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Rationale for Storing Commodities

Why are commodities stored?

For agricultural commodities there is a mismatch in the timing of consumption and production. Consumers want to eat bread every day, but there are only a couple wheat harvests per year. The function of storage is to smooth consumption of a commodity over time, both within and between crop years. The supply of a commodity is equal to production in a given year, plus carryover of stored product from the previous year. Carryover stocks serve two important functions. They meet pipeline needs while buyers are waiting for the following harvest and guard against poor yields the following year.

Individual incentives to store

Farmers, grain elevators, and processors store commodities for several reasons. The first is to make a profit because they anticipate higher prices in the future. Inventory may be stored unpriced, speculating that prices will be higher in the future. Alternatively, the stored commodity may be priced for delivery in a future period, where higher future prices have been established.

Another reason to store commodities is to assure future supply. For example, processors such as wheat millers want to be sure they have the year-round supply necessary to operate at full capacity. Livestock producers may store corn, silage, or forage to assure

the needed year-round supply of feed. Both of these groups store commodities to avoid the catastrophic consequences of running out of the commodity. Increased operational efficiency is another reason to store commodities. Most processors have at least 3 to 7 days of commodity storage at their facility to ensure a constant flow for processing. One of the primary motivations for on-farm storage is to increase harvest efficiency. During harvest, there is often a long wait to deliver commodities to local buyers, which can create bottlenecks.

Alternative Storage Technologies

Bulk commodities are stored in a wide range of storage structures. Commodities are stored on farm and at commercial facilities at various points in the marketing channel, in raw form and after one or more stages of processing. The following is not intended as an exhaustive discussion of storage technologies for bulk agricultural commodities. Instead, it is focused on major commodities and those with particularly notable storage structure issues.

Grain is one of the major commodities stored in the United States, with almost 10 billion bushels of off-farm storage capacity and an addition 12 billion bushels of on-farm capacity. These statistics reflect the storage of corn, wheat, grain sorghum, barley, soybeans, oats, rye, millet, canola, flaxseed, mustard seed, safflower, sunflower, rapeseed, Austrian winter peas, dry edible peas, lentils, chickpeas/garbanzo beans, and other minor grains. Other bulk commodi-

ties including rice, peanuts, storage of oilseeds at crushing facilities, warehouses storing tobacco, seed and other types of dry edible beans are not reflected in U.S. grain storage capacity statistics.

Major types of grain storage structures include concrete silos, steel bins, and flat (rectangular) storage warehouses. Many early grain storage structures were constructed of framed or cribbed wood, but this construction has been virtually abandoned due to fire hazards and other issues. Concrete silos are upright cylinders made of reinforced concrete that can be designed much taller than steel silos. Additionally, concrete silos can be designed in clusters to take advantage of adjacent walls and utilize the area between the silos (interstice area) for additional storage. Concrete silos maximize the storage in a limited space, which becomes important in a plant addition or where land cost is a premium. Concrete silos have a longer useful life expectancy than steel bins. Concrete silos require periodic inspection and maintenance (sealing or caulking) to prevent water penetration to the embedded rebar.

Concrete silos are filled by elevating the grain to the top of the silo by an elevator leg (often called a bucket elevator). The grain is then gravity fed directly into the silo or to a structure located at the top of the silo, known as a headhouse, where it is moved by a belt or drag conveyor to the desired silo. As it leaves the elevator leg the grain may pass through a variety of devices such as scales, samplers, cleaners, or other machines that are necessary for a particular product. The grain is removed from the silo from the bottom; most commonly onto a belt located in the tunnel (basement).

Many concrete grain facilities in the United States were constructed before 1950 using a construction process known as slip form. Slip form construction involves a continuous pour with concrete and rebar added around the clock until the structure reached design height, a process often requiring 7 to 10 days. Early slip form technology limited the diameter of the bins to 20 feet or less, which resulted in storage structures with a number of separate silos. This design provides opportunities to segregate different grain types or quality levels.

Grain is not directly inspected in these small diameter silos but is sampled as it is moved (turned) from one silo to another. The grain from several silos may be blended as it is turned or as it withdrawn from

storage. Historically, insect control treatments were also applied as the grain was turned. Some concrete structures have been retrofitted with recirculation systems that allow one or more silos to be fumigated without moving the grain.

Larger diameter (up to 90 feet) concrete silos can now be constructed. Many larger diameter silos are constructed using a process called jump form. Jump form construction involves a number of separate pours, with the form lifted between each pour and a cold joint installed between each section. Grain in large diameter silos is managed similar to that in steel bins and is not moved during the storage cycle. Pest control is accomplished by fumigating the entire silo of grain.

Steel bins are constructed of horizontally corrugated curved sheets of galvanized steel bolted together. Bins can be constructed from a variety of materials, from carbon steel to stainless steel, and technologies include bolted and welded smooth wall designs. Most steel bins have vertical columns (stiffeners) that may be mounted on either the inside or outside of the bin. Steel bins can be constructed in a wide range of sizes, from a few thousand bushels to hundreds of thousands of bushels. Steel bins cost less to construct than concrete bins, particularly for smaller capacities. As the capacity and height of the structure increases, scale economies make concrete construction more competitive. Like concrete silos, steel bins require periodic inspection and more frequent maintenance such as painting. Improper filling and discharge are the primary causes for premature failure of steel silos.

Steel bins are filled by gravity flowing grain from an auger or elevator leg. When multiple bins are constructed in a complex, they may be fed from gravity chutes connected to a distributor at the top of the elevator leg or by a drag conveyor fed by the elevator leg. Discharge can be either flat bottom or hopper bottom design. Large bins have a flat bottom design and include automatic augers (sweeps) that rotate slowly on the floor of an almost empty bin to ensure that the bin can be emptied as completely as possible without a worker having to enter.

Unlike small diameter concrete storage structures, grain in steel bins is not moved from the bin until it is removed for storage. Steel bins are constructed with access hatches at the top that facilitate inspection of the grain or commodity. Pest-management

treatments are performed by sealing and fumigating the bin.

Flat grain storage structures range in shape from arch-roof types to slant- and straight-wall rectangular units. Grain unloading can be partially mechanized. On a capacity basis, flat storages can be constructed for less than steel bins or concrete silos. Operating costs can be higher because they are more difficult to load and can only be partially unloaded with mechanical conveyors. Achieving uniform air movement for proper aeration of a flat storage structure can be difficult. Flat storage structures are useful for materials that do not flow and cannot be moved with augers or stored in conventional bins where gravity flow is required. For example, the inconsistency and unpredictability in handling characteristics of by-product feed ingredients makes flat storage appropriate for these commodities.

Outside grain storage

In many years producers and commercial operators pile grain and other products (for example, whole cottonseed) in outdoor piles when harvest volume exceeds storage capacity and/or freight logistics make it impossible to move the commodity into the marketing channel. If the commodity is sufficiently dry, often it can be stored in piles during the cooler fall and winter weather without being covered and aerated. Longer-term storage requires tarp covers and provisions for aeration. Outside storage involves higher levels of shrinkage and quality deterioration than storage in a structure. Proper site selection, aeration, tarping, and monitoring are factors in minimizing losses.

Filling and unloading of temporary storage is accomplished with a portable auger or other inclined conveyor. The conveyor is shifted to shape the pile. The grain is reclaimed using a front-end loader or pneumatic vacuum conveyor. The reclamation process may necessitate further grain conditioning via aeration, drying, or blending. Spoiled grain can become comingled with sound grain, contaminating the entire amount with damaged kernels and commercially objectionable odors.

Specialty warehouse configurations

Various agricultural products are stored in specially configured warehouses. Farmers store peanuts in flat storage structures. Although similar to flat grain storage structures, the elevator leg and horizontal belt must be designed to minimize mechanical damage to the peanuts. Spouting must be at a 45-degree angle to ensure adequate flow. Structures known as “deadheads” must be installed at the end of the spout to reduce velocity to prevent damage. The design of the aeration and headspace ventilation system is also an important factor in minimizing quality losses during peanut storage. Pest management systems for peanut storage include both fumigation and timer-released insecticide application.

Each bale of cotton ginned in the United States creates more than 800 pounds of cottonseed that must be placed in temporary or long term storage. Cottonseed is hygroscopic, meaning that it absorbs or gives up moisture to the surrounding air. Cottonseed has a high angle of repose (45 degrees). After the seed has settled, the angle of repose may increase to 90 degrees allowing the seed to “bridge” or remain upright in columns. Cottonseed is handled most efficiently by pneumatic conveyors although it can be handled with belts and screw conveyors.

Cottonseed is stored in clear span metal buildings engineered for the lateral forces exerted by the cottonseed as it is loaded and unloaded. Warehouses are typically lined with ¾-inch plywood to increase wall strength and facilitate cleanout. Long-term storage of cottonseed requires aeration, with 10 cubic feet per ton airflow considered standard. Because cottonseed is hygroscopic, aeration fans in cottonseed warehouses should not be operated when it is humid, foggy, or raining.

Storage Ownership Options

Producers of grain and other bulk agricultural commodities have several storage options. They can invest in on-farm storage structures, store products at commercial storage facilities (by renting storage space and management services), invest in condominium storage and become a part owner of a large-scale facility, or rent on-farm storage from another producer. On-farm storage facilitates harvest

by reducing transportation of grain to the elevator and eliminating the time waiting to unload. It also allows the producer to separate and preserve the identity of a commodity. The producer is not locked into marketing the commodity through a particular facility but instead can merchandise the commodity through the most attractive outlet. The variable costs of on-farm storage facilities are less than commercial storage.

Major disadvantages of building on-farm storage include the initial investment, which may or may not be recouped through the lower variable cost of storage. The producer is responsible for monitoring grain throughout the storage period and absorbing shrinkage and quality loss costs. The investment in on-farm storage is also a sunk cost in an asset that may not be matched with future farming decisions or market conditions. The producer is directly involved in merchandising the commodity and arranging transportation.

Condominium storage involves purchasing or entering into a long-term lease for storage space at a commercial facility. Condominium storage options also occur when a group of producers go together to purchase or construct a large-scale storage facility. Generally, the producer makes an initial investment to reserve the right to use a fixed volume of storage. The storage interest can generally be sold at a later date with approval of the condominium entity. Storage is managed by the facility manager and the entity guarantees grade and quality factors. A service fee based on the volume stored is charged to cover management and the variable costs of storage.

Condominium storage allows producers to take advantage of the economies of scale of larger structures. It also provides another storage option for producers with a large amount of rented land who do not want to invest in on-farm storage without a long-term crop lease. In most cases a producer investing in condominium storage can use it for two or more grains in any proportion (for example, corn or soybeans), which gives greater flexibility than on-farm storage, where bins must be dedicated to a specific crop. Disadvantages of condominium storage include the fact that the commodity is comingled, eliminating marketing opportunities for an identity preserved product. Marketing flexibility also is limited as is the case with commercial storage. The future market and value of condominium storage or storage interest is difficult to predict.

The Storage Decision

The decision whether to store a commodity, how much to store, and how long to store will depend on the individual decision maker's return to storage, which is determined by the price today relative to the price at some future date minus the cost of storage. For existing storage capacity, each individual will balance the expected returns to storage with the variable costs of storage. If the individual does not have storage, then the variable cost of storage will be determined by the commercial rate of storage. If the individual is considering whether to invest in additional storage capacity, then the individual will focus on multiyear returns to storage relative to the fixed costs of building storage. Each of these returns and costs will be discussed in detail.

Expected Returns to Storage

The return to storage is the difference between the cash price today and the price for delivery on some future date, called either the future price or the forward price. If the contemporaneous future price is higher than the current price, this positive price difference represents the return to storage. Decision makers also undertake storage to capture speculative returns, which is the difference between the current cash price and the expected future price. In the case of speculative storage, while the realized returns to storage depend on the realized price on the future delivery date relative to the current price, the decision is made based on the expected future price.

Typical price patterns

The overall returns to storage depend on the level of stocks for a particular commodity (Working 1949). If grain inventories for a particular commodity are large, then the relationship between prices for delivery on two different dates will reflect the "cost of carry", i.e., the variable costs of storing the grain. In contrast, if grain inventories are tight for a particular commodity, the carry in the market tends to be small because competition between firms offering storage services will drive down the price of storage. There tend to be positive returns to storage in years with large inventories, which means that prices increase through the storage period. For years with tight stocks, the highest prices may be offered at harvest

with little price appreciation through the storage period, resulting in minimal return to storage.

Space, or the distance to market, also plays a role in the return to storage. Several studies have shown that the returns to storage increase as the distance to market increases (Wright and Williams 1989; Benirschka and Binkley 1995; Brennan, Williams and Wright 1997). For example, the returns to storage will be negligible or small in New Orleans, La., which is the largest export market, while the returns to storage will be positive and likely cover the full cost of carry in Fargo, N.D., which is far from terminal markets.

Storage hedges and futures market transactions

Hedging in the futures market can be used to “lock in” a positive return to storage (Wisner and Hurt 1996). Storage hedges are used by grain elevators and processors to protect themselves from fluctuations in the value of their inventory. Farmers use storage hedges to capture a return to storage and establish a higher price for their crop. The concept of hedging is best illustrated with an example, but first we need to introduce the concept of basis. Basis is the difference between the local cash price and the futures price, i.e., local cash price – futures price = basis. The futures price is established each day during trading on the commodity futures exchanges, while the basis is established by the local buyer.

Example 1 presents a storage hedge that might have been implemented by a farmer in 2009. For the 2009 crop, the futures market is a carry market, i.e.,

the futures prices for later delivery are higher than the prices for the nearby contract. On October 9, the farmer has a cash bid from the local elevator at \$3.32 per bushel, or \$0.30 under the December 2009 futures, which are trading at \$3.62. On the same day, the May futures price is \$3.83. The expected basis for early May delivery is \$0.10 under May futures, so the expected May hedge price is \$3.73 (\$3.83 – \$0.10 = \$3.73). Thus, the expected gross storage return is \$0.41 per bushel, calculated as the expected \$3.73 May hedging price less the \$3.32 harvest price.

The farmer establishes the storage hedge by selling the May futures at \$3.83 on October 9. With the hedge, the farmer’s market position is long (owns) 20,000 bushels of corn in storage and short (sold) 20,000 bushels of May futures. The hedge is converted to a cash sale on May 3 and the basis on that date is \$0.05 over the May futures.

The pricing summary illustrates how to arrive at the farmer’s net final price. The farmer sells the cash corn on May 3 for \$3.65. On the same day, the farmer lifts the hedge to realize the gains or losses in the futures market. The farmer had sold May futures in October at \$3.83 and subsequently buys back May futures at \$3.60, for a gain of \$0.23.

As shown in the gross returns to storage summary, the gross return to hedged storage (before deducting storage costs) is \$0.56 per bushel. The storage hedge locked in the \$0.21 December to May carrying charge (also called the spread) by selling the May futures. In addition, the basis appreciated from \$0.30 under at harvest to \$0.05 over in May for a gain of \$0.35. The gross storage return of \$0.56 is the sum

Example 1. Storage hedge by farmer.

Date	Cash	Futures	Basis
October 9, 2009	Cash bid for current delivery is \$3.32	December 2009 corn futures is \$3.62	Basis for current harvest delivery is \$0.30 under December 2009 futures
October 9, 2009	Expected net price is \$3.73 for early May 2010	Sell 20,000 bushels of May futures at \$3.83	Expected early May basis is \$0.10 under May futures
May 3, 2010	Sell 20,000 bushels of cash corn at \$3.65	Buy 20,000 bushels of May futures at \$3.60	Basis is \$0.05 over May futures
Pricing summary:		Gross storage return summary:	
The farmer delivered cash corn on May 3 at \$3.65.		December to May Futures spread:	\$0.21
The farmer lifted the futures hedge, gaining \$0.23 (\$3.83–\$3.60), for a net price received of \$3.88.		December to May basis gain:	\$0.35
		Gross return to storage:	\$0.56

of the \$0.21 spread and the \$0.35 basis appreciation. The \$0.56 gross storage return in this example is before hedging costs, which would be roughly \$0.02 to \$0.03 per bushel. To determine if storage is profitable, the farmer must compute the net storage return, which is the gross storage return with hedging and the cost of storing corn from October 9 to May 3 subtracted.

While the expected basis appreciation in October was \$0.20, the actual basis gain was \$0.35. This additional basis gain illustrates that with a storage hedge, as with any hedge, changes in local basis impact the final net price and the gross storage return. For further reading on hedging see Wisner and Hurt (1996).

Speculative storage

In contrast to using storage hedges, other market participants store inventory unpriced, i.e., without using hedges. These decision makers are anticipating that prices will be higher later in the storage season. Although the typical price pattern is for prices to increase during the storage season, anticipated higher prices do not always materialize. Speculative storage is risky; in some years there may be very large returns to speculative storage and in other years there may be losses. For example, consider a soybean farmer who delivers his soybeans on May 1. Figures 1 and 2 illustrate the May 2006 and May 2007 Chicago Board of Trade soybean contracts, respectively.

Now, let's compare the speculative returns for this farmer comparing the May soybean futures prices on the business day closest to October 1 and May 1. In 2006, the May soybean futures were trading at \$6.04 per bushel on October 3, 2005 and at \$5.93 on May 1, 2006, a loss of \$0.11 per bushel before considering the variable costs of storage. In contrast, in 2007 the May soybean futures were trading at \$5.81 on October 2, 2006, and at \$7.34 on May 1, 2007, a gain of \$1.53 before considering costs. Clearly, speculative storage in 2007 would have been very profitable, while it would have led to a loss in 2006. This example illustrates both the risks and the potential rewards of speculative storage.

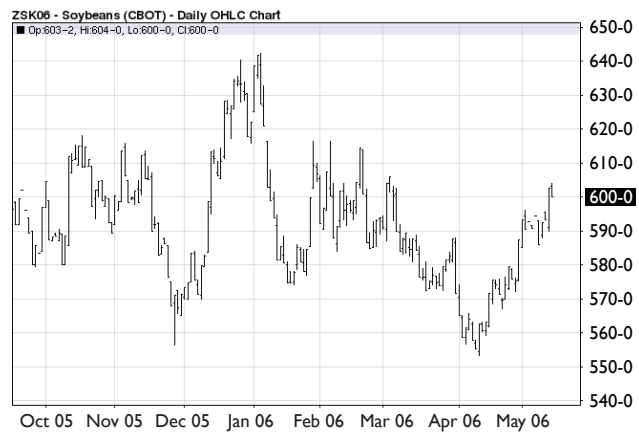


Figure 1. May 2006 Chicago Board of Trade soybean futures contract.



Figure 2. May 2007 Chicago Board of Trade soybean futures contract.

Variable Costs of Storage

The variable costs of storage include the costs that are only incurred if grain is stored. These costs will also be a function of the quantity of stored grain and the length of the storage period.

Interest on inventory

Typically, the largest variable cost associated with storage is the interest cost. This cost represents the foregone interest that would have been earned if the commodity had been sold, or the interest charges that would have been avoided if debt was paid off. The magnitude of interest cost depends on the length of the storage period, the interest rate, and the harvest price of the grain. The following example presented in Table 1 shows how the interest cost increases if corn is stored on farm for 6 months versus 4 months. For this example, the interest rate is the average operating loan interest rate during

the third quarter of 2010 (Federal Reserve Bank of Chicago 2010). The corn harvest price is for central Indiana in October 2010 (Chris Hurt, personal communication). As shown in Table 1, the interest cost of storage increases with the storage period and in the example of corn stored in central Indiana in 2010, the interest cost is 9.6 cents per bushel for four months of storage and increases to 16 cents per bushel for 6 months.

Table 1. Interest cost of storing corn.

	4 months of storage	6 months of storage
Corn harvest price, Central Indiana 2010	\$5.30	\$5.30
Interest rate	6.04%	6.04%
Months of storage/ 12 months per year	0.3	0.5
Interest cost	\$0.096	\$0.16

Utilities

The variable costs include the cost of utilities for drying, aeration, and conveyance (i.e., augers to move grain). For grain to be stored for any length of time, it needs to be dried to a safe storage moisture level. The variable costs associated with drying include fuel for heating the grain and electricity to run the fans. The drying cost will depend on the starting and final moisture levels of the grain, the type of dryer and the drying air temperature, the airflow rate and the outside weather conditions (Uhrig and Maier 1992). When storing grain for long periods of time aeration is often used to both cool the grain in the winter to inhibit insect development and to equalize moisture differences in the grain mass. The variable cost of aeration is the electricity to run the fans. This cost will depend on the length of the storage period. Finally, conveyance costs are associated with moving grain from the dryer into the bins and loading out of the bins into the truck. Augers used for conveyance may be powered by tractors using diesel or may use electricity.

Handling

For farmers who choose to store grain in bins on their farm, there will be an additional handling cost when the grain is sold.

Monitoring costs

Grain that is stored for long periods of time needs to be monitored for any changes in quality. Experts recommend that grain is monitored for temperature, moisture, insects, and molds every 1 to 2 weeks during warm months and every 3 to 4 weeks during cold months (Mason and Woloshuk 2010). Monitoring costs include the labor and equipment used to sample the grain. The balance of these costs will depend on the equipment. For example, if a farmer has a temperature-monitoring system in the storage bin, the cost of monitoring will be primarily the depreciation on the monitoring equipment because checking temperature would take minimal time. In contrast, if the farmer does not have a temperature monitoring system, he would need to climb into the bin with a thermometer to test the temperature of the grain, which requires more time but the equipment cost would be substantially lower.

Pest management costs

There are two categories of costs associated with managing pests: preventive and curative. There are several common steps associated with prevention of insect damage. Before the storage structure is filled with grain, the structure needs to be sanitized. The sanitation process starts with cleaning the structure and removing any spilled grain that could harbor insects. Often an insecticide is also sprayed on the walls and floor of the structure. After the storage structure is filled with grain, the grain will be monitored for insects. The lowest cost way to prevent insect growth, which is only financially feasible when the ambient temperature is low, is to use aeration to chill the grain. At low temperatures, the insects remain dormant or can even be killed. Other prevention strategies include using diatomaceous earth as a protectant on the grain surface. If monitoring finds that insect populations are high, then the grain will need to be fumigated, which is a curative measure. The grain can be fumigated with an insecticide or a chemical such as ozone. Fumigation tends to be expensive because the storage structure needs to be completely sealed before the fumigant is introduced.

Shrinkage

As grain loses moisture, it loses weight. This weight loss is called shrink. Because grain is sold based on weight, and grain continues to lose moisture during the storage period, shrinkage must be considered

one of the storage costs. A common rule of thumb for handling shrinkage is to assume 0.5% shrinkage for “in and out” and an additional 0.25% shrinkage every time the grain is turned. A bin of grain that is turned one time would be expected to have 0.75% total shrink by the time it is removed from storage. Moisture shrinkage is calculated by the formula:

$$\frac{Mi\% - Mf\%}{100 - Mf\%} \times 100 = \% \text{ moisture shrink}$$

Where Mi is the initial moisture content and Mf is the final moisture content. Moisture shrinkage from drying from 15% moisture to 10% moisture would be:

$$\frac{15 - 10}{100 - 10} \times 100 = 5.56\%$$

Quality deterioration

As the length of time in storage increases, grain quality tends to deteriorate (Mason and Woloshuk 2010). Lower quality grain may receive a discounted price, depending on the delivered quality and the buyer’s discount schedule. Any discounts applied to the grain due to this lower quality are a cost of storage. A decision tool developed by Oklahoma State University (Grain Handling Cost Template) estimates the fixed and variable costs of handling and storing grain based on the grain type and price, storage type, handling equipment, interest rate, and electricity rates and other inputs (Kenkel 2010).

Storage Returns Over Variable Costs

From an economics perspective, in the long run the average costs of storage should be equal to the returns to storage. Storage returns in any individual year will vary, so the producer will decide whether to store grain, and how much to store depending on whether the storage returns cover the variable costs. If the producer has existing on-farm storage facilities, he will compare the storage returns to the on-farm storage variable costs. If the producer does not have on-farm storage, then he will compare the storage returns to the commercial storage variable costs.

Decision to Invest in Storage Facilities

When deciding to invest in storage facilities, the decision maker needs to consider the fixed costs associated with the storage investment relative to the expected annual returns to storage. At a minimum, the annual returns over variable costs need to cover the annualized fixed costs of storage.

Fixed costs of storage

The fixed costs of storage are incurred whether or not grain is stored in the facilities. Total annual fixed costs depend on the size of the investment in storage facilities, which includes the storage structure, monitoring equipment, conveyance equipment, aeration, site preparation, concrete pad, and construction. These annual fixed costs of storage facilities include interest, depreciation, taxes, insurance, and maintenance. The interest fixed cost is the interest payment on the loan for the storage facility investment. Depreciation is the investment divided by its useful life, also called straight-line depreciation.

Returns on investment in storage structures

The return on investing in storage structures will depend on the return to storage from holding grain in the storage structure and the cost of the investment in the storage structure. The most basic way to calculate return on investment for storage structures is to use the following calculation:

$$\text{ROI} = \frac{\text{Return to Storage} - \text{Cost of Investment}}{\text{Cost of Investment}}$$

The primary return to storing grain comes from price increases in the futures and basis between harvest and later in the storage season. Some producers also factor in the benefit of capturing price differences between buyers, seasonal premiums, the ability to identity preserve grains, and additional harvest efficiencies. The annual return to storage is the difference between the gain from the price increases minus the variable costs. The lifetime return on investment in the storage structure will include the discounted annual return to storage for the life of the structure and the cost of the investment, which is the fixed cost of building the structure.

Economies of scale in storage structures

As shown by Dhuyvetter et al. (2010), there are significant economies of scale in on-farm storage bins. They estimate the costs associated with site preparation, concrete, and construction and show that as the bin size increases, the required investment decreases on a per bushel basis, but at a decreasing rate. They find that in 2010 in Kansas the investment cost for a 10,000 bushel bin was \$2.31 per bushel compared to \$1.49 and \$1.24 per bushel for 50,000 and 100,000 bushel bins, respectively.

A decision tool developed by Oklahoma State University calculates the predicted cost for various sizes and types of commercial grain bins (Kenkel 2011). Results also indicate that the per bushel cost declines as bin sizes increase (Figure 3). At large capacities the per-bushel cost actually increases (diseconomies of scale) due to the cost of the aeration equipment. The relationship between aeration horsepower and bin capacity is not linear, and aeration horsepower can increase dramatically for very large bins.

Costs and benefits of identity preserved storage

With the introduction of genetically modified crops, much of the food-grade supply chain has implemented identity preserved (IP) programs and most of these programs start at the level of the first handler (Anderson 2004; Stevenson 2004; Voigt 2004; Hurburgh 1994). For instance, National Starch has implemented the TrueTrace™ program and Cargill has implemented the Innovasure™ program, to name just a few of the IP programs for food-grade corn. Any IP program that guarantees quality and segregation will require additional handling efforts, and thus create additional costs. For farmers interested in participating in an IP program that offers premiums, on-farm storage capacity is almost always a prerequisite.

Most of the literature on IP grains has focused on the additional costs associated with an IP program and assumed that these programs would only succeed if the final market was willing to pay a premium sufficient to compensate for these additional costs. Many studies have focused on the additional

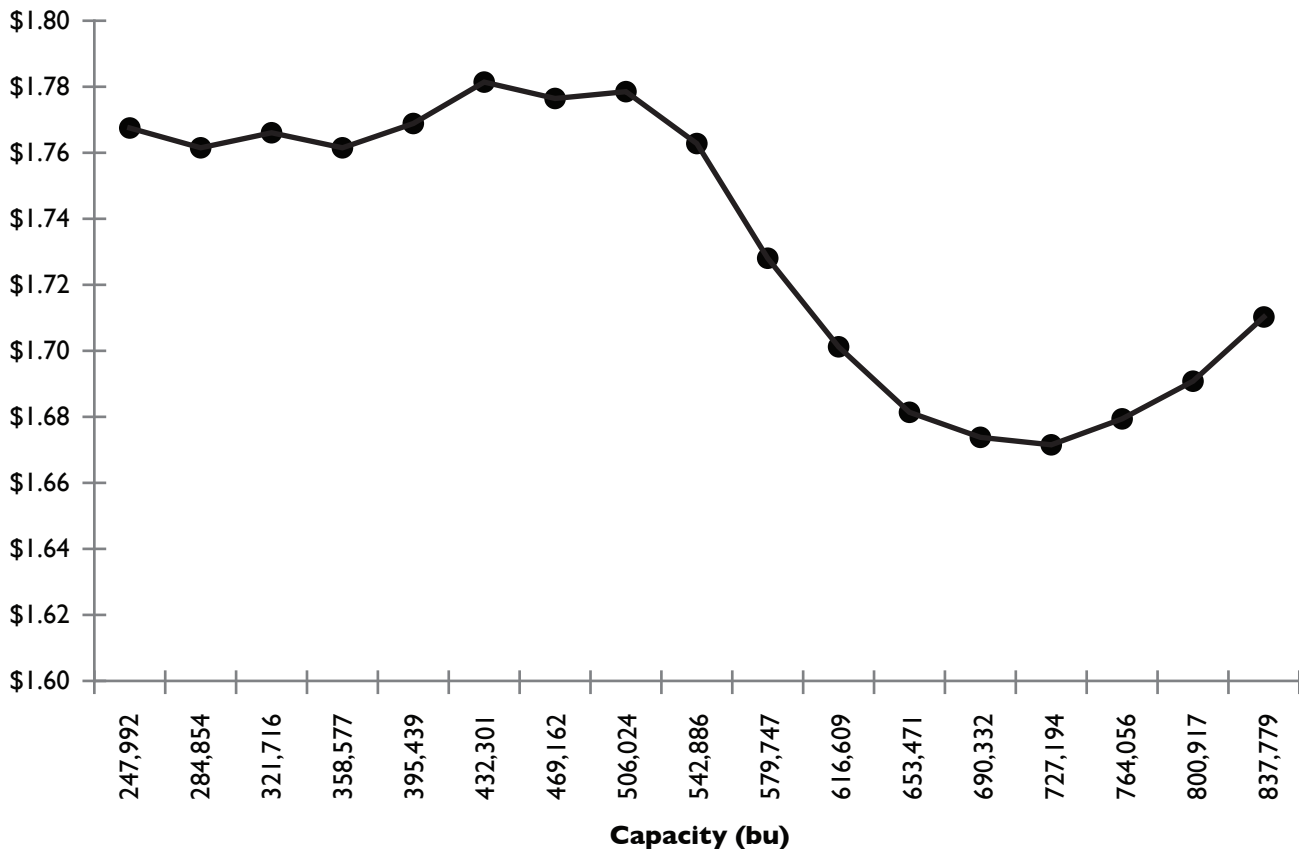


Figure 3. Predicted cost of steel bin construction at various capacities.

costs faced by grain elevators or the entire grain-handling supply chain. Hurburgh (1994) estimated the additional physical costs of segregating soybeans at country elevators based on protein and oil content and found that the additional costs of testing and segregation were two to three cents per bushel. Lin, Williams, and Harwood (2000) estimated that the cost of segregating non-GM grains and oilseeds along the marketing chain from country elevator to export elevator could add about \$0.22 per bushel, not including any premiums to the farmer. Kalaitzandonakes, Maltsbarger, and Barnes (2001) estimated the costs of IP high oil corn at the 5% purity level for three elevators with multiple scenarios of bin filling schedules, crop-to-bin assignments, incoming volumes, and other key parameters and found an additional average IP cost of \$0.35 per bushel. They also highlighted the importance of hidden or opportunity costs (e.g., grind margin loss, losses from underutilization of capacity) that can occur from adapting current commodity operations to IP.

Wilson and Dahl (2005) used a stochastic optimization model to examine the supply chain-level costs of a dual marketing system of GM and IP non-GM wheat relative to a non-GM system for a vertically-integrated export supply chain. They model the costs and risks of adventitious commingling at every stage of the supply chain, incorporating testing accuracy and whether growers truthfully report the GM content of the grain. They estimate the total costs of a dual marketing system relative to a non-GM-only system range from \$0.0145 per bushel at a 5% tolerance level to \$0.0425 per bushel at a 0.05% tolerance level.

Other studies have also examined on-farm IP costs. Huygen, Veeman, and Lerohl (2004) estimated the IP costs at the farm level, primary elevator level, and export elevator level for three supply-chain systems designed to IP non-GM wheat where the GM tolerance levels ranged from 5% to 0.1%. Based on data from 14 seed growers, they estimated that farm-level IP production costs range from \$0.029 per bushel at the 5% tolerance level to \$0.18 per bushel at the 0.1% tolerance level. Their IP cost estimate included only direct production costs such as isolating the crop, controlling volunteer plants, and cleaning of the seeder, combine, truck, bin, dryer, and auger.

Karaca, Alexander, and Maier (2007) conducted a cost-benefit analysis of using an on-farm quality assurance process to deliver IP food-grade non-

GM corn. They found that on average, the additional labor costs associated with the on-farm quality assurance (QA) program ranged from \$0.0053 to \$0.0212 per bushel depending on the equipment management strategy and farm size. Depending on the improvement in the grain quality due to the adoption of the QA program, the producer could gain up to \$0.0842 per bushel from avoided discounts.

Yigezu et al. (2011) use a stochastic dynamic programming model for an Indiana on-farm IP corn storage case study to examine the returns to an integrated pest (both insects and molds) management strategy. They demonstrate that using a monitoring-based IPM strategy that includes both aeration and timing of sales as control variable, is profitable when delivering food-grade IP corn. For farmers who plan to store commodity corn that will be delivered by March when warmer temperatures increase the chance of insect and mold problems, the additional costs associated with monitoring and a more intensive aeration strategy are not justified.

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