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Farmers' grain storage and losses in Ethiopia

Measures and associates

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ABSTRACT

Storage losses at the farm are often assumed to be an important contributor to presumed large post-harvest losses in developing countries. However, reliable and representative data on these losses are often lacking. We study farmers' storage decisions and self-reported storage losses for grain based on two recent large-scale household surveys conducted in major agricultural areas in Ethiopia. We show that a relatively large share of grain production is stored by farm households themselves, mainly for own consumption, and that storage technologies are rudimentary. We find that farmers' self-reported storage losses amount to an average of 4 percent of all grain stored and 2 percent of the total harvest. These storage losses are shown to differ significantly by socio-economic variables and wealth, but also by crop and humidity. We further see strong spatial heterogeneity in storage losses, being significantly higher in the southwestern part of the country. Efforts to scale up the adoption of improved storage technologies to reduce storage losses at the farm level should take into consideration these characteristics.

1. INTRODUCTION

Wastage and post-harvest losses (PHL) in food value chains are increasingly being debated, along with the design of policies to reduce this waste (World Bank 2011; FAO 2011, 2012; Sheahan and Barrett 2017; Bellemare et al. 2017). The debate is receiving increasing attention for two reasons. First, it is assumed that reduction of food wastage and PHL will improve food security by ensuring the availability of more food at lower prices. Second, using water, land, fertilizer, and other resources for producing food that is ultimately wasted raises important environmental issues. Reducing food wastage would alleviate these environmental concerns.

The literature provides limited and widely varying estimates on PHL at different stages of the food value chain, especially so for developing countries (Parfitt et al. 2010).[1] Recent evidence shows that losses in developing countries might be lower than commonly thought. For example, based on nationally representative surveys, Kaminski and Christiaensen (2014) estimate that on-farm post-harvest losses made up 1.4 to 5.9 percent of the national maize harvest of three African countries. In a study that reviews the available evidence, Affognon et al. (2015) question the assumptions underlying high PHL estimates. On the other hand, others estimate that one-third of total food production is lost or wasted (Buzby 2013; FAO 2011, 2012).[2]

In this paper, we contribute to this literature. We focus on storage and losses that occur in storage. Although not all food losses occur at the storage stage, it has been found that an important share of loss does indeed happen during storage (e.g., Minten et al. 2016), making this a potentially promising area of intervention. Moreover, losses often tend to be concentrated in on-farm storage, presumably because producers have simple on-farm storage structures and may not necessarily have the resources to control pests or prevent rotting. While a limited number of commercially-oriented farmers store crops to engage in

[1] Post-harvest losses (PHL) differ according to the type of food, being higher for fresh produce. Kader (2005) estimates global losses of fresh produce at around one-third of total production. Gustavsson et al. (2011) estimate losses between 19 and 32 percent in the case of cereals, between 33 and 60 percent for roots and tubers, and between 37 and 55 percent for fruits and vegetables. The World Bank (2011), however, places grain losses between 10 and 20 percent in sub-Saharan Africa. FAO (2011) evaluates global food losses and waste at 32 percent of total production. Lundqvist et al. (2008) posit that about 50 percent of all food grown is lost either before or after it reaches the consumer. This compares to the estimate of Lipinski et al. (2013) of 23 percent and that of Kummu et al. (2012) at 25 percent.

[2] In the case of South Africa, it was estimated that food waste made up 2.1 percent of South-Africa's annual GDP (Nahman and de Lange 2013), due primarily to wastage at the consumption level (Oelofse and Nahman 2013). In the US, it was estimated that 10 percent of the amount spent on food was wasted (Buzby and Hyman 2012).

temporal arbitrage, most producers store with the intention of consuming their own produce later. Consequently, better storage options might have important implications for both improved income and improved food security.

We assess factors associated with storage decisions and perceived losses during storage of grain in Ethiopia using data from recent large-scale rural household surveys in the country. This topic is important for two reasons. First, losses during storage are assumed to be large in these settings (e.g., Amentae et al. 2017; Harvey 2016).[3] Given the importance of seasonal stress in rural Ethiopia (Dercon and Krishnan 2000; Hirvonen et al. 2016; Abay and Hirvonen et al. 2016), a better understanding of food storage behavior and perceived associated losses is important for informing the food policy debate towards improved food security in the country. Second, improved storage technologies are increasingly becoming available at reduced costs (Gitonga et al. 2013; de Groote et al. 2013; Baoua et al. 2014; Ndegwa et al. 2016; Williams et al. 2017). For example, hermetic closed bags have been shown to be adopted quickly in some areas in Ethiopia. Information from this analysis might therefore help in improving the targeting of efforts towards more widespread adoption of improved storage technologies in the country.

We find that a relatively large share of crop output is stored, mainly for own consumption, and that storage technologies are rudimentary. We further find that 2 percent of harvested quantities of grain are lost during storage and that farmers' self-reported storage losses amount to an average of 4 percent of the total quantity stored. The magnitude of this number is consistent across two large-scale household datasets and seems to confirm similar findings in other settings (Kaminski and Christiaensen 2014). The storage losses are shown to significantly differ by socio-economic factors and wealth, agro-ecological zone, crop, and humidity levels. For example, 4 percent of maize is estimated to be lost during on-farm storage. This compares to 1 percent for teff. We further illustrate that especially the southwest of the country is prone to high storage losses, and we estimate, based only on humidity level differences, that storage losses are expected to be on average 4 percent higher in the Gambella and Southern Nations, Nationalities, and Peoples' (SNNP) regions in the south and southwest of the country compared to the much drier Tigray region in the north. As perceptions are important for decision-making, efforts to improve the adoption of improved storage technologies that reduce storage losses at the farm level should take into consideration these characteristics.

This paper is organized as follows. In the second section, we first describe the econometric methods employed to study the associates of the decision to store grain and of crop damage during storage. Then we discuss the spatial coverage and sampling of the household datasets used for the analysis, characterizing the households in terms of the variables used in the econometric analyses. In section three we discuss descriptive and econometric analyses results on crop storage, while we present results on crop losses during storage in section four. We conclude in section five.

2. ANALYTICAL METHODS AND DATA

2.1. Analytical methods

A number of factors might influence storage behavior of households. First, a household's decision to store crops is influenced by the type and quantity of crops to be stored and the storage facility and crop protection technology at its disposal. In this regard, the likelihood of storing crops is expected to increase with the quantity that a household can dispose into different uses.[4] The likelihood to store crops increases if households perceive their storage facilities can withstand damage to the crops (Omotilewa et al. 2016). The nature of the product is crucial in determining whether and, more importantly, for how long

[3] For a different view, see Hengsdijk and de Boer (2017).

[4] Note, however, that we are not suggesting that higher outputs cause storing of crops since households may, ex-ante, decide to store the crops and produce higher output simultaneously or in the order given.

households will store harvests, since a number of crops are not suited for being stored. While grain - the most commonly grown crops in Ethiopia - can generally be stored for a considerable period of time, yet some grain are more susceptible to specific types of storage or pest-related damage than others.

Second, location specific factors – such as agro-ecology and climate, proximity to markets, and seasonal price gaps – are also among important factors that influence whether and how much of the harvest is stored. Households are less likely to store crops if they reside in an area where the relative humidity is high, since crop rotting is more likely to occur in such areas. Temperature seemingly has an ambiguous effect. In low rainfall areas, a higher temperature could reduce the moisture in stored crop and increase the likelihood of storing crops, as lower storage losses are seen in well-dried crops. However, higher temperatures could also create a favorable environment for insect infestation in wetter areas. Relative to households located farther from markets, those in close proximity may not store or may store a lower quantity, since they can more easily purchase their food at a later period (Hoddinott et al. 2015; Basu and Wong 2015; Omotilewa et al. 2016; Barrett and Dorosh, 1996). Seasonal price differences matter for storage as they might indicate possible rates of return to engaging in on-farm storage (Kaminski and Christiaensen 2014).

Third, storing decisions are also influenced by household characteristics. For example, the size of a household is an important characteristic as it determines the households' food need and storage depletion rates as well as the availability of labor to care for stored crops. Moreover, household head's demographic characteristics (gender, age, and education) influence storage decisions through their effect on the head's attitude towards risk and experience in crop storing.

Finally, the wealth of the household is important for storage decisions as it might be associated with time and risk preferences, liquidity constraints, and access to capital for investments in improved storage methods (Omotilewa et al. 2016).

Households' storage decisions can be analyzed as a function of these variables using appropriate econometric methods. However, some of these explanatory variables are choice variables that may be correlated with unobserved household characteristics that can potentially influence crop storage decisions (Kaminski and Christiaensen 2014). In such cases, estimates of the choice variables are inconsistent as they may be picking up the effects of unobservable household characteristics not included in the analyses. For a causal interpretation, it is more appropriate to use a reduced form equation that relates a household's storage decision with two groups of variables: variables that proxy the choice variables; and observable household characteristics and location specific factors that directly influence storage decisions in addition to their indirect effect through the choice variables.

We follow Kaminski and Christiaensen (2014) in using a reduced form crop storage decision equation. Let household *h*'s net benefit from storing grain crop g, S_{gh}^*, be given as:

$$S_{gh}^* = \alpha + \beta' X_{gh} + \delta' Y_{gh} + \gamma' D_g + \delta' Z_{gh} + \varepsilon_{gh} \qquad (1)$$

Where X_{gh} is a vector of variables representing observable characteristics of household *h* that produces grain type g, Y_{gh} stands for variables used as proxies for those that are potentially correlated with unobservable household characteristics. D_g stands for crop dummies and Z_h for location specific factors. ε_{gh} is a normally distributed stochastic term. A household's net benefit from storing crops is a latent unobservable variable. We only observe the household storing/not storing the crop, which occurs if storing the crop entails a positive/non-positive net benefit, respectively. Given S_{gh}^* the observable choice of the household can be written as

$$S_{gh} = 1 \text{ if } S_{gh}^* > 0 \text{ ; } S_{gh} = 0\text{, otherwise} \qquad (2)$$

Given this setup, we use a probit model to estimate the crop storing decision equation as a function of observable household characteristics; locational/agro-ecological variables (temperature, relative humidity[5], and administrative zone dummies[6]); and a set of crop, household, and location specific proxy variables. The latter includes a proxy for household income (wealth index[7]); and variables that capture the household's economic incentives that influence its decision on crop storage and storing technology/protection used (seasonal producer price gap, seasonal retail price gap[8], distance of larger town/urban center near village, and distance of the nearest market); and crop and harvest month indicators.

Households that do not cultivate grain may systematically differ from those that cultivate these crops. For instance, they may be residing in an area where the soil is not favorable to grow grain crops. In such cases of sample-selection, biased estimates result unless the sample-selection bias is controlled for. In our empirical analyses we account for the sample selection bias by including in equation (2) the inverse Mill's ratio or non-selection hazard of grain growers obtained from a first-stage Heckman's sample selection regression. The first-stage analysis is conducted by including households that did and did not cultivate grain and using as instruments variables that influence households' choice of crops grown but not the decision to store crops, such as land quality and slope, percent of households in the district that cultivate grain crops, and the percentage of total area in the district sown to such crops.

Finally, for the analyses that study factors associated with damage during storage, we posit that most of the factors listed above influence the likelihood of occurrence and extent of damage in the event that the crops are stored. Accordingly, we estimate a probit model to investigate factors associated with the occurrence of damage, whereby we use as a dichotomous dependent variable that takes a value of 1/0 if damage occurred/did not occur as the left-hand side variable. Moreover, to determine whether and to what extent the factors influence losses during storage we estimate a Tobit model.

2.2. Data

This study relies on two household survey datasets. The first dataset was collected in the midline survey of the Feed-the-Future (FtF) program, a United States government global initiative to improve agricultural production and nutrition in a number of developing countries, including Ethiopia. The survey was conducted in July 2015 and covered 84 woredas (districts) in five regions of the country: Tigray, Amhara, Oromiya, Somali, and SNNP region. Nearly 6,700 households, sampled to represent 5.9 million households, were surveyed. For this study, we analyzed data from 5,092 sample households in Tigray, Amhara, Oromiya, and SNNP region who produced at least one of 22 types of grain crops. This survey sample subset represents 4.6 million households in 79 of the 84 districts surveyed in the FtF midline survey.[9]

The second dataset was collected in the midline survey of the Agricultural Growth Program (AGP).[10] The survey was conducted in June 2013 and covered about 7,500 households (sampled to represent 9 million households) that resided in 93 woredas of Tigray, Amhara, Oromiya, and SNNP regions, with high

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[5] Long-term average temperature and relative humidity variables are calculated for each woreda/district that the households resided using daily temperature and humidity data that spans from January 1981 to December 2015.

[6] Ethiopia has 11 regions, which are subdivided into 94 administrative zones and 740 woredas/districts.

[7] Household wealth index is the score for the first component of a principal components analyses applied on household durable assets, livestock, and construction materials used to build homes (roofs and floors).

[8] The price gaps are calculated by taking the difference between zonal average lean-season (May-August) and harvest season (November-February) prices. Meher season crops are harvested mainly during November-February. The FtF dataset indicates that in nearly 90 percent of the observations the crops were harvested during November 2014-February 2015.

[9] We exclude from the analyses households in the predominantly pastoralist region of Somali, which accounted for 1.2 percent of grain producing households, for comparability of the two datasets used in the study. Furthermore, data for a number of variables essential for the analyses are missing for a considerable number of households in Somali region.

[10] See also Bachewe et al. (2014) and Berhane et al. (2013) for more on sampling in the FtF and AGP surveys, respectively.

potential in grain production.[11] The sub-sample analyzed for this study consists of 5,749 grain producers, which represented 7.0 million households residing in all 93 districts covered in the AGP midline survey.

The FtF and AGP midline survey datasets used in this study pertain to the 2014/15 and 2012/13 meher seasons, respectively. Meher is the major cropping season in Ethiopia that follows the major rains during May to September.[12] Although we also conducted the descriptive analysis on grain storage and damage during storage using belg season data, we omit these results given that they provide relatively few additional insights.[13] Furthermore, the study focuses on grain crops for three reasons. First, grain constitutes the most important crop category, accounting for 88 percent of the nationwide crop area and 74 percent of the crop output during the 2014/15 meher (CSA 2015a, 2015b).[14] In the FtF midline dataset, the share of grain in total cultivated area is about the same at 87 percent, while the share of grain output was slightly lower at 70 percent. Second, unlike other crop categories, such as vegetables, root crops, enset, fruits, and other horticultural crops, grain is cultivated in most parts of the country. Finally, all grain crops can potentially be stored using fairly similar storage facilities and for a considerable period of time, as opposed to these other crops. We refer the other crops for future studies since it is difficult in a single study to appropriately cover such diverse crop types with important differences in storage methods, lengths of storage, and types of damage.

The comprehensive household questionnaires used in both FtF and AGP midline surveys were prepared to gather data that can be used to investigate diverse issues. This study mainly uses data collected in the crop production section of the surveys, especially data dealing with crop utilization, storage, and damage during storage. In this part of the questionnaire the respondents were asked whether they stored crops, the number of months harvests were stored, whether and how much of the harvest was damaged during storage, and their subjective assessment of the severity of damage. Data were also collected on the proportion of their harvest that was home-consumed, sold, or used as seeds and for other purposes.

While such large-scale and multi-purpose household surveys are valuable for a number of inferences, they can generate in-depth information for only a limited number of issues or may not cover all research questions to the desired depth as single-purpose surveys can. In this respect, both the FtF and AGP midline surveys have shortcomings as data were not collected on the causes of damage. Moreover, in both surveys data were collected only on the proportion of crops totally lost during storage, which may ignore losses in nutritional value of crops damaged but not totally lost.

There are two caveats related to the FtF midline dataset in particular. First, the questionnaire used in the FtF survey does not directly inquire on the quantity of grain stored, in contrast with the AGP midline survey. We compute the quantity stored for households in the FtF dataset by deducting from total disposable output the quantity that was sold in the same month the crop was harvested. Given this indirect method, caution is needed when interpreting the results on quantity stored obtained from the FtF midline survey. However, we note that the results generally are similar to those obtained from the AGP midline survey dataset, indicating that the assumption used in our computations was reasonable.

[11] Currently, the AGP includes all regions of the country except the predominantly pastoral regions of Afar and Somali, and Addis Ababa, the capital city.

[12] The second cropping season, belg, follows the shorter rains starting in March. Although belg production is important in some parts of the country its contribution to overall area and output is lower. The FtF dataset indicates that the area cultivated during belg accounted for 6 percent of the total cultivated area during meher and belg 2014/15 while belg season output accounted for 5.2 percent of the total output.

[13] We can provide these results upon request.

[14] These shares changed little during the last decade (Bachewe et al. 2017).

Second, the proportion of households that reported to have stored grain in the FtF dataset appears lower than the proportion that actually store the crops.[15] The number of households in the FtF survey that reported having stored grain may have been lower because what constitutes storing a crop was not precisely defined in the FtF survey instrument. In contrast, in the AGP midline survey there was an additional question that prompted households to choose the storage technology they used from a list of different methods, which may have helped respondents in better defining what storing a crop meant. This difference in how information on storage of crops was obtained from survey households should be kept in mind in interpreting and comparing results related to crop storage across the two surveys.

2.3. Demographic and farm characteristics of households

Table 2.1 summarizes household characteristics from the FtF and AGP midline datasets, including most of the variables used in the econometric analyses. Households in the two datasets display similar characteristics. Our description below focuses on households in the more recent FtF midline survey dataset. The dataset used in this study includes 12,231 crop level observations, so an average household produced 3.2 types of grain crops during meher 2014/15. There were about 5 members in an average household, 25 percent of the households had female heads, and an average head was nearly 45 years old at the time of the survey. About 30 percent of the heads were literate and an average literate head had completed fifth grade.[16] Total crop and grain area averaged 1.26 and 1.04 hectares (ha), respectively, while total disposable grain output[17] averaged 915 kg.

Seasonal gaps of producer and retail grain prices averaged 1.9 and 1.3 birr/kg, representing 24 and 12 percent, respectively, of the price gaps. The distance to the closest town of 50,000 or more population averaged 18 kilometers, while distance to the nearest daily or periodic market averaged 11 kilometers. Long-term and post-harvest year temperature averaged 19.8°C and 20.0°C respectively and the respective values of average relative humidity were also close at 60.8 and 62.3 percent.

[15] We present two pieces of evidence for this. The first evidence is the large discrepancy between the proportion of harvest home-consumed (Table 3.2, column 8) on the one hand and the proportion of observations in which crops were stored (Table 3.1, column 5) on the other. That crops were stored in only 47 percent (5,488) of the observations implies that in the remaining cases all of the output was put to use in the few days after harvest since crops stored even for few weeks are taken as legitimate cases (of storing crops). This, in turn, implies the quantity of grain used for home consumption should be little or else it should involve storing. However, the data contradict this claim. Out of the 6,110 cases in which crops were not stored, households used all (100%) of the harvest for home consumption in 47 percent (3,128) of the cases, out of which the harvests exceeded 100 (200) kilograms (kg) in 65 (36) percent. The other evidence is the finding in the AGP midline survey dataset that a considerably higher proportion of households store the crops and these proportions are higher than the proportion of most crops home-consumed, the latter of which is similar in both datasets.

[16] Unlike other variables, the proportion of literate heads and household wealth index are considerably different in the two datasets.

[17] Disposable output is computed as total/gross output less payments in kind made for hired-in labor and land rented or sharecropped.

Table 2.1. Descriptive statistics of grain producing households

Variable	FtF midline survey (2014/15) Mean	Standard deviation	AGP midline survey (2012/13) Mean	Standard deviation
Average number of grain crops cultivated	3.17	1.50	2.92	1.39
Household characteristics				
Female headed households (percent)	25.4		26.6	
Age of household head (years)	44.7	14.73	44.5	14.64
Household heads with primary education (percent)	18.3		26.3	
Household heads with secondary education (percent)	12.0		10.0	
Highest grade completed by literate heads	5.1	2.76	4.4	2.57
Household size (number of members)	5.09	2.15	4.92	2.06
Household wealth index*	0.16	1.71	0.21	3.12
Total household crop area (ha)	1.26	1.29	1.29	1.66
Total grain area (ha)	1.04	1.10	1.04	1.22
Total grain output (kg)	915.1	1,043.2	925.9	1,047.0
Community/village characteristics				
Seasonal producer price gap (percent)[a]	24.4	19.57	23.8	17.48
Seasonal retail price gap (percent)[b]	12.1	15.09	19.9	17.41
Distance of town near village (km)	17.7	65.47	14.5	17.42
Distance of market near village (km)	11.0	9.46	11.1	9.56
Number of months between harvest and interview	7.3	1.44	7.2	1.15
Average annual temperature[c]	19.8	2.57	19.8	2.94
Post-harvest year average temperature[c]	20.0	2.58	19.9	3.12
Average annual relative humidity[c]	60.8	4.43	60.9	4.49
Post-harvest year average relative humidity[c]	62.2	7.58	68.3	9.41
Number of households	5,092		5,749	
Number of crop-level observations	12,231		12,807	

Source: Authors' computation using AGP (2013) and FtF (2015) midline survey datasets except those with superscripts of a, b, and c, which are from CSA (2017a), CSA (2017b), and NASA (2017), respectively.

3. Grain crops storage and associates of the decision to store crops

3.1. Grain storage

In this section, we analyze patterns in grain storage. A number of stylized facts can be deducted from this analysis. First, a large share of farming households store crops, but the share depends on the type of crop. Table 3.1 indicates that out of 5,092 households that produced one or more type of grain crops, the proportion that cultivated maize (53 percent) was the highest followed by those that cultivated teff (43 percent) while a lower proportion (10 percent) cultivated oilseeds.[18, 19] Out of grain-producing households covered in the FtF midline survey, about 56 percent stored harvests of one or more types of crops (Table

[18] For exposition purposes, we categorize 17 grain crops into three groups in the tables presented in this and next sections. Millet, oats, dagusa (finger millet, *Eleusine coracana*), sinnar/gerima (wild oats), and rice are grouped into *Other cereals*, while *Pulses* includes eight crops: horsebean, lentils, shiferaw/haleko (*Moringa*), chickpea, cowpea, adenguare (kidney bean), vetch, and haricot beans. Four crops are included under *Oilseeds*: linseed, groundnut, sesame, and nueg (niger seed, *Guizotia abyssinica*). Data on PHL and crop utilization of all crops were collected at crop level. The summary in the tables are computed for the three crop groups as follows: quantity stored and disposable harvest (kg), and cultivated area (ha) are computed by summing the respective quantities of the crops in each group. Households that produce or store one or all of the crops in each crop-group are considered equally. The proportion of harvest stored is computed by dividing the sum of quantities stored to the sum of disposable outputs. We also use the latter method to compute the proportion damaged and utilized for different purposes.

[19] National agricultural production estimates from CSA for the same 2014/15 meher season (CSA 2015a, 2015b) indicate that a similar proportion of farmers nationally cultivated maize (56 percent) and teff (42 percent), while the estimate of those nationally that cultivated oilseeds (19 percent) was higher that the FtF survey estimates.

3.1). When considering observations at individual crop level, harvests were stored for about 47 percent. Teff and maize are not only produced but also stored by the two highest number of households. However, the proportion of households that stored sorghum and other cereals was higher relative to those that stored teff, wheat, and maize. Oilseeds are stored by the lowest proportion of households.

Table 3.1. Households producing and storing grain and cultivated area, meher 2014/15

Crop	Households that cultivated crop		Households that stored crop		Average crop area (ha)		
	Number	Percent	Number	Percent	Non-storing	Storing	All
Teff	2,193	43.1	1,122	51.5	0.49	0.62	0.56
Barley	1,203	23.6	540	44.9	0.35	0.45	0.40
Wheat	1,482	29.1	725	49.0	0.37	0.56	0.46
Maize	2,691	52.8	1,233	45.8	0.29	0.44	0.36
Sorghum	878	17.2	507	57.7	0.46	0.82	0.67
Other cereals	765	15.0	437	57.1	0.32	0.42	0.37
Pulses	1,899	37.3	773	40.7	0.30	0.44	0.36
Oilseeds	487	9.6	129	26.8	0.82	0.97	0.86
Aggregations							
Households	5,092	-	2,874	56.4	0.72	1.29	1.04
Crop groups (8)	11,598	-	5,488	47.3	0.38	0.54	0.46
Crops (22)	12,231	-	5,698	46.6	0.38	0.52	0.44

Source: Authors' computation using FtF midline (2015) survey dataset.
Note: To clarify our discussions, we may use one or more of the three levels of data aggregation listed in the last three rows of this table. The first and most disaggregated level comprises 22 crops and 12,231 crop level observations. When the 22 grain crops are categorized into the eight crop groups listed in this table (as well as in other tables in this document), the number of observations is reduced to 11,598. The third level of aggregation comprises the 5,092 households for which data from the FtF midline survey (2014/15) was analyzed.

Second, households that store a crop are characterized by higher output of that crop. The numbers in Table 3.1 indicate that an average household that stores [all types of] grain crops cultivates a larger area. This seems intuitive given that households that allocate larger areas to crops are expected to produce more and, hence, are more likely to store, be it for own consumption or for sale. Furthermore, the data in Table 3.2 indicate that households that store crops have relatively higher average yields (gross output per ha) in all crops.

Table 3.2. Grain output and utilization, meher 2014/15

Crop	Disposable output (kg)			Disposable output per ha (kg/ha)			Percent utilized for			
	Non-storing	Storing	All	Non-storing	Storing	All	Con-sumption	Sale	Seed	Other uses
Teff	243	376	312	598	693	648	65.9	24.7	7.4	2.0
Barley	363	474	413	1,059	1,096	1,076	74.8	10.8	12.7	1.8
Wheat	401	692	543	1,068	1,217	1,141	67.9	17.3	13.3	1.5
Maize	336	709	507	1,372	1,729	1,535	82.2	12.5	3.1	2.2
Sorghum	300	558	449	773	868	828	84.4	8.0	5.8	1.8
Other cereals	307	476	403	948	1,172	1,076	80.0	8.8	7.1	4.1
Pulses	209	337	261	857	841	850	66.2	22.6	9.7	1.5
Oilseed	223	261	233	346	390	358	19.8	72.6	6.5	1.1
Average	297	519	402	953	1,103	1,024	71.3	18.8	7.9	2.0

Source: Authors' computation using FtF midline (2015) survey dataset.

Third, households store for sale as well as own consumption purposes. The last four columns of Table 3.2 underline the subsistence nature of crop production in Ethiopia where at least 65 percent of the harvest is home-consumed for all crops except oilseeds, which for the most part are produced for sale. With nearly 25 percent teff output sold, it is the most commercialized cereal. Moreover, patterns in utilization of crops among households that do and do not store harvests is about the same with 72 and 70 percent used for consumption and 19 and 18 percent sold, respectively.[20]

Fourth, households that store, store a relatively large part of their production. Table 3.3 summarizes the quantity and proportion of grain stored for households in the FtF midline survey. The table indicates that the estimated proportion of disposable harvest stored ranged from 81 percent in pulses to nearly 88 percent in barley and oilseeds. The AGP midline dataset, in which the households reported the quantity of harvests they stored, indicates that the proportion of harvest stored was the lowest in wheat (78 percent) and highest in oilseeds (89 percent). Despite differences in data collection methods and computations involved, both datasets indicate that households that store grain generally store about 80 to 90 percent of their disposable harvest.

Table 3.3. Quantity of grain and number of months stored, meher 2014/15

	Quantity stored		Number of months crops were stored,	Percent of households that stored crops for ... months			
Crop	kg	percent	average	0 to 3	>3 to 6	>6 to 9	>9 to 12
Teff	300	81.8	6.2	17.6	43.4	25.3	13.7
Barley	405	87.8	6.3	16.5	38.1	34.4	10.9
Wheat	569	85.1	6.1	16.9	42.5	30.5	10.0
Maize	573	84.5	5.4	20.6	52.6	20.8	5.9
Sorghum	463	86.4	6.8	8.3	33.9	46.0	11.8
Other cereals	396	86.4	6.0	11.7	53.8	25.2	9.4
Pulses	256	80.8	5.6	22.0	45.4	24.1	8.5
Oilseed	242	87.5	6.2	21.5	35.6	28.9	14.1
Average	422	84.2	6.1	16.9	43.2	29.4	10.6

Source: Authors' computation using FtF midline (2015) survey dataset.

Fifth, households store mostly for about six months. Data were collected by crop on the length of storage. The analysis of these data show that households store harvests for about six months (Table 3.3, fourth column) and this is similar across crops, with a difference in average storage period of only six weeks between the crops stored for the shortest and longest periods. The last four columns of Table 3.3 indicate that, out of 5,488 crop group level observations in which grain was stored, the highest proportion, 43 percent, was stored for three to six months. The proportion stored for six to nine months is higher than that stored for three or fewer months and over nine months combined.

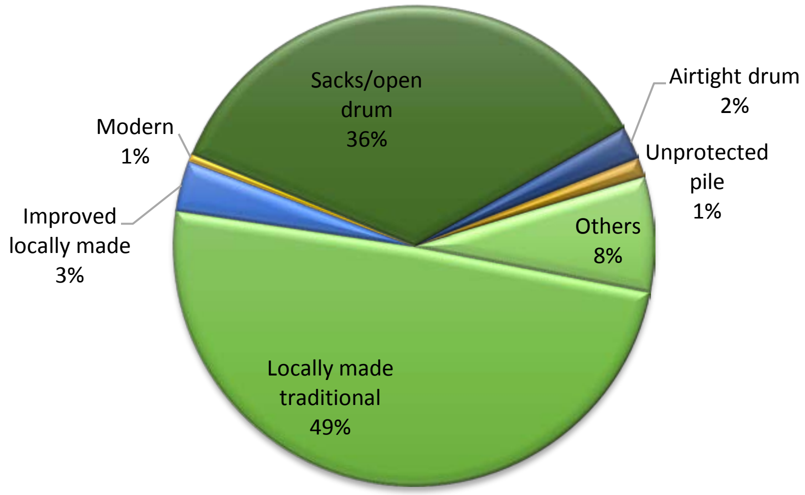
Finally, storage methods are rudimentary. Data on how and where farmers stored their harvest was collected in the AGP midline survey. We summarize the data in Figure 3.1. This indicates that during the 2012/13 meher season a high proportion (49 percent) of grain crops were stored in traditional locally made storage material. [21] The next highest proportion (35 percent) were stored using sacks or open drums. The two traditional storage methods were important in the order given for six of the eight crop groups listed in the tables above, together accounting for at least 83 percent of the storage method in all crops. Unprotected piles were used in 1.3 percent of households. Modern storage was used in only 0.6 percent of the cases. The order of importance of the storage techniques depicted in Figure 3.1 for an average crop

[20] However, the numbers in Table 3.2 differ from national figures. CSA (2015b) indicates that relative to the numbers in Table 3.2 the national proportions used for consumption are lower in all crops except oilseeds. In contrast, the proportions sold are higher by 5 percent for pulses and at least 15 percent higher in the remaining crops. That is, relative to the FtF midline survey dataset, the nationwide figures imply a higher level of commercialization.

[21] That is, out of 8,366 crop group observations in which harvests were stored locally made traditional stores were used in 4,134.

also held in all eight crops, except that modern stores were more important than unprotected piles in oilseeds and other cereals.

Figure 3.1. Technology used to store crops, meher 2012/13



Source: Authors' computation using AGP midline (2013) survey dataset

3.2. Associates of the decision to store grain crops

Results of the econometric analyses to study the associates of households' decision to store grain crops are provided in Table 3.4. Columns 2 and 3 and 4 and 5 provide results obtained using the FtF and AGP midline survey datasets, respectively. Whenever statistically significant, the estimates obtained from the two datasets have qualitatively similar implications.

The results indicate that household characteristics are important for storage decisions. Both datasets indicate that, holding other factors constant, households with female heads are more likely to store grain crops, possibly indicating more smoothened seasonal spreads in agricultural output use linked with different time and risk preferences for such households. Moreover, both datasets show that, relative to households with illiterate heads, those with heads that had some primary and secondary education are more likely to store grain, and the association is stronger among those with more years of education.

The AGP dataset further indicates that household size is positively associated with the likelihood of storing crops, possibly due to both higher food needs and availability of more labor to care for stored crops in larger households. The FtF dataset indicates that the likelihood of storing crops is positively associated with household wealth, possibly because wealthier households can rely on different sources of income or do not have to sell their harvest as quickly as poorer households. Households with older heads, which appear to be endowed with more land, are more likely to store crops.

Economic conditions and incentives matter as well for storage decisions. Both datasets indicate that the lean-harvest season producer and retail price gaps – reflecting possible higher returns to storage ceteris paribus – are positively associated with the likelihood of storing crops. The estimates indicate that a one standard deviation increase in the producer and retail price gaps are associated with a 24 and 54 percent increase, respectively, in the likelihood of storing crops in the FtF dataset, while these numbers are slightly different in the AGP dataset – 22 percent and 110 percent, respectively.

Table 3.4. Reduced form probit model estimates of associates of storing crops

	Dependent variable: Stored harvest? 0/1			
	FtF dataset, Meher 2014/15		AGP dataset, Meher 2012/13	
Variables	**Marginal effect**	**SE**	**Marginal effect**	**SE**
Female household head, 0/1	0.078***	0.013	0.075***	0.019
Age of household head, years	0.001***	0.0003	-0.0002	0.0003
Household head did not completed primary education, 0/1	0.069***	0.013	0.032***	0.011
Household head completed primary education, 0/1	0.134***	0.017	0.071***	0.026
Household size	0.003	0.002	0.006***	0.002
Household wealth index	0.030***	0.003	-0.002	0.001
Seasonal producer price gap, percent	0.012***	0.004	0.012*	0.008
Seasonal retail price gap, percent	0.036***	0.005	0.063***	0.016
Distance of larger town near village, km	-0.0000	0.0001	0.002***	0.000
Distance of market near village, km	0.0004	0.001	0.0004	0.0005
Average annual temperature, °C	-0.002	0.003	0.028***	0.002
Average annual relative humidity, percent	-0.022***	0.004	-0.009***	0.002
Months between harvest and survey	-0.115	0.211	-0.462***	0.112
Months between harvest and survey squared	0.005	0.010	0.021***	0.006
Crop indicators	Yes		Yes	
Administrative zone indicators	Yes		Yes	
Harvest month indicators	Yes		Yes	
Inverse Mills ratio	-0.657***	0.041	-0.656***	0.164
Chi^2	1,663.6		1,236.8	
Log-Likelihood	-7,316.0		-7,201.5	
Number of observations	11,794		12,347	

Source: Authors' analyses using FtF (meher 2014/15) and AGP (meher 2012/13) midline survey datasets.
Notes: Estimates with ***, **, and * are significant at 1 percent, 5 percent, and 10 percent, respectively.

Finally, locational factors influence storage behavior. In particular, both datasets indicate that long-term relative humidity is negatively associated with storing crops. The estimate of long-term average relative humidity obtained from the FtF and AGP datasets imply that a one standard deviation increase in long term average relative humidity is associated with a 10 and 4 percent decline, respectively, in the likelihood of storing crops. The AGP dataset indicates that long-term average temperature is positively associated with the likelihood of storing crops. We shall discuss this result further in section 4.

The estimate of distance of farmers' villages to periodic markets is insignificant in both datasets while the estimate in the AGP dataset of distance of farmers' villages to larger towns or urban centers of 50,000 or more population is significant and positive. This indicates that farmers residing in villages farther from large population centers (by one standard deviation) are more likely to store crops – by about 2 percent. This could be because income sources of households in such areas are less diversified, so households in such areas rely more on crop production for their food needs. As they often have less access to markets (Bachewe et al. 2016), they prefer to rely more on auto-consumption of their harvest compared to market purchases (Stifel and Minten 2017).

Estimates of the inverse Mill's ratio (non-selection hazard), which are obtained from the first-stage (Heckman) sample selection regressions, are negative and significant in both datasets. The latter indicates that the likelihood of storing crops improves with an increase in the likelihood of cultivating grain. Furthermore, equations that include the inverse Mill's ratio perform better than those that assume no sample selection, with a likelihood ratio test statistic exceeding 175, while the one percent critical value is

6.63.[22] Finally, estimates of the crop group dummy variables indicate that, relative to the omitted crop (teff), the likelihood of storing sorghum is higher and that of pulses and oilseeds is lower. These results are consistent with the descriptive results in Table 3.1.

4. Losses and associates of losses during storage

4.1. Storage losses

In the FtF midline survey, respondents that reported to have stored crops were also asked if they suffered damage to crops in storage. They then had to choose from ten categories of storage losses: 1 to 10 percent, 10 to 20 percent, …, 90 to 100 percent. Furthermore, households that suffered damage were asked to indicate if the intensity of damage was minor, medium, or major. We use the information on intensity of damage together with the categories of harvest losses to assign specific loss percentage.[23]

Out of 5,488 observations of crops in storage, no damage was reported in 3,800 cases – 71 percent of the observations. This varied from 58 percent in maize to 78 percent in teff and 82 percent in oilseeds. Out of the 1,688 cases in which damage was reported, losses averaged 10 percent or lower in 18 percent of these cases. The data further indicate that in 4.4, 4.1, and 2.5 percent of the cases the crop shares lost ranged from 10 to 20, 20 to 50, and over 50 percent, respectively. We estimate using the method discussed earlier that on average 4.2 percent of the grain was lost to damage during storage. This amounted to about 18 kg out of the 422 kg of harvest stored (Table 4.1).[24] Considering all observations, including cases in which crops were not stored, it is estimated that about 2 percent of the total grain harvest was lost. Losses during storage were the highest in maize (8 percent), which was followed by pulses, while it was the lowest in teff and other cereals.[25]

Table 4.1. Estimated losses during storage, meher 2014/15

		Percent of crop damaged during storage				Damage, for crops in storage		Damage, all observations	
Crop	**None**	**1-10**	**10-20**	**20-50**	**50-100**	**%**	**kg**	**%**	**kg**
Teff	78.5	16.2	2.3	1.7	1.2	2.3	7.3	1.2	3.8
Barley	77.0	13.5	3.5	3.1	2.8	4.0	20.4	1.8	9.1
Wheat	72.8	17.8	2.9	4.6	1.9	3.8	19.8	1.9	9.7
Maize	58.1	22.2	8.3	6.2	5.3	7.9	38.8	3.6	17.8
Sorghum	61.7	21.3	7.9	7.5	1.6	5.1	20.9	2.9	12.1
Other cereals	73.5	23.1	1.4	1.6	0.5	1.5	11.1	0.9	6.3
Pulses	66.2	18.6	7.0	4.7	3.5	5.6	13.8	2.3	5.6
Oilseed	82.2	10.1	1.6	3.1	3.1	3.8	13.0	1.0	3.6
Average	71.3	17.9	4.4	4.1	2.5	4.2	18.1	1.9	8.5

Source: Authors' computation using FtF midline (2015) survey dataset.

We conduct the same exercise using the AGP dataset (meher of 2012/13). The results are surprisingly similar. Particularly, average losses during storage were estimated at 2.5 percent (Table 4.2). The two

[22] Under the null hypotheses of no sample selection the test statistic: -2*(log likelihood under H_0 - log likelihood under H_1) has a mixed χ^2 distribution with degrees of freedom equal to the number of restrictions (1 in this case).

[23] We assign a value of 2, 12,…, 92 percent for damage in each of the increasing damage brackets if the household also indicated that the intensity of damage was minor. We assign a value of 5, 15,…, 95 for damage in the respective ten categories if the intensity of damage was medium and a value of 8, 18,…, 98 if the intensity was stated as major. In Table 4.1 we summarize the percentage of harvest damaged so calculated.

[24] One can also calculate damage in storage in kg using the numbers given: (average damage*average quantity stored). However, the latter results slightly differ from those in Table 4.1, which are first calculated for each observation and then averaged.

[25] The lower proportion of damage in *Other cereals* was in dagusa (finger millet), which accounted for 72.5 percent of the total number of observations in that group and in which PHL averaged less than 0.8 percent, making dagusa the least damaged crop.

datasets are also similar in implying that less than 2 percent of total grain output is lost to damage, and that losses during storage is highest in maize, pulses, and sorghum and lowest in teff and other cereals.

Table 4.2. Estimated losses during storage, meher 2012/13

	Percent of crop damaged during storage					Damage, for crops in storage		Damage, all observations	
Crop	None	1-10	10-20	20-50	50-100	%	kg	%	kg
Teff	68.5	28.9	0.9	1.0	0.8	1.6	4.3	1.1	3.0
Barley	64.1	29.4	3.1	1.1	2.3	3.4	13.7	2.3	9.1
Wheat	69.2	26.3	2.0	0.8	1.7	2.5	12.6	1.7	8.5
Maize	53.6	38.7	3.6	2.8	1.2	3.1	14.6	2.0	9.4
Sorghum	52.9	39.8	4.4	1.1	1.8	3.3	14.6	2.6	11.4
Other cereals	60.6	36.6	0.8	0.9	1.1	1.8	5.7	1.4	4.6
Pulses	60.8	32.6	2.7	1.8	2.0	3.0	6.5	1.9	4.1
Oilseed	58.9	39.5	0.5	0.0	1.1	1.7	5.3	0.9	2.9
Average	61.1	34.0	2.2	1.4	1.5	2.5	9.7	1.7	6.6

Source: Authors' computation using AGP midline (2013) survey dataset.

4.2. Associates of losses during storage

Table 4.3 provides results of the econometric analyses conducted to study the associates of storage losses. We conduct the analyses employing a probit and Tobit models on both the FtF (meher 2014/15) and the AGP (meher 2012/13) datasets. The first two rows of Table 4.3 indicate to which model and dataset the results in each pair of columns pertain. Statistically significant estimates obtained from the two models are mostly consistent with expectations and have qualitatively the same implication in the two datasets for almost all variables.

The results indicate that, apart from its influence on the decision to store crops, the sex of the household head has no effect on the occurrence and extent of damage. The AGP dataset indicates that crop damage is less likely to occur in households with older heads, while the dataset also implies both the likelihood and extent of damage is lower in households with heads that had some secondary education than for those with illiterate heads. The latter might be plausible since educated heads can grasp written material, among others, on proper storage. Furthermore, the AGP dataset implies that household size is positively associated with the likelihood of damage occurring in stored harvest. However, no significant results appear in the Tobit specification.

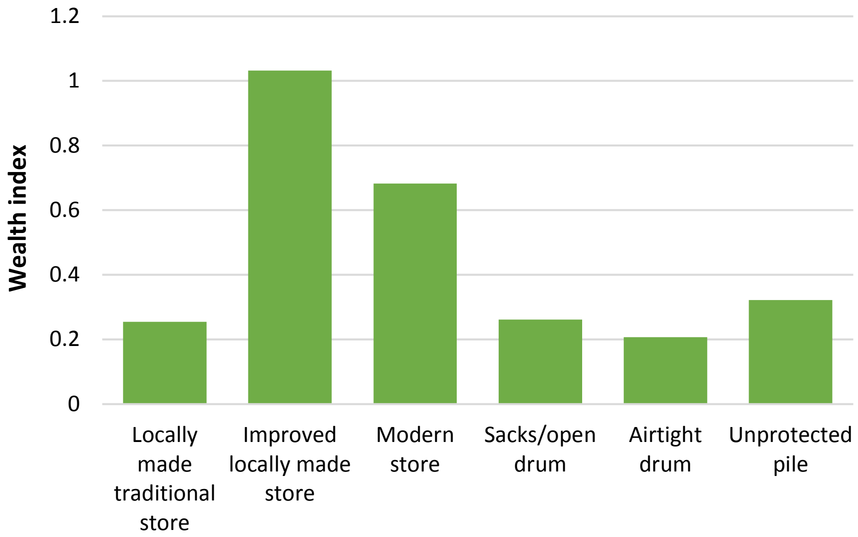
Table 4.3. Reduced form estimates of associates of crop damage during storage

	Probit: Dependent variable: Harvest damaged, 0/1				Tobit: Dependent variable Post-harvest losses during storage, percent			
	FtF (Meher 2014/15)		AGP (Meher 2012/13)		FtF (Meher 2014/15)		AGP (Meher 2012/13)	
Variables	**Marginal effect**	**SE**	**Marginal effect**	**SE**	**Coefficient**	**SE**	**Coefficient**	**SE**
Female household head, 0/1	0.014	0.015	-0.001	0.014	1.249	1.465	-0.213	0.699
Age of household head, years	0.0003	0.0004	-0.001*	0.000	0.010	0.039	-0.030	0.019
Household head did not completed primary education, 0/1	-0.0000	0.016	-0.020	0.013	-1.123	1.573	-0.111	0.627
Household head completed primary education, 0/1	-0.010	0.021	-0.067***	0.020	-2.951	1.978	-4.102***	1.011
Household size	0.001	0.003	0.006**	0.003	0.391	0.287	0.005	0.132
Household wealth index	-0.009**	0.004	-0.003*	0.002	-0.782**	0.380	-0.179**	0.079
Seasonal producer price gap, percent	0.010	0.007	-0.014**	0.006	0.356	0.631	-0.414	0.282
Seasonal retail price gap, percent	-0.014*	0.007	-0.0004	0.006	0.603	0.630	0.129	0.289
Distance of larger town near village, km	0.0003*	0.0002	0.001***	0.0003	0.064***	0.011	0.013	0.013
Distance of market near village, km	-0.002*	0.001	0.002***	0.001	-0.223***	0.075	0.129***	0.027
Average annual temperature, °C	0.036***	0.004	0.001	0.004	1.918***	0.321	-0.361**	0.182
Average annual relative humidity, percent	0.031***	0.002	0.004***	0.001	0.382***	0.140	0.306***	0.072
Months between harvest and survey	0.543*	0.322	1.155**	0.537	29.562	28.241	35.31	26.51
Months between harvest and survey squared	-0.027*	0.015	-0.053**	0.026	-1.535	1.337	-1.632	1.262
Crop dummies	Yes		Yes		Yes		Yes	
Administrative zone dummies	Yes		Yes		Yes		Yes	
Harvest month indicator	Yes		Yes		Yes		Yes	
Inverse Mills ratio	-0.113***	0.037	-0.079**	0.037	-10.50***	3.242	-3.807**	1.831
Constant					-254.9*	147.0	-207.1	137.2
Sigma					30.94***	0.585	19.71***	0.263
Chi^2	1,141.4		466.0		743.9		268.4	
Log-Likelihood	-2,804.8		-5,293.0		-9,629.1		-16,551.9	
Number of observations	5,497		8,287		5,497		8,287	

Source: Authors' analyses using FtF (meher 2014/15) and AGP (meher 2012/13) midline survey datasets.
Notes: Estimates with ***, **, and * are significant at 1 percent, 5 percent, and 10 percent, respectively.

The results indicate that both the likelihood and extent of damage occurring in stored crops is negatively associated with household wealth. These results are consistent across both datasets. This result might be capturing the association between the occurrence and extent of damage and households' expenditure on crop storage/protection. The AGP dataset indicates that the wealth index has a statistically significant positive correlation with using improved locally made storage. Figure 4.1 shows the positive correlation between using improved storage technology and the wealth index.

Figure 4.1. Correlation between wealth and storage technology, meher 2012/13



Source: Authors' analyses using AGP midline (2013) survey dataset.

The results from the AGP and FtF datasets also show that the likelihood of damage occurring in stored grain is negatively associated with the producer and retail price gaps. The negative relationship between price gaps and the likelihood of occurrence of crop damage may stem from the increased care (labor) and investment in loss reduction technologies that is made as the crops become more valuable. The results indicate that an increase in producer and retail price gap of one standard deviation reduces the likelihood of damage by 24 and 21 percent, respectively. These results are remarkably close to the 26 and 19 percent, respectively, obtained by Kaminski and Christiaensen (2014).[26] The insignificant coefficients of producer and retail price gaps in the Tobit model estimates of both datasets imply, however, that the variables do not influence the extent of damage.

The regression results are mostly consistent with what is expected regarding the influence of temperature and humidity during post-harvest on stored crops. Higher relative humidity during the post-harvest period increases both the likelihood and extent of damage in stored crops in both datasets. Moreover, the same pattern of association was observed in the FtF dataset for average temperature. The FtF dataset implies that the likelihood of damage occurring increases by 9 and 23 percent with a one standard deviation increase in post-harvest temperature and relative humidity, respectively. On the other hand, the AGP dataset implies that damage during storage declines with average temperature during post-harvest. We, thus, find ambiguous effects of temperature in these two datasets, but the negative estimate in the AGP dataset might be plausible since higher temperatures could lower moisture content in stored crops and could lower crop damage in storage.

[26] If the farmer is aware of these price movements, it might be to the farmer's advantage to engage in storage where the farmer will incur losses compared to a situation where he or she has to buy food at higher prices. If the storage losses, storage costs, and the opportunity costs of funds are lower than seasonal price movements, the farmer should best store.

Estimates of the coefficient on the number of months between harvest and the survey time and its square term imply that the likelihood of occurrence of damage increases quadratically while the extent of damage is not associated with an increase in the period since harvest. The crop dummy variables indicate that, relative to teff, the likelihood of damage in storage occurring is higher in all crops except oilseeds and other cereals, while the extent of damage is higher in all crops except oilseeds. This is seemingly consistent with the frequency and storage loss percentage reported in Table 4.1.

Estimates of the inverse Mill's ratio are negative and significant in all equations, which indicates that a higher likelihood of growing grain crops is associated with a lower likelihood of occurrence of damage and PHL during storage. Moreover, both datasets and equations that include the variable perform superior to those that assume away sample selection.

4.3. Mapping zonal grain losses during storage

Humidity is among the most important and consistent variables in influencing the occurrence and extent of storage losses (see Table 4.3). We use the estimate of relative humidity in the storage loss equation obtained from the FtF dataset together with the data on relative humidity to make a simple prediction of grain losses during storage. To make the prediction we start from percentage storage loss equation, which, without loss of generality, can be specified as:

$$PHL_{g,h} = f(X_{g,h}, Hum_h) \quad (3)$$

where $PHL_{g,h}$ represents PHL percentage of household *h* for crop *g*. Hum_h represents relative humidity in the woreda/district household h resided while $X_{g,h}$ represents a vector of all other variables used in the PHL percentage equation. Then, assuming all factors represented by $X_{g,h}$ in the last equation are constant, the relationship between changes in PHL percentage and relative humidity can be represented as:

$$\triangle PHL_{g,h} = \beta \triangle Hum_h \quad (4)$$

where β is the estimate of relative humidity in the PHL percentage equation.

$$\widehat{PHL_{g,h}} = \beta(Hum_h - \overline{Hum}) + \overline{PHL_g} \quad (5)$$

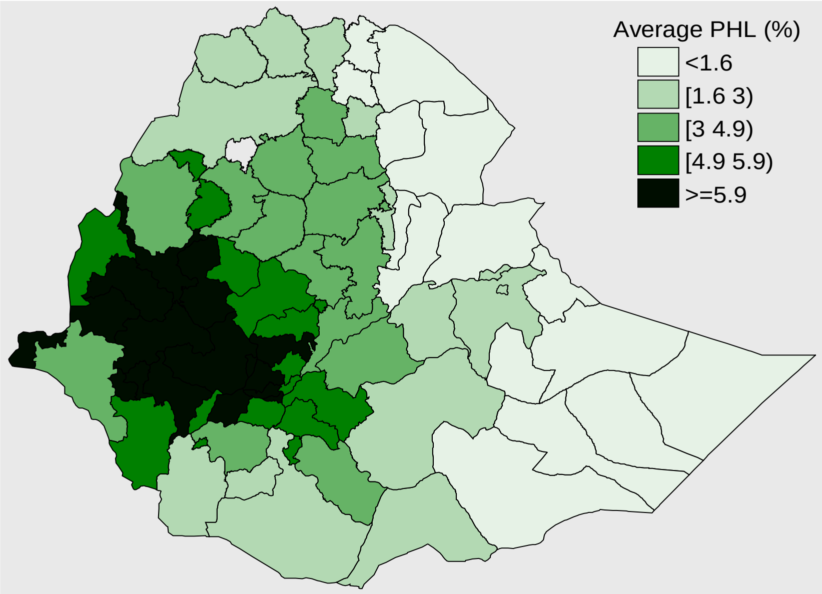
Then, the predicted PHL of each woreda ($\widehat{PHL_{g,h}}$) is computed as a function of the average PHL observed in the dataset ($\overline{PHL_g}$) and the difference between the relative humidity in the woreda (Hum_h) and relative humidity of an average woreda ($\overline{Hum}$).[27]

We summarize the results obtained from this exercise in Figure 4.2 and Table 4.4, which depict the zonal and regional average predicted PHL. The map indicates that the eastern parts of the country, such as Afar, Somali, Harari, and Dire Dawa regions, which receive relatively lower rainfall and are drier, are expected to experience the lowest losses in grain in storage. In contrast, Gambella and Benishangul-Gumuz regions, and northern SNNP, which generally have higher average relative humidity, are expected to have the highest storage losses (Table 4.4). The predictions indicate that western parts of Oromiya and southern Amhara have fairly higher grain storage losses.[28]

[27] The prediction is conducted at woreda level since the variables involved in the last equation are woreda or higher level aggregates.

[28] Predicted storage loss percentages display patterns similar to those observed in the actual data. In particular, the average PHL of 4.5 percent predicted for the four regions in the FtF dataset is close to what is observed in the dataset.

Figure 4.2. Predicted zonal averages of share of grain damaged during storage



Source: Authors' analysis using FtF midline (2015) survey dataset. PHL = post-harvest loss.

Table 4.4. Regional average predicted storage losses in grain

Region	Predicted losses, percent
Tigray	1.9
Afar	1.1
Amhara	3.5
Oromiya	5.0
Somali	0.6
Benishangul-Gumuz	5.1
SNNP	5.6
Gambella	6.4
Harari	2.0
Dire Dawa	2.0
All regions	3.9
Four main cropping regions	4.5

Source: Authors' analyses using FtF midline (2015) survey dataset.
SNNP = Southern Nations, Nationalities, and Peoples' Region. The four main cropping regions are Tigray, Amhara, Oromiya, and SNNP.

5. Conclusions and policy implications

There is increasing attention globally and nationally to reduce post-harvest losses as a way to ensure improved access to food. While explicit targets are being set on levels of food losses, there is, however, little empirical work in this area. Storage is an important under-investigated issue in developing countries, especially so in Africa. This is important as a large part of the continent is characterized by one major harvest a year, leading to significant requirements for storage or trade to assure access to food and, therefore, food security over the year. A significant body of research has been devoted to looking at the rewards to storage as well as at seasonal stress because of lack of food (Dorosh and Rashid 2013; Hirvonen et al. 2016; Abay and Hirvonen 2016), but relatively less attention has been given to farmers' storage behavior decisions and the losses that are incurred in that process.

This study investigates factors associated with storing grain crops, the likelihood of damage in stored crops, and the extent of losses during storage. This is done both descriptively and using econometric analyses for farm households in Ethiopia. The study uses data collected in two large-scale household surveys for the 2012/13 and 2014/15 meher major cropping seasons.

It is found that losses during storage were 4 percent of the stored quantities of grain, making up 2 percent of the total harvested production. These results were consistent for the two large-scale datasets analyzed. As could be expected, we find significant differences by type of grain. Damage is reported more frequently and is among the highest in maize while the reverse is true for teff. Regarding storage behavior, it was found that a large number of households engaged in storage, be it for sale or for own consumption. However, storage is mostly unsophisticated and two unimproved storage techniques together accounted for 83 percent of the total storage technology used.

Results of the econometric analyses to study factors associated with the decision to store grain crops indicate that socio-economic factors are important – households with female, educated, and older heads and wealthier and larger households are more likely to store crops. However, location and community characteristics matter as well. For example, as shown in other countries, lean-harvest season producer and retail price gaps are positively associated with the likelihood of storing crops. For the analysis on associates of storage losses, wealthier households reported significantly lower losses, ceteris paribus, as they are seemingly better able to invest in crop protection and improved storage technologies. Higher relative humidity was consistently found to increase both the likelihood and the extent of losses during storage. Extrapolating results of the regression models to the national level shows that losses are significantly higher in the southwest of the country, with losses in the southern and southwestern regions of SNNP and Gambella almost 4 percent higher than in the northern region of Tigray. Moreover, because of these expected larger losses in these areas, households also are less likely to store.

Our findings have a number of important implications on debate in this area. First, our study suggests that perceived losses during storage on the farm are seemingly lower than those measured by more objective methods (Amentae et al. 2017; Harvey 2016). This might indicate a lack of awareness by farmers of actual storage losses. This matters as farmers will only invest in improved – but costlier – storage technologies if they perceive that they will address a real problem. This finding implies that awareness training will be needed during further upscaling of efforts to increase the adoption of improved storage technologies.

Second, while the policy debate has focused solely on reducing food losses at different levels in the value chain, an important question is, especially in the case of storage, how the economic cost of reducing losses compare with the value of the food “saved”, i.e., in terms of increased revenue for those selling the food or the cost of replacing lost food that was meant for consumption. Improved (hermetic) bags, storage silos, and pesticides are becoming increasingly available at reduced costs, but they are more costly than traditional storage methods and further assessments of their benefits compared to their costs would be useful. The numbers provided in this paper could help in such analyses.

Our analysis also points to some possible areas for further research. We have only looked at grain storage in this paper. It could be argued that such crops are least affected by losses at the farm and further assessments are needed for other crops where appropriate storage might be more complicated to achieve. It would also be good to understand storage behavior and storage losses of cash crops, such as coffee and sesame, given that they might be helpful to assure smoothened income over the year and could help reduce seasonal stress (e.g., Taddesse et al. 2016).

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