Evaluating the profitability of on-farm storage pest management in developing countries

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Abstract

We present a simple financial model for storage researchers to measure the profitability of storage protection for marketing farmers in developing countries. We examine the relationship between the value of a stored commodity and price seasonality for profitable storage under a range of possible fixed costs of storage and opportunity costs of capital. The cost of storage protection has a larger effect on storage profitability with low value commodities such as maize, while the opportunity cost of capital has a larger effect on storage profitability of high value commodities such as cowpeas and common beans. We present an example using dry beans in Rwanda, contrasting the profitability of storage protection with hermetic Purdue Improved Crop Storage (PICS) bags versus chemical protectants. Results from this example show that while PICS bags financially outperform chemical protectants, profitability varies greatly by year. The goal of this paper is to offer researchers a straightforward way to evaluate the potential impact of new stored product protection technologies or management practices.

Keywords: profitable storage, financial model, price seasonality, oppportunity cost of capital

1. Introduction

There is growing consensus that postharvest losses (PHL) in developing countries contribute to food insecurity (World Bank, 2011; Affognon et al., 2015). In order to measurably reduce PHL, farmers in developing countries must first have access to effective and affordable storage technologies. Second, farmers must adopt these more effective storage technologies. Since farmers will only adopt technologies that are more profitable than their current storage practices, it is valuable to conduct an *ex ante* evaluation of the profitability of a new storage technology before introducing it to farmers.

The goal of this paper is to compare the profitability of several storage technologies for smallholder farmers to better understand what drives adoption of technologies that reduce PHL. We utilize the financial model on storage returns developed by Jones et al. (2014a). Profitable storage depends on the relationship between the stored products' value, the expected seasonal price increase, price discounts for damaged grain, the opportunity cost of capital and the cost of storage protection. We focus on the case of dry beans in Rwanda because dry beans are an important cash crop and insect damage is a serious concern for marketing farmers. Mvumi et al. (2012) found Rwandan dry bean farmers are penalized for insect damage, often resulting in market rejection if insect damage is too high. In addition, we draw on data about the Rwandan dry bean market from Jones et al. (2014b) to compare farmers' returns to storage for a range of technologies including chemical protectants and hermetic Purdue Improved Crop Storage (PICS) bags.

2. Materials and Methods

2.1. Estimating returns to storage

The farmer will only choose to store for market sale if she expects market prices in the future to be sufficiently higher than harvest prices to make storage profitable. Therefore we analyze storage returns against the base case of sale in the immediate post-harvest period (t=0). We use the Jones et al. (2014a) model and the data required to measure returns to storage are:

1) commodity price at harvest period
2) quantity of grain to be stored
3) length of storage period
4) price seasonality (increase or decrease) across the storage period
5) cost of storage technology
6) quantity lost to insect damage, known as dry weight loss (DWL)
7) percentage of damaged grains
8) price discount for damaged grains
9) rate of opportunity cost of capital (OCC)

To compute the return to storage, future revenue at time (t) is computed net of investment costs and associated opportunity costs of capital. The investment costs represent both the investment in storage protection and the value of the commodity at harvest. The return to storage is simply the gain divided by the investment cost. For the complete details of the model see Jones et al. (2014a).

2.2. Dry bean market in Rwanda

Rwanda has two production seasons each year; Season A is aligned to the short rains from September to December and Season B is aligned to the long rains from March to June. While some households also grow beans in Season A, we focus our paper on Season B data since this period is most important for the Rwandan dry bean market.

We use inflation-adjusted price data from the Rwanda Ministry of Agriculture (MinAgri) to calculate seasonal price increases for dry beans during Season B by region for 2007 to 2011. Table 1 shows that averaging across all years and all regions, the average Season B price increase for dry beans is 37% between the harvest low and the high price. The seasonal price increases vary more by year than by region; the yearly average seasonal price increase varies between a low of 12% in 2009 and a high of 58% in 2011, while the regional variation across the years varies between a low of 23% in Kigali and a high of 42% in the Western region. It is important to note that the smallholder farmers' optimal storage decision will differ from one year to the next depending on the realized seasonal price variation. However, farmers will make their storage decisions based on their expectations about the seasonal price variation.

Table 1 Seasonal price increases for dry beans in Rwanda during Season B (MinAgri).

	2007	**2008**	**2009**	**2010**	**2011**	**Average**
Eastern	40%	46%	10%	36%	60%	38%
Kigali	--	33%	11%	17%	30%	23%
Northern	61%	42%	16%	24%	62%	38%
Southern	66%	37%	14%	27%	33%	30%
Western	37%	51%	9%	45%	67%	42%
National	46%	44%	12%	33%	58%	37%

For the optimal storage period, we again use the price data from MinAgri to calculate the length of time between the minimum price at harvest and the maximum price later in the season for dry bean prices during Season B. Table 2 shows that the average optimal storage length for all years and all regions is 3.5 months. Again, the optimal period varies more by year than by region, with the shortest time being 3.2 months in 2008 and the longest being 3.8 months in both 2009 and 2010. Since the overall variation in time period is relatively small, for our analysis we will assume the farmer stores the dry beans 3.5 months.

Table 2 Optimal storage period in months based on time between minimum and maximum dry bean prices in the market during Season B.

	2007	**2008**	**2009**	**2010**	**2011**	**Average**
Eastern	3.8	3.0	3.8	4.1	2.8	3.4
Kigali	--	4.5	2.5	3.0	4.0	3.5
Northern	3.7	3.3	3.5	3.8	3.5	3.6
Southern	3.5	2.4	4.4	3.2	3.5	3.4
Western	3.8	3.3	3.9	4.0	3.4	3.7
National	3.7	3.2	3.8	3.8	3.3	3.5

A typical harvest price for dry beans is 350 RwF/kg (RATIN). For price discounts associated with damaged beans, we use estimates calculated by Jones, Alexander and Smith (2014) who surveyed traders about their willingness-to-pay for damaged beans. Table 3 presents the results on trader price discounts for grain that has between 5% insect damage and 30% insect damage, as well as the traders' willingness-to-purchase damaged beans. When insect damage is only 5%, the majority of traders are willing to purchase the beans at an average price discount of 3.5%. When insect damage is 10%, almost all of the traders are willing to purchase the beans for an average discount of 8.2%. Once insect damage reaches 20% or more, the majority of traders reject the beans. For farmers who store beans for market sale, there is a strong market incentive for farmers to invest in storage technology to avoid price discounts and market rejection.

Table 3 Trader price discounts and willingness-to-purchase for dry beans with insect damage (Jones et al., 2014b).

	Level of insect damage (%)			
	5	**10**	**20**	**30**
No Discounts (%)	35.8	7.4	1.4	1.4
Price Discounts (%)	62.8	87.2	36.5	12.8
Reject (%)	1.4	5.4	62.2	85.8
Average price discount (%)	3.5	8.2	16.0	21.5

2.3. Storage technology options

The Rwandan smallholder farmer has the choice of multiple storage technologies. We have decided to compare two different storage technologies: the chemical insecticide malathion and the triple-layer hermetic Purdue Improved Crop Storage (PICS). The cost of malathion is 375 RwF for 100 kgs of beans and the farmer would also need to purchase a polypropylene bag for 400 RwF for a total cost of 775 RwF. The cost of a 100 kg PICS bag is 1,500 RwF and, as long as the inner layers are not punctured, the PICS bag may be reused.

We assume that PICS performance in Rwanda for dry beans is the same as other cases and assume that there is minimal insect damage after 3.5 months. We do not have data on the performance of malathion for dry beans in Rwanda, but anecdotal reports indicate that it is effective at controlling insects. Thus we will consider the case where malathion is equally effective at controlling insects as PICS, and we will also consider the case where after 3.5 months of storage the beans have 5% insect damage.

3. Results and Discussion

The smallholder farmer faces the decision at harvest of whether to sell or store the bean crop. If the farmer chooses to store the crop, then she must decide which technology to use based on the relative profitability of the technologies. Table 4 is calculated using the Excel spreadsheet that accompanies Jones et al. (2014a). Table 4 compares the farmer's returns to storage against the base case of selling 100 kgs of dry beans at harvest for 4 different cases: malathion that is effective at controlling insects resulting in only 0.5% insect damage, malathion that is ineffective where 5% insect damage occurs, PICS that is only used one year, and PICS that is used for two years so that the cost of the technology is spread across the two years. In all cases, Table 4 assumes the harvest price is 350 RwF, the farmer stores 3.5 months, the bean prices increase 37% 3.5 months after harvest to 479.5 RwF, and that the farmer faces a 25% opportunity cost of capital. This opportunity cost of capital is applied to the for gone income the farmer would have received for selling at harvest plus the cost of the technology. The OCC is almost the same for all 4 cases because the major opportunity cost of storing the crop is associated with not selling at harvest and receiving 35,000 RwF.

In the case where current technology of malathion is effective at controlling insects, the farmer would have a 26.1% return to storage, earning an additional 9,326.7 RwF over selling at harvest after technology and opportunity costs are taken into account. By comparison, if the farmer is considering PICS for one year of use which is also effective at controlling insects, the farmer would have a 23.4% return to storage. If the farmer uses PICS for two years, this return to storage increases to 26.2%, roughly the same as the case when malathion is effective. If two technologies are equally effective, then the lower cost technology will always earn the farmer a higher return.

Now consider the case where malathion is less effective at controlling insects and results in 5% insect damage after 3.5 months which the traders discount at 3.5%. In this case, the farmer would only have a 15.6% return to storage. If malathion is less effective than PICS at controlling insect damage, then the farmer would have a clear incentive to adopt PICS even for only one year of use. If the effectiveness of malathion were to decline and result in 10% insect damage then the farmers return to storage would be only 3.4%, only slightly better than selling at harvest. If the farmer only has access to malathion and its effectiveness were to decline so that more than 10% insect damage accumulates, then the optimal decision would be for the farmer to sell at harvest.

Table 4 Comparison of storage returns for chemical protectants and PICS hermetic relative to the decision to sell at harvest.

Storage technology	Base case Sell at harvest	Chemicals Minimal damage	Chemicals 5% insect damage	PICS One year of use	PICS Two years of use
Harvest Quantity for Storage (kg)	100.0	100.0	100.0	100.00	100.0
Months Stored	*	3.5	3.5	3.5	3.5
Dry weight losses (%)	*	0.5%	5.0%	0.5%	0.5%
Quantity Sold (kg)	100.0	99.5	95.0	99.5	99.5
Total Price Discount for Grain Damage [compared to clean grain] (%)	*	0.0%	3.5%	0.0%	0.0%
Commodity Price for undamaged grain (t) Months after Harvest	*	479.5	479.5	479.5	479.5
Final Price Received	350	479.5	462.7	479.5	479.5
Commodity Revenue	35,000	47,710	43,958	47,710	47,710
Total Technology Cost	*	775.0	775.0	1,500.0	750.0
Rate of OCC	*	25.0%	25.0%	25.0%	25.0%
Total OCC	*	2,608.6	2,608.6	2,661.5	2,606.8
Economic Gain on Storage	*	9,326.7	5,574.6	8,548.8	9,353.5
Economic Return to Storage	*	26.1%	15.6%	23.4%	26.2%

For any storage technology, the profitability of storage in a given year will depend on the price seasonality and the farmer's opportunity cost of capital. Table 5 presents the return to storage for dry beans in Rwanda that are stored in a PICS bag for 3.5 months, assuming it is effective at controlling insects. We consider a range of seasonal price increases from the observed low seasonal increase of 12%, including the national average of 37%, observed high of 58%, as well as a hypothetical high price seasonality of 100%. For the OCC, we consider 10% which is similar to what developed country farmers face, 25% which is a relatively low OCC for developing country farmers, and 50% which is a frequently observed interest rate on a loan for develpoing country farmers (Buckley, 1997; Stewert et al., 2010). If a farmer faces an OCC of only 10%, then the farmer earns a positive return for all analyzed seasonal price increases. Of course, as the price seasonality increases, so does the return to storage. When the OCC is at 25 or 50% and the seasonal price increase is only 12%, then the farmer should sell at harvest because storage is not profitable and the farmer would lose almost 8% at 50% OCC. Once the seasonal price increase reaches 25%, the farmer earns a positive return to storage even with a high OCC of 50%. Moreover, once the seasonal price increase becomes large, either at 58 or 100%, storage becomes very profitable.

Table 5 Returns to storage for dry beans in Rwanda stored in PICS over 3.5 months, assuming it is used one year and is effective at controlling insects for a range of seasonal price increases and OCC.

OCC	Price Seasonality				
	12%	**25%**	**37%**	**58%**	**100%**
10%	3.9%	16.3%	27.8%	47.8%	87.9%
25%	-0.4%	12%	23.4%	43.5%	83.5%
50%	-7.7%	4.7%	16.1%	36.2%	76.2%

For any storage technology, the profitability of storage in a given year will depend on the price seasonality and harvest price for the crop. Table 6 presents the return to storage for dry beans in Rwanda that are stored in a PICS bag for 3.5 months assuming a 25% OCC, for a range of harvest prices from 250 RwF per kg to 450 RwF per kg and a range of seasonal price increases. Table 6 illustrates the impact of the harvest price on the return to storage. As harvest prices increase from 250 RwF to 450 RwF per kg, then the returns to storage increase at each level of price seasonality. Notably, when price seasonality is the low 12%, when harvest prices increase to 450 RwF per kg, the returns to storage move from negative to positive.

Table 6 Returns to storage for dry beans in Rwanda stored in PICS over 3.5 months, assuming it is used one year and is effective at controlling insects for a range of seasonal price increases and harvest prices.

Harvest Price (RwF per kg)	Price Seasonality				
	12%	**25%**	**37%**	**58%**	**100%**
250	-2.2%	10.0%	21.3%	41.0%	80.4%
350	-0.4%	12%	23.4%	43.5%	83.5%
450	0.6%	13.1%	24.6%	44.8%	85.3%

4. Conclusions

For agribusinesses, NGOs, and Extension that want to introduce a new storage technology, the success of the technolgy transfer effort will depend on the farmers' economic environment of price seasonality, value of the crop as measured by harvest price and access to credit. In regions where prices are fairly stable and the seasonal price increase is small, then the overall low returns to storage will either reduce farmers incentive to adopt a storage technology or even be a disincentive to store at all. By contrast, in regions where the seasonal price increases are large, efforts to introduce a new storage technology are more likely to succeed since the farmers can earn substantial returns even at high OCC. That said, for farmers who do not have access to credit and are severely cash constrained, they may experience an effective OCC on the order of 100%. In these cases a credit intervention may be needed to enable the farmer to invest in new storage technology. Lastly, for any given OCC and level of price seasonality, storage interventions should be targeted at the crops with the highest per kg harvest prices as these crops will earn the highest returns to storage.

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