase prices of good quality grains are not markedly higher than those for poor quality grains, and prices overlap over some range. Good grains are purchased for as low as GH¢ 40[16] in peak periods (shortly after harvest), which is also the minimum purchase price reported for poor grains in the same period. Furthermore, purchase prices for poor grains range up to GH¢ 180 in the same period, and purchase prices for some good grains still fall within this range. Similarly, in off peak periods, both good and poor grains can equally be purchased for GH¢ 80 – GH¢ 160. Hodges (2012) referred to this as the continuous relationship between price and quality in informal markets. On one hand, this overlap may portray the conflict between the "perception of quality" and "real quality" of grains in informal markets; alternatively, it may imply that in some cases the prices for good and poor quality grains do not differ in these markets. Both reflect the implication of the lack of a standard grading system, while the latter implies that price is a poor signal of unique quality in these markets. This highlights the complexity of estimating incentives for better quality supply in informal market settings.

4.5.2 Premiums for quality loss reduction

Results show that with clearly defined grades, the majority of marketers are averse to physical losses. Only 0.35% and 10.07% are indifferent (i.e., $p_q = 0$) to Q_{50} /Q_{70} and Q_{50}/Q_{60}, respectively (Table 4.1b). Regression results in Table 4.2 and post-estimation results in Table 4.3 show potential premiums significantly differ between quality levels even for a slight reduction in physical losses. Premiums offered for all levels significantly differ from the reference quality $Q_{60.}$ On average, marketers are willing to pay GH¢ 20.69 for Q_{70}, GH¢ 31.88 for Q_{80}, GH¢ 39.33 for Q_{90}, and GH¢ 51.34 for Q_{100} over the reference situation (Q_{60}).

[16] Exchange rate at 4th quarter 2015: ≈ 4.15 GH¢ = 1 EUR = 1.15 USD

Table 4. 2 Premiums offered for reduced quality loss and determinants

	Co-efficients
Constant ($ß_0$)	36.5645*** (5.3214)
Q_{70} ($ß_1$)	20.68838*** (2.6024)
Q_{80} ($ß_2$)	31.8819*** (2.5581)
Q_{90} ($ß_3$)	39.3300*** (2.5804)
Q_{100} ($ß_4$)	51.3426*** (2.6710)
Purchase collusion [Coll] ($ß_5$)	-4.2268 (3.4221)
Participation in association [Assoc] ($ß_6$)	11.7572*** (3.1224)
Location ($ß_7$)	-4.7705 (3.3713)
Marketer type ($ß_8$)	-19.5237*** (4.3882)
Purchase contract ($ß_9$)	-6.6856* (4.0437)
Purchase poor grain ($ß_{10}$)	4.1554 (3.4959)
Maximum inventory ($ß_{11}$)	0.0147 (0.03223)
Marketing experience ($ß_{12}$)	-0.3744 (0.1948)
$collQ_{70}$ ($ß_{13}$)	14.5963*** (3.3577)
$collQ_{80}$ ($ß_{14}$)	12.4133*** (3.2448)
$collQ_{90}$ ($ß_{15}$)	10.3043*** (3.2580)
$collQ_{100}$ ($ß_{16}$)	12.0181*** (3.4296)
$assocQ_{70}$ ($ß_{17}$)	-3.9774 (3.0336)
$assocQ_{80}$ ($ß_{18}$)	-3.2530 (3.0088)
$assocQ_{90}$ ($ß_{19}$)	-1.7210 (3.0525)
$assocQ_{100}$ ($ß_{20}$)	-5.6693* (3.2347)
Wald χ^2 (20)	1576.44
Prob > χ^2	0.0000
Within R^2	0.6808
Between R^2	0.1387
Overall R^2	0.3536
Sample size/Number of clusters (*N*)	288
Number of observations	1440

Note: In the model, the variable Q_{60} was used as the base category for the explanatory variables representing quality. The coefficient values are given with $P > |z|$ test significance levels of *** $P < 0.01$, ** $P < 0.05$ and * $P < 0.10$. Values in parenthesis are standard errors. Exchange rate at 4th quarter 2015: ≈ 4.15 GH¢ = 1 EUR = 1.15 USD.

In relative terms, potential premiums for higher quality levels (Q_{80}-Q_{100}) are between 50% and 148% higher than premiums for Q_{70} (Table 4.2). Additionally we find significant differences between other quality levels (Table 4.3). On average, the potential premium offered for a 100 kg bag of grain of Q_{80} significantly differs from that offered for Q_{70} by GH¢ 11.19 ($P < 0.01$); Q_{90} from Q_{80} by GH¢ 7.45 ($P < 0.01$); and Q_{100} from Q_{90} by GH¢ 12.01 ($P < 0.01$). Similar results in Compton et al. (1998) and Vandeplas and Minten (2015) indicate higher prices or premiums for reduced quality losses in other agricultural produce. The sufficiency of these premiums as financial rewards for farmers' investments in PHL reduction needs further investigation, especially for employing integrated approaches which are neither activity-specific nor cause-specific.

Table 4. 3 Difference in premiums offered over quality levels (post-regression estimation)

Comparison	Difference in premium
Q_{70}/Q_{60}	20.68838***
Q_{80}/Q_{70}	11.1935***
Q_{90}/Q_{80}	7.4481***
Q_{100}/Q_{90}	12.0126***

Note: The coefficient values are given with $P > |z|$ test for Q_{70} / Q_{60} and $P > |\chi^2|$ test for subsequent comparisons, with significance levels of *** $P < 0.01$, ** $P < 0.05$ and * $P < 0.10$. Exchange rate at 4th quarter 2015: ≈ 4.15 GH¢ = 1 EUR = 1.15 USD.

4.5.3 Marketers interaction and premiums offered

Table 4.4 shows that both proxies for assessing the effect of marketers' interaction induced by associations strongly suggest higher premiums for quality where some form of interaction exists. Considering the cross-terms between the dummy specifying purchase collusion among marketers and the quality levels allows for the following conclusions: at a lower quality of Q_{60}, potential premiums are lower by GH¢ 4.23, but not significantly different between marketers who collaborate to decide purchase prices and those who do not. However, at subsequent higher quality levels, potential premiums for both categories of marketers significantly differ, with those who collaborate offering higher premiums of GH¢ 10.37(P < 0.01), GH¢ 8.19 (P < 0.05), GH¢ 6.08(P < 0.10), and GH¢ 7.79 (P < 0.05) more than those who do not collaborate.

Table 4. 4 Purchase collusion, association participation and difference in premium (post-regression estimation)

Quality level	Purchase collusion and difference in premium	Association participation and difference in premium
Q_{60}	-4.2268 ($ß_5$)	11.7572*** ($ß_6$)
Q_{70}	10.3695*** ($ß_5 + ß_{13}$)	7.7798** ($ß_6 + ß_{17}$)
Q_{80}	8.1865** ($ß_5 + ß_{14}$)	8.5042** ($ß_6 + ß_{18}$)
Q_{90}	6.0775* ($ß_5 + ß_{15}$)	10.0362*** ($ß_6 + ß_{19}$)
Q_{100}	7.7913** ($ß_5 + ß_{16}$)	6.0879* ($ß_6 + ß_{20}$)

Note: The coefficient values are given with $P > |z|$ test for the reference quality level Q_{60} and $P > |\chi^2|$ test for subsequent quality levels, with significance levels of *** P < 0.01, ** P < 0.05 and * P < 0.10. Exchange rate at 4th quarter 2015: ≈ 4.15 GH¢ = 1 EUR = 1.15 USD.

The cross-terms between the dummy specifying marketers' participation in association and the quality levels also show significantly higher potential premiums across all quality levels for participants in comparison with nonparticipants. Table 4.4 shows that premium differences between both groups over the quality levels range from GH¢ 6.09 – GH¢ 11.76 on average. Although these market associations likely influence the conduct of the market in favor of members and induce exploitation, the results here strongly suggest that these associations can play a role in ensuring rewards for loss reduction in supplies. The regression result supports studies (Ahlerup et al. 2009; Lyon 2000; van Rijn et al. 2012) linking group interaction and social capital to innovation uptake, growth and development, while serving as a substitute where formal and legal institutions are lacking.

4.5.4 Additional determinants and premiums offered

As regards the additional determinants of the valuation of quality loss reduction, Table 4.2 shows that there is no substantial influence of location, marketing experience, maximum inventory and the current purchase of poor grains on potential premiums, whereas marketer type and purchase contract significantly influence premiums. Theoretically, premiums offered for improved quality are expected to be higher when poor quality is being purchased, but the results do not suggest this. As discussed earlier, one possible reason for this divergence may be the likely inconsistencies resulting from subjective grading in the markets studied. Hence, disparities may occur between grains *considered* as good quality and those of *really* good quality, and, consequently, there may be no concrete difference between marketers who indicate also purchasing poor grains and those who indicate solely purchasing good grains. The interaction with cross-border traders will likely trigger significantly higher premiums in Techiman market than Nkoranza; however, the result suggests that there is no discernible difference in potential premiums between both markets. This might be due to cross-border markets also being informal. In that case, traders from these cross-border markets face a similar situation of undefined incentives for the supply of grains with reduced quality loss.

Premiums offered for quality loss reduction significantly differ ($P < 0.01$) by marketer types. On average, assemblers are more averse to quality loss and offer GH¢ 19.52 more than other marketers. These assemblers are often criticized for being exploitative, especially in remote areas where market access for farmers is limited. However, the findings suggest nonexploitation regarding valuing quality loss reduction. This result suggests the importance of assemblers in the marketing channel when tackling quality loss reduction and canvassing for better rewards for farmers, and supports findings in Sitko and Jayne (2014), where assemblers were observed to offer prices to farmers that are on average 80% greater than the retail or wholesale prices for maize.

As expected, potential premiums from marketers with purchasing contracts are lower on average by GH¢ 6.69 ($P < 0.1$) than premiums from those without contracts. This does not imply a lower aversion to quality loss for marketers with contracts, but suggests a lower risk of obtaining poor quality grains as derived in *hypotheses 2*. In most cases, these contracts are usually informal and nonbinding, hence marketers are not compelled to accept supplies or adhere to agreements if supplies are observed to be of poor quality during purchase. Also, because contracts promote traceability, the supply of poor quality or mixed grains can result in a breach of trust if observed post-purchase. This indirectly highlights the importance of marketer-farmer contracts in supply risk reduction. Poole et al. (2003) also suggested closer coordination mechanisms, such as buyer-seller contracts, as a pathway to overcoming inefficiencies in developing countries marketing systems.

4.6 Conclusion and policy implication

There is sparse empirical evidence on marketers' aversion to quality loss in informal markets in SSA. Such assessments are necessary in providing farmers with information on the potential demand and rewards for supplying produce with reduced quality loss in local markets in SSA. In this study, we use survey data to assess marketers' aversion to quality loss in maize grain supplies with reference to the *informal market scenario* depicting the current situation in our study markets and a *hypothesized grade scenario* depicting our study market where institutional infrastructure is introduced. Based on the *hypothesized grade scenario*, we test the hypothesis that interaction among marketers has a two-sided effect on aversion to quality loss. These contradictory effects were hypothesized to result from two types of interaction induced by marketers association. First are interactions resulting in collusion among association members and thereby reducing potential premiums from marketers for quality loss reduction. Second are interactions promoting quality awareness and thereby increasing members' aversion to quality loss.

We find that purchase price of good and poor grains overlap in informal markets and these markets appear not to adequately reward quality loss reduction in supplies. However, it is difficult to conclude on the value for loss reduction or the reason for the price overlap due to the subjective nature of quality assessment under *the informal market scenario*. The results from the *hypothesized grade scenario* shows that marketers are averse to quality loss and are willing to offer significant premiums to ensure the supply of grains with reduced physical damage, where well-defined grades exist. Although further research is required to assess the sufficiency of these premiums for farmers' engagement in quality loss reduction, these results suggest that the nature of markets have a role to play in the potential rewards accruing to farmers. Rewards are clearly defined when the complexities of quality assessment in the study markets are eliminated. This highlights the need for institutional infrastructure, such as grades and standards, in improving the potential rewards for the supply of quality produce quality and addressing PHL reduction in a sustainable way.

A second important takeaway is the effect marketers' interaction has on the value for reduced physical damage in supplies. Although marketers' associations in some parts of SSA are viewed as being exploitative of farmers and engaging in anticompetitive practices, we find that potential premiums offered by marketers, whose interactions are induced by these associations, indicate a higher value for reduced physical loss for such marketers; even where such interactions are considered exploitative. It is important to note that this study does not suggest that anticompetitive practices are beneficial overall or that exploitation by these groups should be institutionalized. However, it highlights the importance of interaction among marketers in raising quality awareness in SSA markets, and the role associations can play in advocating for the supply of quality produce and ensuring rewards for quality loss reduction. Hence, working with these associations towards ensuring a sustainable approach to PHL reduction in SSA is vital.

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4.8 Appendix

A 4.1: Additional explanatory variables and basis for inclusion in the model

Variables	Basis / supporting literature
Market type (identified by location)	Food quality and safety assurance, and individual sanitary standards of importing countries are important factors for exporting markets (Hathaway 1999; Holleran et al. 1999; Orriss and Whitehead 2000). Hence quality awareness and premiums should be higher in exporting markets.
Marketer type	Maize assemblers (who purchase strictly from farmers) purchase grains at higher prices than other marketers (Sitko and Jayne 2014), hence we also expect higher premiums from assemblers for quality.
Purchase contract	Purchase contracts with suppliers are a way of averting risk. Based on *hypothesis 2*, we expect marketers with these contracts to offer lower premiums.
Poor grain purchase	Current quality levels are important determinants and expected to be a decreasing function of premiums for higher quality (Zapata and Carpio, 2014). Hence, we expect that marketers who also purchase poor grains will offer higher premiums to ensure quality loss reduction.
Inventory	Marketers who store grains should be more averse to the extent of physical loss during purchase in order to reduce the probability of further deterioration in storage. Hence, we expect premiums to increase as inventory size increases.

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A 4.2: Sample of questions asked by enumerators during in-person interviews with maize marketers.

DEMOGRAPHIC AND SOCIO-ECONOMIC CHARACTERISTICS

	Questionnaire ID:	
1	Region:	
2	Community:	
3	District:	
4	Sex: ________	Male=1, female=2
5	Age:________(years)	
6	Type of Education	No formal=0, Koranic=1, Adult literacy training = 2, Primary=3, Secondary =4, Tertiary=5, MSLC =6.
7	Number of Years of Education	
8	Did you receive any formal agricultural training?	Yes = 1; No = 0
9	How long have you been marketing agricultural products (years)?	
10	How would you describe the scale of your marketing operations?	Large scale = 1 ( ); Small scale commercial/Smallholding = 2 ( ) Shared /cooperative = 3 ( ); Others = 4 (specify)
11	How long have you been marketing agricultural products (years)?	Yes = 1; No = 0

Kindly fill the table below on other sources of income you have received in the last 12 months.

Categorized income sources	Frequency of income [1]=Once a year [2]=Every 6 months [3]=Every 3 months [4]=Monthly [5]=Weekly	Amount per time
Farming activities		
Paid employment		
Remittances		
Rent income		
Hunting/wild food gathering		
Traditional medicine		
Others (specify)		

Please provide us with some information on the members which make up your household.

No	Household Members	Status in the household (1=husband, 2=wife, 3=son, 4=daughter, 5=relative)	Age (years)	Education (1=none, 2=Arabic, 3=primary, 4=secondary, 5=tertiary, 6= MSLC)	Years of Education	Income earner/ [1]= agric income [2]=non-agric income [3]=No income
	Males					
	Females					

4.8 Appendix

Please fill the following with respect to your physical assets

Asset	Quantity owned	Total Value (Cedi)	Life span (years)
Market shops			
Motor vehicle			
House			
Motor cycle			
Bicycle			
Tricycle			
Wheel barrow			
Private well			
Private borehole			
Water pump			
land			
Water tanks			
Generator			
Mobile Phones			
Fixed phone			
Others:			
i.			
ii.			
iii.			

Kindly fill the table below on other sources of credit for your marketing activities in the last 12 months.

Source of credit [1]= marketers association/other social groups [2]=money lender [3]= Bank [4]=Friends/relatives [5]= Govt; [6]= Others (specify)	No. of times	Total Amount	Repayment schedule [1]=Once a year [2]=Every 6 months [3]=Every 3 months [4]=Monthly [5]=Weekly	Interest

PROCUREMENT OF PRODUCTS

Please fill the table below on the all items you marketed in the last 12 months (agricultural).

Agricultural produce marketed	Years of experience in marketing this produce	Average Quantity procured monthly (bags or basins)	Average Quantity sold monthly (bags or basins)	Amount sold per unit (e.g GHC 10 per bag)

4.8 Appendix

Please supply information about other operating cost you incur related to marketing of maize (e.g marketing association fees, daily levies, transportation cost).

Item	Frequency [1]=Once a year [2]=Every 6 months [3]=Every 3 months [4]=Monthly [5]=Weekly [6]=Daily	Amount per time

Where do you procure your maize?

		[1]= Yes; [2] = No	Distance to point of sale
i	At farm gate from farmers		
ii	In the market from farmers		
iii	In the market from other marketers		
iv	Others (Specify)		

Please fill the table below

		Codes	Response
a	Do you have a contract to procure maize from any of your suppliers?	[1]=Yes [2]=No	
b	If yes to (a) above,		
	i) with who?	[1]=Farmers (debtors) [2]=Other Farmers [3]=Fellow Marketers (Debtors) [4]= Other Marketers [5]=Others(specify)	
	ii)For how long?		
	iii) Frequency of procurement	[1]=Once a year [2]=Every 6 months [3]=Every 3 months [4]=Monthly [5]=Weekly	
c	Who makes the decision on quantities to be procured and sold?	[1]=Farmers group/ association [2]=Marketers group/ association [3]=Based on contracts [4]=Based on bargaining [5]=Others (specify)	
d	Who makes the decision on the prices you buy at?	[1]=Farmers group/ association [2]=Marketers group/ association [3]=Based on contracts [4]=Based on bargaining [5]=Others (specify)	

Kindly fill the table below on the quality of your procurements in the rainy and dry seasons

	Quality of maize grain purchased [1] With less than 30% loss [2] With up to 30% loss [3] Between 30 – 50% loss [4] With more than 50% loss	Amount purchased (e.g GHC 10 per bag)	Quantity purchased (in bags/ basins)	Major outlet(s) for this particular purchase [1]=Other Marketers [2]=Food Processors [3]=Feed millers [4]=Livestock farmers [5]=Other consumers (specify)	Average amount sold at (e.g GHC 10 per bag)
MINOR (DRY) SEASON					
MAJOR (RAINY) SEASON					

For you last two procurements of maize grain, kindly fill the table below on the quality of your purchase and those you sold to

	Quality of maize grain purchased [1] With less than 30% loss [2] With up to 30% loss [3] Between 30 – 50% loss [4] With more than 50% loss	Amount purchased (e.g GHC 10 per bag)	Quantity purchased (in bags/ basins)	Major outlet(s) for this particular purchase [1]=Other Marketers [2]=Food Processors [3]=Feed millers [4]=Livestock farmers [5]=Other consumers (specify)	Average amount sold at (e.g GHC10 per bag)
1.					
2.					

<u>HYPOTHESIZED PROCUREMENT OF PRODUCTS (WITH SIMULATED GRDING SCHEME)</u>

What is the maximum amount you be willing to pay (in Cedis) per bag of maize supplied if your supplier can assure you of the quality of maize listed below.

MAIZE GRAIN QUALITY	MAXIMUM AMOUNT WILLING TO PAY
50 % good grain	
60% good grains	
70% good grains	
80% good grains	
90% good grain	
100% good grain	