GOVERNMENT STORAGE PROGRAMS AND SUPPLY AND DEMAND FOR STORAGE: AN EMPIRICAL ANALYSIS FOR HARD RED WINTER WHEAT

By

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CHAPTER I

INTRODUCTION

Problem Statement and Objectives

Grain elevators, handlers, and merchandisers, provide valuable services to agriculture and society by collecting, handling, cleaning, grading, processing, distributing, and storing grain. Consequently, these firms fulfill a vital role in the marketing of wheat and wheat by-products such as flour and feed. In order for a firm to provide these services with a seasonally produced commodity such as wheat, holding inventories is essential. In the early 1980s, however, when excess storage capacity became prevalent in the industry (Dahl 1991), wheat merchandisers found it difficult to earn a return on their storage facilities.

Storage revenues are an important source of income for grain elevators. Elevators may earn revenues by storing grain for producers, for the government, or by purchasing grain from producers and storing the grain in hopes of selling later at a higher price. In the latter case, an elevator may wish to reduce price risk by entering into a storage hedge. A storage hedge can help protect against declining value of inventories, by transferring price risk for basis risk. In addition, an elevator may use a storage hedge in order to increase returns to storage activities (Hieronymus, pg. 179).

To illustrate a storage hedge, assume an elevator manager wishes to store grain until a later date. As the manager buys wheat, futures contracts are sold equal to the amount of grain to be stored. At the end of the desired storage period, the manager buys back the future contracts and sells the grain. The storage hedge will be successful if the basis, defined as cash price minus a particular futures price, increases over the storage period by at least the costs of storing the grain over the time period.

However, wheat merchandisers contend that profitability of storage hedges has declined after 1982, with some in the wheat industry attributing this decline to the increased proportion of stocks under government control during the mid-1980s (Tomek and Robinson, pg. 276). Government storage activities may have reduced the need for private firms to store wheat, reducing in turn the monetary incentive for private firms to store.

Profitability of storage hedges is related to the market-determined price of storage (spread), which is the difference between a spot price and a futures price, where the spot price can be a cash price or another futures price. The spread is related to the storage costs of a commodity over the time interval the commodity is to be stored. In order to understand the factors that influence profitability of storage hedges, it is necessary to understand the factors that influence the spread. Since the spread is a price, i.e. the price of storage, and prices are determined by supply and demand, it will be necessary to understand the factors that influence the supply of and demand for storage of the commodity in question.

The primary objective of this study is to increase understanding of profitability of storage hedges, and to determine the effect of market and government factors on supply of and demand for storage for hard red winter wheat.

Chapter II

LITERATURE REVIEW

The purpose of this review is to examine past research and to set up the theoretical basis from which supply of and demand for storage of hard red winter wheat can be analyzed. The first section sketches the development of the supply of and demand for storage theory, while the second section discusses the role of government vs. private stocks in determining the price of storage.

Supply of Storage Theory

The relationship between the spread--the difference between two futures prices or a futures price and spot price--and the amount of storage of a commodity was first described by Working (1934). Drawing through a scatter plot of points, Working (1949) developed what he called the supply of storage curve.[1] Figure 1 is a graphical representation of Working's supply of storage curve.[2] As can be seen, this curve is upward sloping and nonlinear. On the vertical axis is the spread or, as Working (1949) termed it, the price of storage, which is related to the costs of

[1] Other authors including Brennan (1958), Telser (1958), Weymar (1974), Gray and Peck (1981), Thompson (1986) and Tilley and Campbell (1988), have found the same pattern with different commodities and time periods.

[2] The supply of storage does not refer to the supply of storage space, but rather the supply of commodities as inventories (Brennan 1958).

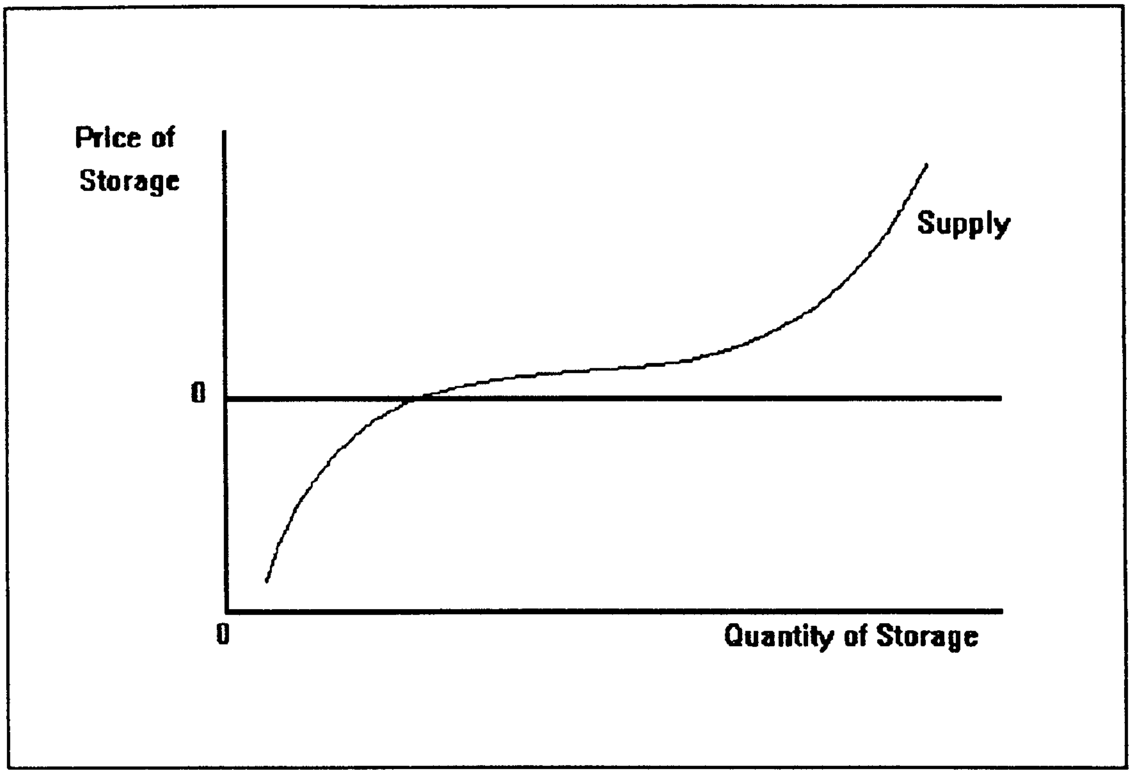

Figure 1. Working's Supply of Storage Curve

carrying the commodity and is positively related to the duration of the storage period. Working (1949) states that with a surplus of stocks, the futures price for a distant contract month tends to be the same day's futures price for an earlier contract month plus the cost of storing the wheat from the earlier month to the distant month. The difference between the prices of the two contract months, the spread, is the price of storage. The price of storage can take on positive, negative, or zero values.

Positive prices occur when futures prices for more distant months exceed nearer futures prices. This is known as a positive carrying charge. For a wide range of stocks, it is believed that the cost of storing an additional bushel is fairly constant, leading to a nearly horizontal portion of the supply of storage curve. However, as stocks increase and storage space becomes scarce, the marginal cost of storage increases sharply because of the need to construct additional storage facilities. This is represented by the portion of figure 1 where the curve increases sharply upward. This portion of the supply of storage curve is not usually observed in the United States (Tomek and Robinson, p. 228).

Negative prices occur when the spot price or nearer futures price exceeds the more distant futures price. This is known as an inverse carrying charge, and leads to the portion of the supply of storage curve that dips down into the negative price range. Inverse carrying charges arise when supply shortages occur. For example, supply shortages in period 1 cause the spot price in period 1 to increase above more distant futures prices in order to encourage firms to release stocks into consumption channels. However, even when the return to storage is negative, firms still hold a significant amount of stocks. Because of this, Tomek and Gray (1970) note that although there is a limit to a positive price of storage--a futures price is never above the cash (spot) price by more than the cost of storage due to arbitrage--there is no limit to a negative price of storage, the amount that cash price can rise above futures price.

Working (1948) gives two possible reasons why stocks are carried when the price is zero or negative. First, most of the costs of storing grain are fixed in the short run. This reduces a firm's short-run losses from storing grain. Secondly, many firms supply storage as a necessary function of their primary operation. Merchandising and processing firms are examples. Consequently, any losses incurred by storing grain may be compensated by profits from the firm's primary operation. In addition, firms may carry stocks when the price of storage is negative because of what Kaldor (1939) termed "convenience yield".

Convenience Yield

Williams and Wright (1991, pp. 247-8) state that firms holding stocks gain a "convenience yield" by having stocks readily available. Firms hold stocks for a return below their costs of physical storage and capital invested because inventories reduce the need for numerous changes in production schedules and reduce vulnerability to interruptions in deliveries.

Brennan (1958) states that the marginal convenience yield is a decreasing function of the amount of stocks held. Thus, the marginal convenience yield may exceed the marginal physical costs of storage when inventories are low, creating an inverse price structure with futures price below spot price.

<u>Risk Premium</u>

Keynes (1930) and Hicks (1946) hypothesized that the excess of the expected spot price over the futures price is a type of insurance premium (risk premium) hedgers must pay speculators to encourage them to bear the risk of an adverse price change. For example, if in June the September futures price is $2.40 and the spot price expected to prevail in September is $2.50, a speculator might buy the September futures at $2.40 and at maturity sell it at the prevailing spot price of $2.50. The speculator is thus rewarded for taking risk.

Brennan (1958), expanding on Kaldor and Working's contribution to the theory of the price of storage, argues the need for Keynes and Hick's third component of the net marginal cost of storage--namely, the risk premium. Brennan states that the net marginal cost of storage is made up of a marginal outlay on physical storage plus a marginal risk aversion factor (risk premium) minus a marginal convenience yield.

When stock levels are low the risk of a commodity losing its value is small, but as stock levels rise the risk of loss of inventory value is increased, possibly to the point that a firm's credit position is threatened. Brennan argues that the market must offer a risk premium to encourage firms to increase inventories because the risk of loss of value is part of the cost of storage. Weymar (1966) also contends that firms with available storage space can be enticed to store additional inventories when a risk premium can be expected.

Keynes and Hicks argue that futures prices are biased downward which gives rise to the risk premium. This implies that futures prices will tend to trend upward over the life of the contract (Telser 1958). Working (1948) states that if there is such a tendency in futures prices, it is probably very small and not statistically verifiable. Telser (1958) verifies Working's statement and argues against the concept of a risk premium. Using wheat and cotton futures prices data, he demonstrates that there is no upward trend in futures prices.

Paul (1970) assumes the risk-premium away by arguing that the risk to the purchaser of a futures contract for the delivery of the grain at time t is the same as the risk to the owner of grain who holds it for sale at time t. He goes on to say that "attempts to measure risk-premium have borne little fruit" (pg. 3), and therefore he considers it negligible.

Demand for Storage

Brennan (1958) confirms Working's price of storage theory for shell eggs, cheese, butter, wheat, and oats. Brennan models the spread as the intersection of the demand (which is related to the commodity's consumption) and the supply of storage (see figure 2). Brennan contends that the supply of storage function is relatively stable because the marginal physical cost function is relatively stable, and the marginal convenience yield function and the marginal risk-aversion function will not shift significantly from month to month. He generates an empirical supply of storage curve by assuming the demand for storage function fluctuates over a stable supply curve. Brennan also broadens the definition of convenience yield by including in it potential profit from an unanticipated price increase.

Telser (1958), like Brennan, models the spread as the intersection of the supply and demand for stocks. Telser also assumes the demand for storage shifts over a stable supply curve, thus generating the industry's stockholding schedule. Telser mentions that the demand for storage function can also be estimated by using a model dealing solely with consumers' demand for the commodity. However, neither Telser nor Brennan attempt to empirically generate the demand for storage function.

In his empirical model, Telser measures the relationship between the spread and stocks and also two other variables; consumption and the fraction of total stocks held by the government. Telser contends that since the spread is equal to the marginal cost of storage minus a marginal convenience yield of a given level of stocks, factors which affect the marginal cost of storage and the marginal convenience yield determine the spread. Therefore, he states that since both increased consumption and an increased fraction of government stocks held increase the marginal convenience yield for a given quantity of stocks, they should influence supply negatively.[3]

Working (1948) suggests that only supplies already in existence have any impact on the price spread. However, Weymar (1966) argues that expectations about inventory level over the storage period also affect the spread. For example, if the expectation of inventory level changes before the storage period expires, then the price difference relationship will adjust to reflect this change.

Paul's (1970) work on the supply of storage differs from previous studies in that he studies the pricing of all grain storage, not just that of a particular commodity. Paul assumes the convenience yield to be zero because he aggregates all grains into

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[3] The relationship between the spread and government held stocks is discussed further in the next section.

one population, and argues that as long as one of these grains does not exhibit a convenience yield, it can be representative of the entire population.

Paul includes in his estimation of the determinants of the price of storage two variables: the first is the quantity of grain stored as a percent of total binspace (q_s/Q), and the second is the quantity of grain sold off the farm as a percent of total binspace (q_h/Q). The variable q_s/Q is a proxy for quantity supplied. The variable q_h/Q is a proxy for handling since it is a measure of the amount of grain moving into the system. It reflects the concept of an alternative output, such as corn versus oats, but in this case it is binspace for storage of grain versus binspace for handling grain.

Paul finds the signs of the estimated coefficients to be compatible with economic theory. Handling pressure has a greater impact on the price of storage than quantity stored. Despite Paul's assumption of no convenience yield, he concludes that his estimation appears to support the existence of a convenience yield.

The studies cited above have assumed a stable supply curve over which a demand curve shifts. Sexauer (1977), however, studying the relationship between carrying charge and Maine potato stocks, contends that for a discontinuous inventory, semiperishable commodity like potatoes, the supply of storage function is also shifting significantly over time. Consequently, he uses simultaneous equations to estimate the supply and demand schedules.

Sexauer concludes that for potatoes, the shifts in the supply function are great enough to map out the demand function. He was not able to estimate the supply function, possibly due to omitted variables or an identification problem.

Tomek and Robinson (pg. 228) argue that the supply of storage function may shift due to changes in interest rates and the price of the commodity going into storage. In essence, the opportunity cost of storing the grain increases as the interest rate and/or the price rises. Thus, the firm requires a larger spread in order to make storage profitable.

The Role of Stocks in Determining the Price of Storage

As noted above, the supply of storage theory relates stocks to the differences in spot prices and futures prices. Government's role in storage, however, complicates this theory, since stocks controlled by the government are less accessible to the market. Government controlled stocks result primarily from two programs; the nonrecourse loan program and the Farmer-Owned Reserve.

Nonrecourse Loan

The nonrecourse loan's primary objective is to provide farmers with a source of credit and to prevent all of a commodity from being marketed at harvest time (Knutson and Boehm, pg. 238). At harvest time, the farmer is given the option to place his grain under loan at the current support price. If he accepts the loan, then the grain becomes collateral against the loan. The farmer must pay all storage costs and may sell the commodity at any time provided the farmer pays off the loan plus accrued interest charges. If the farmer defaults on the loan, the grain becomes the property of the Commodity Credit Corporation (CCC) in full payment of the loan. The farmer, in most cases, will not default on the loan if the market price rises above the loan rate plus accrued interest costs. Thus, to the extent that production is enrolled in government programs, the loan rate acts as a floor on the market price, since the farmer will forfeit the grain if the market price drops below the loan rate.

Farmer-Owned Reserve

The farmer-owned reserve's (FOR) objectives are to stabilize prices and provide increased supply assurance to domestic and foreign customers (Knutson and Boehm, pg. 256). With the FOR, which is an extended 27 month program, the farmer receives the nonrecourse loan entry price (loan rate). The storage costs may be paid by the government and interest costs are waived for the three year period (9 month nonrecourse period plus the 27 month FOR period). In addition, the farmer agrees not to sell the commodity until the market price reaches the release price, at which time interest and storage cost subsidies may end and the farmer may choose to sell the commodity.

As Gray (1962, pg. 27) states "...the loan is said to be 'working' as more wheat moves into loan, tightening up free market supplies and forcing prices up to or beyond loan levels." If cash prices are above support prices, farmers will place less wheat under loan, and more will move into the free market system (Ehrich 1966). On the other hand, increased loan use will occur when cash prices are low relative to support prices and more grain will move into government storage.

Ehrich (1966) points out that the amount of wheat placed under loan and the amount forfeited to the CCC depend largely on the relationship between market cash prices and support prices. Nevertheless, certain nonprice factors affect the degree of loan use. These include: compliance with acreage allotments and ineligibility, availability of storage space, and ability to meet quality standards.

CHAPTER III

THEORETICAL MODEL FOR SUPPLY OF AND DEMAND FOR STORAGE

This section introduces a theoretical model for supply of and demand for storage, basing the model on those introduced by Brennan (1958), Telser (1958), Sexauer (1977), and Thompson (1986).

Supply of and Demand for storage functions are similar to supply and demand functions of elementary price theory. The demand for storage function is derived from consumers' demand for consumption of a commodity in period t and consumers' expected consumption in period t+1. The supply of storage schedule is derived from the profit-maximizing behavior of firms in the industry. The equilibrium price of storage and inventory level is the intersection of these two schedules.

The Demand for Storage

Consumption in any period is assumed to be dependent on price in that period. Therefore, where P_t and C_t equal price and consumption in period t, the inverse demand function can be written as:

$$P_t = f_t(C_t),\ \frac{df_t}{dC_t}<0. \tag{1}$$

Consumption in any period is equal to stocks carried into the period plus production in the period minus stocks carried out of the period. Equation (1) can then be written as:

$$P_t = f_t(S_{t-1}+X_t-S_t), \tag{2}$$

where S_{t-1} is stocks carried into period t from period t-1, X_t is production in period t, and S_t is stocks carried out of t into period t+1. Consequently, the demand for storage from period t to period t+1 can be written as:

$$P_t^{t+1}-P_t = f_t^{t+1}(C_t^{t+1})-f_t(C_t), \tag{3}$$

or

$$P_t^{t+1}-P_t = f_t^{t+1}(S_t+X_t^{t+1}-S_t^{t+1})-f_t(S_{t-1}+X_t-S_t). \tag{4}$$

Telser states that the demand for storage schedule relates the quantity of stocks carried out of a period with the realized price change, and the supply schedule relates the carry out to the expected price change. He assumes that on average the realized price change equals the expected price change.

Brennan and Telser model the demand for storage as an *ex post* relationship. Sexauer, however, argues that since P_{t+1}, S_{t+1}, and X_{t+1} are not known in period t, the inverse demand for storage should be specified as an anticipated demand for storage with expected price P_t^{t+1} replacing P_{t+1}, expected production X_t^{t+1} replacing X_{t+1}, and expected stocks S_t^{t+1} replacing S_{t+1}, where the subscript denotes the period in which expectations are formed for the period denoted by the superscript. This anticipated demand curve should be downward sloping with respect to S_t. Therefore, equation (4) states that the expected price difference between period t and period t+1 is a function of expected consumption (disappearance) in period t+1, and consumption (disappearance) in period t. Figure 2 illustrates this relationship.

Changes in stocks carried into t (S_{t-1}), production in t (X_t), expected stocks in t+1 (S_t^{t+1}), and expected production in t+1 (X_t^{t+1}) will cause shifts in the demand for storage. For example, an increase in stocks carried into t will cause a rightward shift in the demand for storage from D to D^1 in figure 2. Price of the commodity in t will fall, causing the spread between P_t and P_t^{t+1} to increase and induce more storage in t. An increase in production in time t will produce the same effect.

A decrease in expected production in t+1 will also cause a rightward shift in the demand for storage. With less grain expected to be produced in t+1, expected price in t+1 will increase, thereby increasing the spread. In turn, firms will be enticed to hold more stocks because of the increased price difference from t to t+1.

Increasing expected stocks carried out of t+1 also produces a rightward shift in the demand for storage curve. With more stocks taken from t+1 into the next period, the expected price in t+1 rises, which increases the spread between P_t and P_t^{t+1}. Again, with an increased price of storage, firms will carry additional stocks from t to t+1. Opposite movements of these exogenous variables will produce leftward shifts in the demand for storage function from D to D^2 in figure 2, with a resulting decrease in the spread.

Thompson (1986) suggests that, in addition to the above variables, changes in government held stocks may shift the demand for storage curve. For example, as the demand for government storage increases, demand for private storage decreases and a smaller spread results, which decreases the monetary incentive for private firms to store.

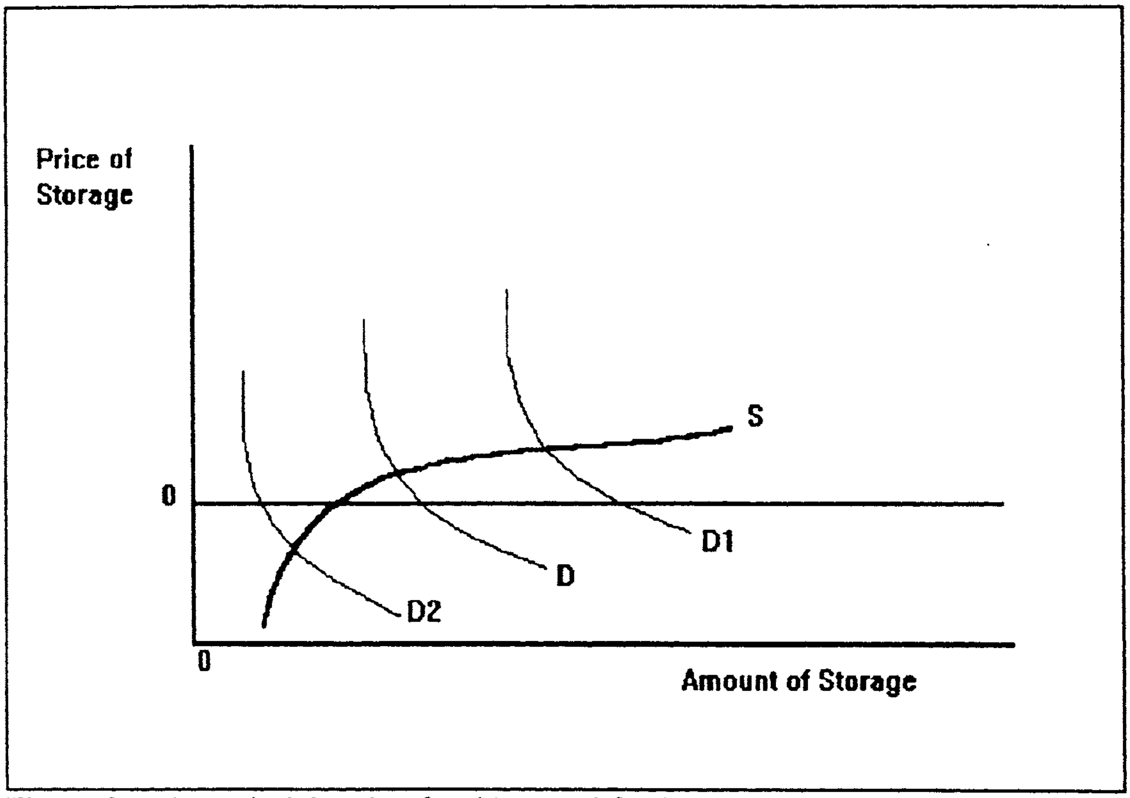

Figure 2. Theoretical Supply of and Demand for Storage Curves

The Supply of Storage

The supply of storage function can be derived from the profit maximizing behavior of firms in the industry. Assuming perfect competition, a firm will seek to maximize profits by holding an amount of stocks where the marginal revenue from holding these stocks from t to t+1 is equal to the marginal cost of holding them from t to t+1. The net marginal cost of storage is defined as the marginal physical cost of storage plus a marginal risk premium minus a marginal convenience yield, all of which are functions of inventory size. Physical costs of storage include rent, interest charges, handling and processing charges, cost of deterioration, insurance, etc. As discussed in the literature review, the convenience yield is the benefit firms receive by holding stocks to meet customer needs even though the spread may be negative, and the risk premium is the amount hedgers must pay speculators to induce them to take risk.

Assume a firm wishes to determine the amount of stocks, S_t, that should be held from period t to t+1. Let the total net cost of storage, $nc(S_t)$, equal the total physical cost of holding S_t, $tc(S_t)$, plus the risk premium, $rp(S_t)$, minus the convenience yield from holding these stocks, $cy(S_t)$. Then:

$$nc(S_t)=tc(S_t)+rp(S_t)-cy(S_t). \tag{5}$$

Let the spread, or price of storage, Sp_t, equal the expectation in t of price in t+1 minus the price in t, ($Sp_t = P_t^{t+1} - P_t$). In perfect competition Sp_t is independent of the amount of stocks held by the firm. The gross revenue from holding stocks S_t can then be defined as Sp_t times S_t, Sp_tS_t. The net profit then becomes:

In order to find the quantity of stocks that maximizes profit, equation (6) is

$$\Pi = Sp_t S_t - tc(S_t) - rp(S_t) + cy(S_t). \tag{6}$$

$$Sp_t = tc'(S_t) + rp'(S_t) - cy'(S_t). \tag{7}$$

differentiated with respect to S_t and set equal to zero. This yields:

Equation (7) states that for maximum profit, marginal revenue must equal marginal cost plus a marginal risk premium minus a marginal convenience yield. It is assumed that the first derivatives of $tc(S_t)$ and $rp(S_t)$ are greater than zero and that their second derivatives are greater than or equal to zero. The first derivative on $cy(S_t)$ is assumed to be greater than or equal to zero and its second derivative is assumed to be less than or equal to zero. A maximum solution is achieved if these conditions are met (Brennan; Telser).

The firm's net marginal cost curve can be found by solving equation (7) for S_t as a function of Sp_t. The firm's net marginal cost curve is positively sloped, which can be seen by taking the derivative of equation (7) with respect to S_t:

$$\frac{dSp}{dS_t} = tc''(S_t) + rp''(S_t) - cy''(S_t) > 0. \tag{8}$$

Assuming no external economies or diseconomies of scale in the storage industry, the industry supply of storage curve can be derived by horizontally adding each firms' individual net marginal cost curve. Thus, the inverse industry supply of storage function can be written as:

$$Sp_t = g_t(S_t). \tag{9}$$

Telser (1958) states that factors that affect the marginal convenience yield and the marginal cost of physical storage determine the spread, as seen in equation (7).

Therefore, a variable that increases the marginal cost of physical storage or the risk premium of a given level of stocks increases the spread and should enter the right hand side of equation (9) with a positive sign. A variable that increases the marginal convenience yield of a given level of stocks will decrease the spread and should enter the right hand side of equation (9) with a negative sign.

Equilibrium

The equilibrium between quantity of stocks carried out of t and the spread is determined by the intersection of the supply of and demand for storage curves. Using equations (4) and (9), the market equilibrium condition can be expressed as:

$$g_t(S_t) = f_t^{t+1}(S_t + X_t^{t+1} - S_t^{t+1}) - f_t(S_{t-1} + X_t - S_t). \tag{10}$$

Figure 3 illustrates the equilibrium condition. D, D^1, and D^2 are demand for storage curves and S and S^1 are supply of storage curves. The demand for storage function will shift due to changes in expected production and consumption, and changes in government storage programs. For example, assume that in figure 3, D and S are the initial demand and supply in t with an equilibrium spread of P^0 and equilibrium stocks of S_t^0. Furthermore, suppose production in t+1 is expected to increase. This will cause the demand for inventories to fall and D will shift leftward to D^1 resulting in a new equilibrium spread of P^1 and stocks of S_t^1. The supply of storage function will shift due to changes in interest rates, price of the commodity going into storage, amount of stocks controlled by government, and consumption in time t. For example, increasing interest rates will increase the

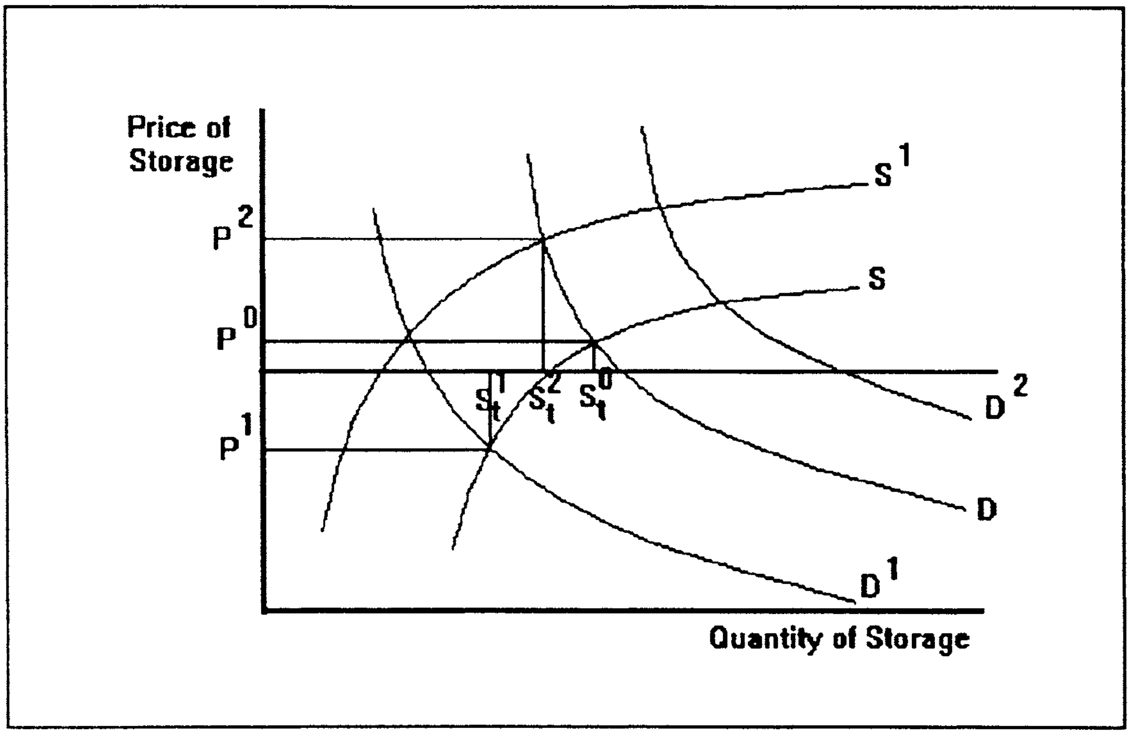

Figure 3. Equilibrium Between Supply of and Demand for Storage Curves.

marginal physical cost of storage, shifting the supply of storage curve leftward from S to S^1. The new equilibrium quantity of stocks becomes S_t^2 and the spread rises to P^2.

Simultaneous Determination of the Supply of
and Demand for Storage curves

Working, Telser, and Brennan, working primarily with seasonally produced, continuous inventory commodities, assume a stable supply of storage function, and a shifting demand for storage function. Thus, they are able to estimate the supply curve using a single equation approach. Sexauer, however, noted that in some cases, both the supply and demand curves are shifting so that the single equation approach is not valid. For example, he argued that the supply of storage curve for potatoes, a seasonally produced, semi-perishable commodity, is likely shifting along with the demand curve.

The problem, discussed by E.J. Working (1927), is one of knowing the relative variability of the supply and demand curves in question. For example, figure 4 shows the relationship between a stable supply curve and a shifting demand curve. In this case, the supply curve is "mapped out" (figure 5) by the shifting demand curve and is said to be identified. Thus, it can be estimated by ordinary least squares (OLS). The demand curve, however, cannot be estimated using OLS.

Figure 6 shows the relationship between a variable demand and supply curve, with shifts being approximately equal. The equilibrium points of these two shifting curves are shown in figure 7. They produce a "shotgun" pattern and suggest that neither the supply nor demand curve can be estimated using OLS. An estimation of,

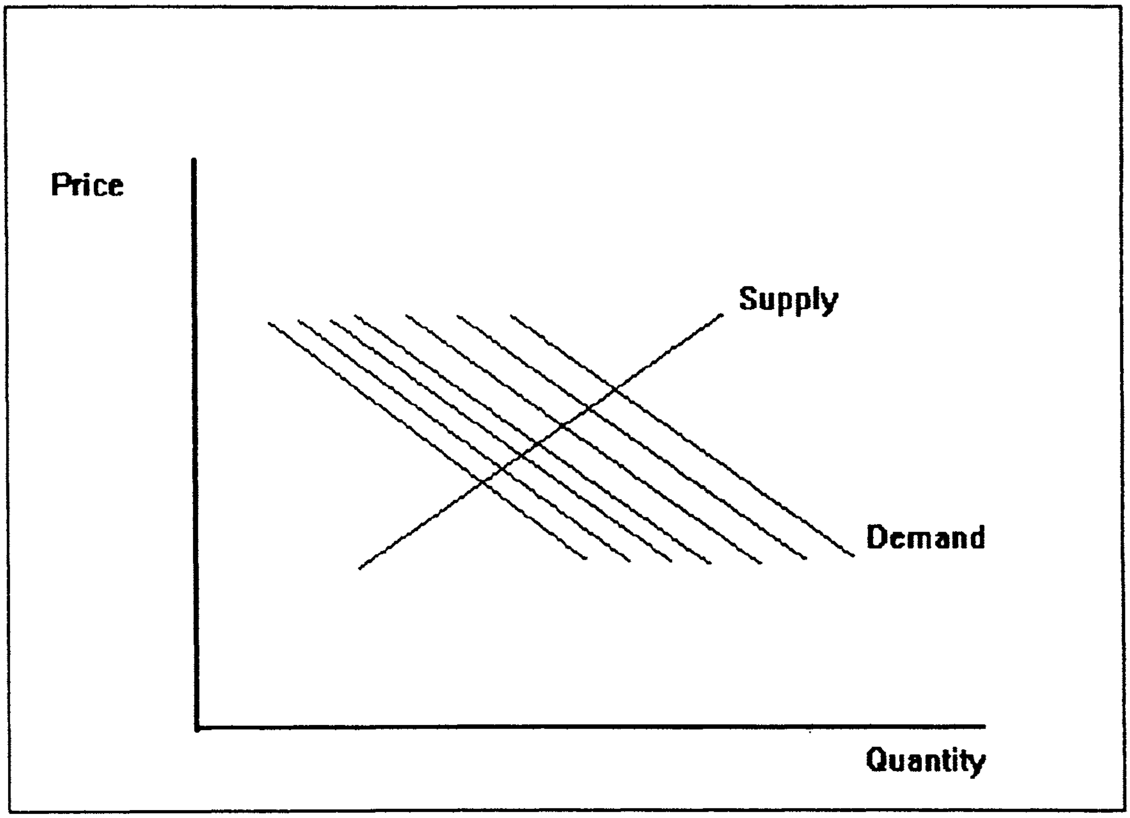

Figure 4. Stable Supply and Shifting Demand Curves

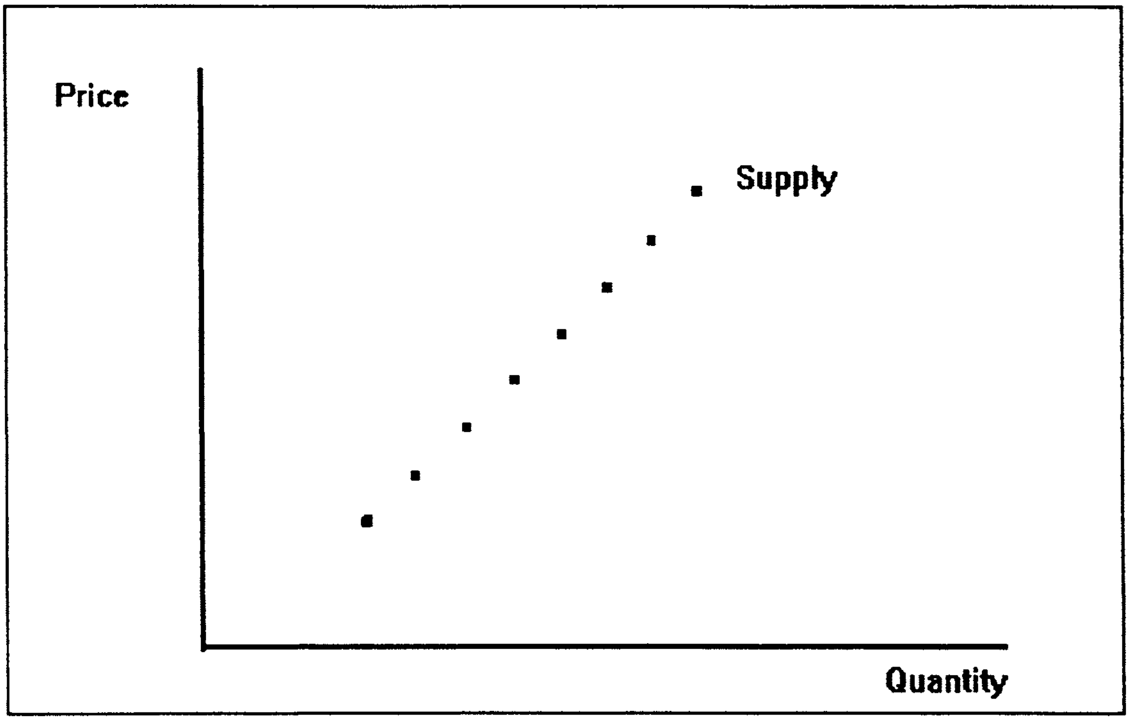

Figure 5. Stable Supply Curve Mapped out by Shifting Demand Curve

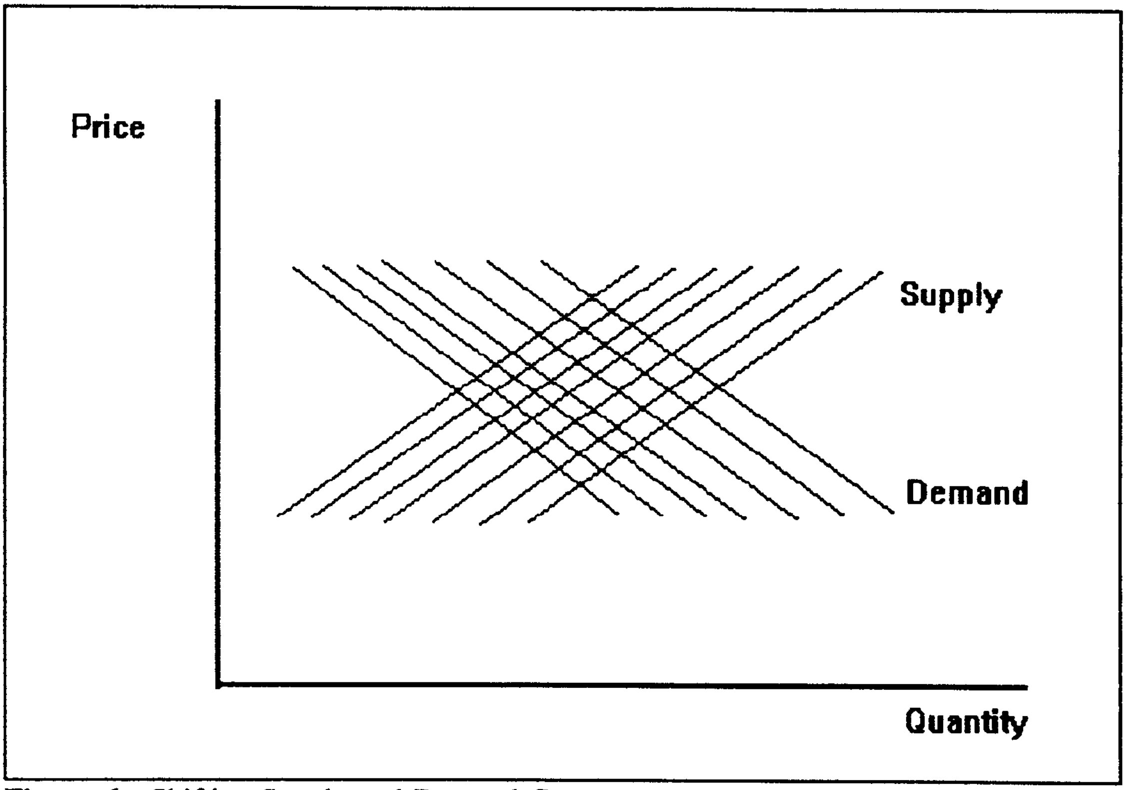

Figure 6. Shifting Supply and Demand Curves

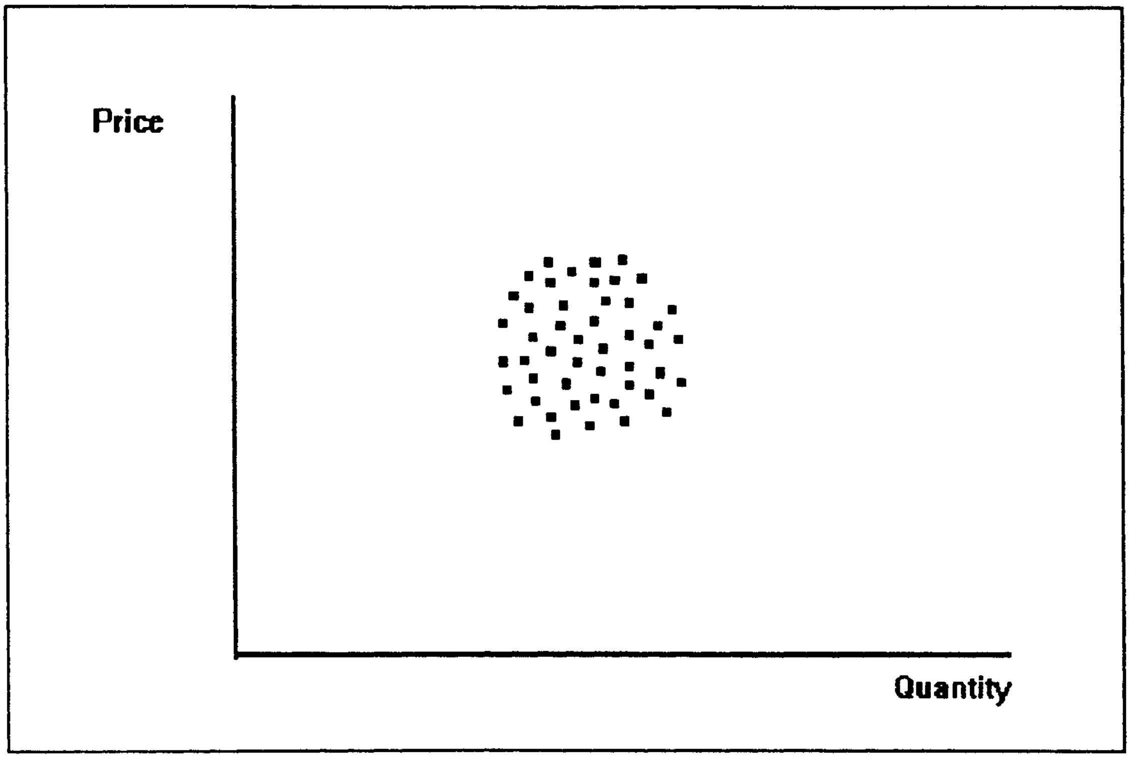

Figure 7. "Shotgun" Pattern due to Shifting Supply and Demand Curves

say, the supply curve in this situation would not yield the true supply function, but, in fact would yield a hybrid of the supply and demand functions (Judge et al., 1988, pg. 628).

The problem of simultaneous equations arises when an equation of a model contains more than one endogenous variable. This is referred to as a simultaneous equations system and violates the classical linear regression assumption that each regressor is independent of the equation errors. Classical linear regression estimation procedures assume one-way causality. That is, the right hand side independent variables are assumed to impact the dependent variable, with no feedback in the other direction. In such cases, the OLS model is appropriate. However, it is usually inappropriate in the case of price and quantity data that are jointly determined by supply and demand (Judge et al., 1985, pg. 564). Using OLS on an equation in a simultaneous system yields biased and inconsistent parameter estimates (Judge et al., 1985, pg. 570). The reason is that the presence of one or more endogenous variables used as regressors ensures a contemporaneous, nonvanishing correlation between the disturbance term and the set of explanatory variables even as the sample size approaches infinity (Judge et al., 1985).

A popular model used to explain simultaneous equations systems is the simple Keynesian model of a consumption function and equilibrium condition (Judge et al., 1988, pg. 621; Kennedy, pg. 126; and Wallace and Silver, pg. 336), and is used here to illustrate. The model is:

$$C=a+bY+\varepsilon \tag{11}$$

$$Y=C+I \tag{12}$$

where C is consumption, Y is income, I is investment, a and b are parameters to be estimated, and ε is a random error term with mean zero and constant variance σ^2. Assume that I is an exogenous variable (determined outside the system), and C and Y are endogenous variables (determined within the system). Suppose the error term in equation (17) increases. This induces a change in C, which through the equilibrium condition changes Y. Y, however, is the independent variable in equation (17) and C again is affected. Thus, the error term and Y are positively correlated.

Equations (17) and (18) are referred to as structural equations. In order to solve this system of simultaneous equations, the system must be solved for the reduced form equations, which express the endogenous variables as linear functions of all the exogenous variables. For equations (17) and (18) the reduced form equations are:

$$Y=\frac{a}{1-b}+\frac{1}{1-b}I+\frac{1}{1-b}\varepsilon \tag{13}$$

$$C=\frac{a}{1-b}+\frac{b}{1-b}I+\frac{1}{1-b}\varepsilon \tag{14}$$

which can then be written as:

$$Y=\pi_1+\pi_2 I+v_1 \tag{15}$$

$$C=\pi_3+\pi_4 I+v_2 \tag{16}$$

The π's are parameters of the reduced form equations and are nonlinear functions of the structural form parameters. The v's are the reduced form error terms and are functions of the structural form errors. In matrix notation the model can be written as:

$$Y\Gamma+X\mathrm{B}+E=0 \tag{17}$$

If Γ is non-singular, equation (23) can be solved for Y and yields:

$$Y\Gamma\Gamma^{-1}+X\mathrm{B}\Gamma^{-1}+E\Gamma^{-1}=0 \tag{18}$$

$$Y+X\mathrm{B}\Gamma^{-1}+E\Gamma^{-1}=0 \tag{19}$$

$$Y=-X\mathrm{B}\Gamma^{-1}-E\Gamma^{-1} \tag{20}$$

$$Y=\Pi X+V \tag{21}$$

where Y is the matrix of endogenous variables, X is the matrix of exogenous and lagged endogenous variables, Γ is the matrix of coefficients of the endogenous variables, B is the matrix of coefficients of the exogenous and lagged endogenous variables, E is the matrix of unobservable values taken by the random error vectors, and 0 is a matrix of zeros. Π is the matrix of reduced form coefficients and is equal to $-\mathrm{B}\Gamma^{-1}$, and V is the matrix of reduced form error terms and is equal to $-E\Gamma^{-1}$. The reduced form parameters often are of use only if there is a way of using them to derive estimates of the structural parameters. This leads to the question of identification.

The idea of identifying an equation in a simultaneous system revolves around whether or not there is enough information contained in the system in order to obtain consistent estimates of the structural parameters (Wallace and Silver, pg. 340). An equation in a simultaneous system can be under identified, over identified or exactly identified. In order to determine if an equation is identified, it must pass two tests, the order and rank conditions. The order condition states that the number of excluded exogenous variables must be greater than or equal to the number of included endogenous variables less one (Kennedy, pg. 138). However, this is only a necessary condition and not a sufficient one, and therefore, the rank condition must also be checked. Unfortunately, the rank condition is somewhat more difficult to employ. The rank condition states that the rank of the matrix of parameters (from all the equations) associated with all the variables excluded from the ith equation must equal the number of equations in the system minus one (Kennedy, pg. 142).

When using nonlinear forms of the variables, the identification process can be complicated even further. The identification procedures discussed above which are appropriate for a model that is linear in the parameters and in the variables is not applicable (Judge et al., 1985, pg. 582). However, Judge et al. go on to say that the problems arise when endogenous variables are used in different equations with different functional forms. Fortunately, this is not the case in this study, so normal identification procedures should apply.

CHAPTER IV

EMPIRICAL MODELS, PROCEDURES, AND DATA

Introduction

The purpose of this chapter is to discuss the models, procedures, and data that are used to satisfy the objectives stated in Chapter I. Using the theoretical models discussed in Chapter III as a basis, empirical models to be used in estimating supply of and demand for storage are developed. The first section develops an empirical model using a theoretical model based on previous work. The second section discusses an alternative model for the supply of and demand for storage system which solves some problems associated with the first model. The third section discusses simultaneous equations estimation procedures which are used to estimate the parameters of both systems, and the final section discusses the data used in estimating the supply of and demand for storage systems for hard red winter wheat.

Supply of and Demand for Storage Model (I)

In this section, three separate storage periods (harvest to November of the same year (I), harvest to February of the following year (II), and December to February of the following year (III))[4], are evaluated to determine the effects of

[4]Harvest, in this analysis, corresponds with the month of June.

market and government factors on the supply of and demand for storage for storage periods of various durations and of different time periods within a crop year.

Supply of Storage

The theoretical supply of storage function indicates that the spread is equal to a marginal physical cost of storage plus a marginal risk premium minus a marginal convenience yield. Therefore, variables that increase the marginal physical costs of storage and/or the marginal risk premium should enter the empirical supply of storage equation with a positive sign, while variables that increase the marginal convenience yield should enter the equation with negative sign. Empirical studies of the supply of storage are divided on whether or not a risk premium exists and whether or not it is needed in the determination of the price of storage. Since the primary concern with this study is on the impact of government storage, and the data available provides very few observations, it is assumed that the risk premium is zero. Hence, no measurement of a risk premium is used in the empirical supply of storage function.

The empirical supply of storage function is:

$$Sp_t = f_t(S_t, GS_t, C_t, CC_{t\ to\ t+1})$$

Sp_t

$Sp_t = P_t^{t+1} - P_t$, is the market determined price of storage (spread). For storage period I, Sp_t is the December futures price minus the July futures price on June 20th of each year; for storage period II, Sp_t is the March futures price minus the July futures price on June 20th of each year; and for storage period III, Sp_t is the March futures price minus the December futures price on December 1st of each year.

S_t

S_t is total stocks in period t, the quantity of storage supplied during the period t to t+1. For storage period I, S_t is September 1 total stocks; for storage period II, S_t is September 1 total stocks; and for storage period III, S_t is December 1 total stocks.

GS_t

GS_t is the ratio of Commodity Credit Corporation (CCC) stocks plus farmer-owned reserve (FOR) stocks plus outstanding loans to total stocks in period t. For storage period I, GS_t is September 1 CCC plus September 1 FOR plus September 1 outstanding loans divided by September 1 total stocks; for storage period II, GS_t is September 1 CCC plus September 1 FOR plus September 1 outstanding loans divided by September 1 total stocks; and for storage period III, GS_t is December 1 CCC plus December 1 FOR plus December 1 outstanding loans divided by December 1 total stocks.

C_t

C_t is consumption in period t and is calculated as domestic disappearance plus exports. For storage period I, C_t is total disappearance from July to November; for storage period II, C_t is total disappearance from July to February; and for storage period III, C_t is total disappearance from December to February.

$CC_{t\ to\ t+1}$

$CC_{t\ to\ t+1}$ is carry costs of storing grain from period t to period t+1. Carry costs equal daily variable storage costs plus daily interest costs times the number of days the grain is stored.

Demand for Storage

The theoretical demand for storage function states that the spread is a function of consumption in t and expected consumption in t+1, where consumption in any period is defined as stocks carried into the period plus production in the period minus stocks carried out of the period.

The empirical demand for storage function is:

$$Sp_t = f_t(S_t, GS_t, S_{t-1}, X_t, X_t^{t+1}, S_t^{t+1})$$

Sp_t, S_t, and GS_t are defined above.

S_{t-1}

S_{t-1} is total stocks carried into period t from period t-1. For storage periods I and II, S_{t-1} is June 1 total stocks, and for storage period III, S_{t-1} is September 1 total stocks.

X_t

X_t is production in period t. For storage periods I and II, X_t is production for the marketing year in which the storage period begins. For storage period III, Xt is zero since no hard red winter wheat is produced during that storage period.

X_t^{t+1}

X_t^{t+1} is the expectation (at time t) of production in period t+1. For all three storage periods, X_t^{t+1} is zero since no hard red winter wheat is produced during t+1.

S_t^{t+1}

S_t^{t+1} is the expectation (at time t) of stocks to be carried out of period t+1. Since S_t^{t+1} is not observable at time t, S_{t+1} is used as a proxy for S_t^{t+1}. For storage period I, S_{t+1} is December 1 total stocks; for storage periods II and III, S_{t+1} is March 1 total stocks.

The supply of and demand for storage functions modeled above written in simultaneous equations notation are:

$$Sp_t^s\gamma_{11}+S_t\gamma_{21}+X_1\beta_{11}+GS_t\beta_{21}+C_t\beta_{31}+CC_{mot+1}\beta_{41}+e_1=0 \tag{22}$$

$$Sp_t^d\gamma_{12}+S_t\gamma_{22}+X_1\beta_{12}+GS_t\beta_{22}+S_{t-1}\beta_{52}+X_t\beta_{62}+S_{t+1}\beta_{72}+e_2=0 \tag{23}$$

where the γ's and β's are the structural parameters to be estimated and X_1 is the intercept. The identity

$$Sp_t^s=Sp_t^d \tag{24}$$

closes out the system and assumes the system is in equilibrium.

Hypothesized Relationships

The explanatory variables used in developing the supply of and demand for storage functions are based on theory and past research. The purpose of this section is to discuss each variable's hypothesized relationship within its equation. In the discussion of each of the variables below it is assumed that the other variables in the equations are held constant.

Supply of Storage Equation

Total Stocks (S_t)

The total stocks variable is the quantity of storage supplied. It equals free stocks plus Commodity Credit Corporation stocks plus Farmer-Owned Reserve stocks plus outstanding loans. This variable is expected to have a positive relationship with the price of storage; as the price of storage increases (decreases), total stocks increase (decrease). Over larger quantities of stocks, the supply function is expected to be highly elastic. For smaller quantities of stocks, the supply function is expected to take the form suggested by the convenience yield theory, i.e., positive levels of stocks being carried at negative prices.

Ratio of Commodity Credit Corporation Stocks Plus Farmer Owned Reserve Stocks Plus Outstanding Loans to Total Stocks (GS_t)

This variable represents the ratio of CCC stocks plus FOR stocks plus outstanding loans to total stocks. It measures the percentage of total stocks composed of government-controlled stocks. Telser (1958) argues that the marginal convenience yield of a given level of stocks increases (decreases) as the proportion under government control increases (decreases). Therefore, as the ratio of CCC stocks plus FOR stocks plus outstanding loans to total stocks increases (decreases), the supply of storage curve is expected to shift to the right (left), decreasing (increasing) the price of storage. As larger quantities of stocks are encountered, the marginal convenience yield is expected to go to zero; therefore, during periods of higher levels of stocks, government storage should not have as large an impact on the supply of storage.

Consumption (C_t)

Consumption in period t is hypothesized to have an impact on the price of storage similar to that of government storage programs. If consumption increases (decreases) the marginal convenience yield of the remaining stocks is expected to increase (decrease), this will cause the supply of storage curve to shift right (left), decreasing (increasing) the spread (Telser). As Telser explains it, if total stocks are 100 units and consumption is expected to be 50 units per month, then 100 units of total stocks equal two months' supply. However, if total stocks are 150 units and consumption is expected to be 100 units, then total stocks only equal one and a half months' supply. In the second scenario, the total stocks are "less" which implies that the marginal convenience yield of total stocks in scenario two is greater.

Carry Costs ($CC_{t\ to\ t+1}$)

Carry costs are the costs of storing the grain from period t to period t+1. CC_{ttot+1} equals daily storage costs (rent, etc.) plus daily interest cost multiplied by the number of days the grain is stored. Carry costs are hypothesized to have a positive relationship with the price of storage. For example, if carry costs increase (decrease), the supply of storage curve is expected to shift to the left (right) reflecting the higher (lower) cost of storing grain. This will cause the price of storage to increase (decrease).

Demand for Storage Equation

Total Stocks (S_t)

Total stocks is the same variable as in the supply equation. It is hypothesized to have a negative relationship with the price of storage, giving rise to a downward sloping demand for storage curve.

Ratio of Commodity Credit Corporation Stocks Plus Farmer-Owned Reserve Stocks Plus Outstanding Loans to Total Stocks (GS_t)

GS_t is defined as in the supply of storage function. On the demand side, government storage is expected to have a negative impact on the spread. As Thompson (1986) argues, as the demand for government storage increases (decreases), the demand for private storage decreases (increases), which reduces (increases) the price of storage.

Stocks Carried into Period t (S_{t-1})

Stocks carried into period t are expected to be positively related to the price of storage. As S_{t-1} increases (decreases) more (less) stocks are carried into period t. This puts downward (upward) pressure on price in period t, which increases (decreases) the spread, P_t^{t+1}-P_t.

Production in Period t (X_t)

Production in period t is hypothesized to have a positive impact on the price of storage. As production increases (decreases) in period t, the price in period t is expected to decrease (increase), which increases (decreases) the spread. For the December to February storage period, Xt is assumed to be zero since no production of hard-red winter wheat occurs during that period.

Expected production in period t+1 (X_t^{t+1})

The expectation in time t of production in period t+1 is hypothesized to have a negative relationship with the price of storage. If production in period t+1 is expected to increase (decrease), the demand for storage curve in period t will shift to the right (left) reflecting the need for less (more) grain in the future, and the price of storage will decrease (increase). Since no production of hard red winter wheat occurs during period t+1 in any of the three storage periods, X_t^{t+1} is assumed to be zero.

Expected Stocks Carried Out of Period t+1 (S_t^{t+1})

The expectation of the amount of stocks carried out of period t+1 is hypothesized to have a positive relationship with the spread. If stocks carried out of period t+1 are expected to increase (decrease), the demand for storage curve in period t will shift to the right (left). The price of storage will increase (decrease), indicating a need for more (less) grain in the future.

The following section discusses an alternative model which addresses problems present in the previous model.

Supply of and Demand for Storage Model (II)

The model discussed in the previous section is not without problems. First, the spread is assumed to be endogenous, although in reality it is known at the beginning of a storage period and should be considered exogenous. Second, consumption in period t is considered exogenous. However, consumption in t is being simultaneously determined along with price and the amount of storage, and should be considered endogenous. Third, instead of using the equilibrium identity that the spread in the demand equation equals the spread in the supply equation, a better approach may be to use the identity that consumption equals stocks coming into the period plus production in the period minus stocks leaving the period. Finally, variables in future time periods such as consumption in t+1 should be forecasted as opposed to using actual values in the estimation process.

Another improvement over model I may be using the realized price of storage in the demand relationship as opposed to using the expected price of storage (spread). Telser (1958) argues that the demand for storage schedule relates the quantity of stocks carried out of period t to the realized change in price, while the supply of storage schedule relates the quantity carried to the expected price of storage (the spread). It was assumed in past research that on average the expected price of storage equals the realized price of storage. Thus, the spread was used to represent the price in both supply and demand equations in models such as Sexauer's 1977 model. In the system modeled below, the spread represents the expected price of storage in the supply of storage function and the actual basis change from harvest to November represents the realized price of storage for the demand for storage function. The harvest to November storage period is the only one modelled in this section. The supply of and demand for storage system modeled below corrects the problems discussed above and allows for a fuller conceptualization of the system.

Supply of Storage

The empirical supply of storage function is:

$$S_t = f_t(Sp_t, GS_t, CC_{t \text{ to } t+1})$$

S_t is total stocks at the end of period 1 (December 1 total stocks, million bushel units).

$Sp_t = P_t^{t+1} - P_t$, is the market's expectation of the price of storage at the beginning of the storage period. Sp_t for the harvest to November storage period equals the December futures price minus the July futures price on June 20th of each year.

GS_t is the ratio of Commodity Credit Corporation stocks plus farmer-owned reserve stocks plus outstanding loans to total stocks in period t.

$CC_{t \text{ to } t+1}$ is estimated carry costs of storing grain over period t to period t+1. Carry costs equal daily variable storage costs plus daily interest costs times the number of days the grain is stored.

The supply of storage function modeled above shows that suppliers of storage base their storage decisions on the market's expectation of the return to storage, the percentage of government controlled stocks to total stocks, and estimated carrying costs of storing grain over the storage period.

Demand for Storage

The demand for storage function is:

$$BC_t = f_t(C_t, FC_t^{t+1}, GS_t)$$

BC_t is the change in the basis from harvest to November. It is used here as the realized price of storage. For example, if an elevator manager places a storage hedge at harvest and lifts the hedge at the end of November, the basis change from harvest to November will be the realized gross return. It is calculated as the basis at the time the hedge is liquidated minus the basis at the time the hedge was placed. In this analysis, hedges are placed on or about June 20th of each year, and liquidated on the last trading day of November.

C_t, consumption in period t, is calculated as domestic disappearance plus exports. For the harvest to November storage period, consumption equals total disappearance from July to November. Consumption over period t can also be calculated as stocks entering period t (S_{t-1}) plus production in period t (X_t) minus period t ending stocks (S_t).

FC_t^{t+1} is forecasted consumption in period t+1. A simple ARIMA model is used to forecast consumption in period t+1.

GS_t is defined above.

In the actual estimation, consumption in period t in the demand curve is substituted for by the variables in the right hand side of the identity equation. These variables are discussed below.

S_t is period t total ending stocks. For the harvest to November storage period, S_t is December 1 total stocks.

S_{t-1} is stocks carried into period t from t-1. For the storage period under analysis, S_{t-1} is June 1 stocks.

X_t is production in period t.

The demand for storage function modeled above implies that over a storage period the basis change, the level of stocks demanded for storage, and consumption of the commodity are simultaneously determined.

The supply of and demand for storage system in this analysis is a three equation system: a supply of storage equation, a demand for storage equation, and a technical identity equation ($C_t = S_{t-1} + X_t - S_t$) used to close out the system. As stated above, in the actual estimation procedures used, C_t in the demand equation is substituted for by the right hand side variables of the identity equation. The system written in simultaneous equations notation is:

$$S_t\gamma_{11}+Sp_t\beta_{11}+GS_t\beta_{21}+CC_{not+1}\beta_{31}+X_1\beta_{81}e_1 = 0 \tag{25}$$

$$BC_t\gamma_{22}+S_t\gamma_{12}+GS_t\beta_{22}+X_t\beta_{42}S_{t-1}\beta_{52}+S_{t-1}^2\beta_{62}+FC_t^{t+1}\beta_{72}+X_1\beta_{82}+e_2 = 0 \tag{26}$$

where the γ's and β's are the structural parameters to be estimated. The identity

$$C_t=S_{t-1}+X_t-S_t \tag{27}$$

closes out the system.

Hypothesized Relationships

The explanatory variables used in this supply of and demand for storage system are very similar to those used in model I. However, some notable differences exist so this section discusses each variable's hypothesized relationship within its equation in model II.

Supply of Storage Equation

Spread (Sp_t)

The spread (price of storage) variable is the market's expectation of the return to storage over time period t. It equals the December futures price minus the July futures price on June 20th of each year. This variable is expected to have a positive relationship with total stocks. If the harvest time spread increases (decreases), suppliers of storage have an incentive to increase (decrease) their quantity of stocks. Over larger quantities of stocks, the supply function is expected to be highly elastic. For smaller quantities of stocks, the supply function is expected to take the form suggested by the convenience yield theory, i.e., positive levels of stocks being carried at negative prices. However, it is argued that during harvest time storage periods when stocks are usually at their highest levels, the supply of storage curve is relatively flat. Therefore, the endogenous variables are used in their linear form. Linear variables are also required in order to use the identity equation for consumption.

Ratio of Commodity Credit Corporation Stocks Plus Farmer Owned Reserve Stocks Plus Outstanding Loans to Total Stocks (GS_t)

This variable represents the ratio of CCC stocks plus FOR stocks plus outstanding loans to total stocks. It measures the amount of total stocks composed of government-controlled stocks. Telser (1958) argues that the marginal convenience yield of a given level of stocks increases (decreases) as the proportion under government control increases (decreases). Therefore, as the ratio of CCC stocks plus FOR stocks plus outstanding loans to total stocks at harvest time increases (decreases), period t ending total stocks are expected to be higher (lower) and ending free stocks lower (higher). Thus, increasing government storage decreases free stocks and increases the convenience yield of the remaining free stocks.

Carry Costs ($CC_{t \text{ to } t+1}$)

Carry costs are the costs of storing the grain from period t to period t+1. $CC_{t \text{ to } t+1}$ equals daily storage costs (rent) plus daily interest cost multiplied by the number of days the grain is stored. Carry costs are hypothesized to have a negative relationship with period t ending stocks. If carry costs increase (decrease) at harvest, the supply of storage curve is expected to shift to the right (left) reflecting the higher (lower) cost of storing grain (the shift is down since the supply equation is modeled as a quantity dependent equation). This causes the quantity of stocks stored to decrease (increase).

Demand for Storage Equation

Total Stocks (S_t)

Total stocks is the same variable as in the supply equation except that it is hypothesized to have a negative relationship with the basis change (realized price of storage) which by the identity implies that consumption in t (C_t) has a positive relationship with the basis change.

Ratio of Commodity Credit Corporation Stocks Plus Farmer-Owned Reserve Stocks Plus Outstanding Loans to Total Stocks (GS_t)

GS_t is defined as in the supply of storage function. On the demand side, government storage is expected to have a negative impact on the basis change. As Thompson (1986) states, as the demand for government storage increases (decreases), the demand for private storage decreases (increases), which reduces (increases) the price of storage.

Stocks Carried into Period t (S_{t-1})

Stocks carried into period t are expected to be positively related to the basis change. As S_{t-1} increases (decreases), more (less) stocks are carried into period t. This puts downward (upward) pressure on price in period t relative to price in period t+1, which decreases (increases) the harvest time basis and provides more opportunity for larger (smaller) basis gains over the storage period.

Production in Period t (X_t)

Production in period t is also hypothesized to have a positive impact on the basis change for the same reasons as stocks carried into period t.

Forecasted Consumption in Period t+1 (FC_t^{t+1})

The expectation in time t of consumption in period t+1 is hypothesized to have a negative relationship with the basis change. If consumption in period t+1 is expected to increase (decrease), the demand for storage curve in period t will shift to the right (left), reflecting the need for more (less) grain in the future, decreasing (increasing) the realized price of storage.

According to the order and rank tests discussed in Chapter 3, the supply and demand equations in model I are both over identified. In model II, the supply equation is just identified since only one endogenous variable appears in the equation, but the demand equation is over identified. Consequently three stage least squares estimation procedures are used on both models to provide more efficient estimates of the structural parameters.

Data

Data used in this analysis covers the period 1974 to 1992 and provides 19 observations. The data consists of daily Kansas City Board of Trade wheat futures prices and daily Gulf bids from 1974 through 1992 (dollars per bushel). Interest rates are those paid by an elevator for borrowed money from Bank for Cooperatives (Wichita, Kansas) (dollars per dollar), and storage costs are an elevator's variable costs of maintaining wheat in storage (dollars per bushel).

Total stocks, CCC stocks, FOR stocks, outstanding loans, production, and total disappearance data are from the USDA Wheat Situation and Outlook Report, February 1993 and March 1992, and are in million bushel units.

CHAPTER V

EMPIRICAL RESULTS AND INTERPRETATION

Supply of and demand for storage determine the price of storage and the level of stocks. Therefore, in order to help understand why profitability of storage hedges for hard red winter wheat declined in the mid-1980's, the supply of and demand for storage curves for HRW wheat for three storage periods are estimated and presented in the following sections. Simultaneous equations estimation procedures discussed in Chapter III are used in the analysis. Results are presented first for Model I, then for Model II.

Results of the Simultaneous Estimation of the Supply of and Demand for Storage System (Model I)

Theory and past research suggest that the supply of storage function likely is nonlinear, but do not indicate a particular functional form. Consequently, various functional forms of the model are estimated in an attempt to determine the form that gives the best fit to the data and allows for a nonlinear supply of storage curve. Parameter estimates and their t-values for the system of equations are presented in Table 1, and discussed in the following sections. Table 1 shows the three separate storage periods along the top row: harvest to November, harvest to February, and

December to February. Under each storage period a supply and demand equation is presented.

R^2 in simultaneous equations estimation procedures such as two and three stage least squares is not well defined. In fact, it is possible to obtain a large negative R^2 with the limit being negative infinity. This indicates that the model does not fit the data very well (Shazam manual pg. 276). Therefore, in addition to R^2, the squared correlation coefficient between the observed and predicted values of the dependent variable (denoted R^{2***} in table 1) is presented.

Harvest to November Storage Period: Supply Equation

The supply equation for the harvest to November storage period exhibits the form suggested by theory. This can been seen in figure 8 which represents the regression estimates in table 1. On the vertical axis is the July to December spread, and on the horizontal axis is total stocks. The other variables in the equations are held constant at their means. As can be seen, the supply of storage curve is highly elastic over larger levels of stocks where the price of storage just covers storage costs. This is to be expected during storage periods corresponding with the beginning of a crop year when stocks are plentiful. At lower levels of stocks, the supply curve exhibits the form suggested by convenience yield theory; i.e. positive levels of stocks carried at negative prices of storage. The reason this particular curve does not extend into the region of negative spreads is because it is the harvest time storage period. No negative spreads occurred during storage periods I or II. For the harvest to November (period I) supply curve, each variable exhibits the hypothesized sign and is discussed below.

Table 1. Statistical Coefficients of the Simultaneous Equations Estimation of Specified Variables on the Spread, using Three Stage Least Squares.

Storage period	Harvest November		Harvest February		December February	
Equation	Supply	Demand	Supply	Demand	Supply	Demand
R^2	0.52	0.43	0.37	0.61	0.35	0.31
R^{2***}	0.53	0.49	0.40	0.64	0.35	0.31
$1/S_t$	-68.4740	144.370	-110.340	252.110	-397.96	-1584.3
	(-2.54)*	(2.53)*	(-2.20)*	(2.62)*	(-2.07)*	(-1.22)
GS_t	-0.0710	-0.5830	-0.1769	-1.0353	-0.3840	-0.4344
	(-0.90)	(-3.32)*	(-1.23)	-(3.97)*	(-3.23)*	(-2.91)*
$1/C_t$	328.850	-	716.870	-	-42.862	-
	(2.30)*	-	(1.83)**	-	(-0.80)	-
$CC_{t\ to\ t+1}$	0.9939	-	1.0230	-	0.0994	-
	(4.10)*	-	(3.27)*	-	(0.38)	-
$1/S_{t-1}$	-	-230.62	-	-383.70	-	7.4028
	-	(-2.53)*	-	(-2.83)*	-	(0.54)
$1/X_t$	-	-1153.4	-	-1886.2	-	-
	-	(-2.64)*	-	(-3.33)*	-	-
$1/S_{t+1}$	-	107.840	-	48.873	-	594.52
	-	(0.41)	-	(0.32)	-	(0.94)
Constant	-0.27256	0.9730	-0.4436	1.6298	0.4180	0.5436
	(-1.74)**	(4.39)*	(-1.43)	(3.27)*	(2.25)*	(2.04)*

Values in () are approximate t statistics; * Indicates significance at the 5% level; ** Indicates significance at the 10% level; ***R^2 between observed and predicted values.

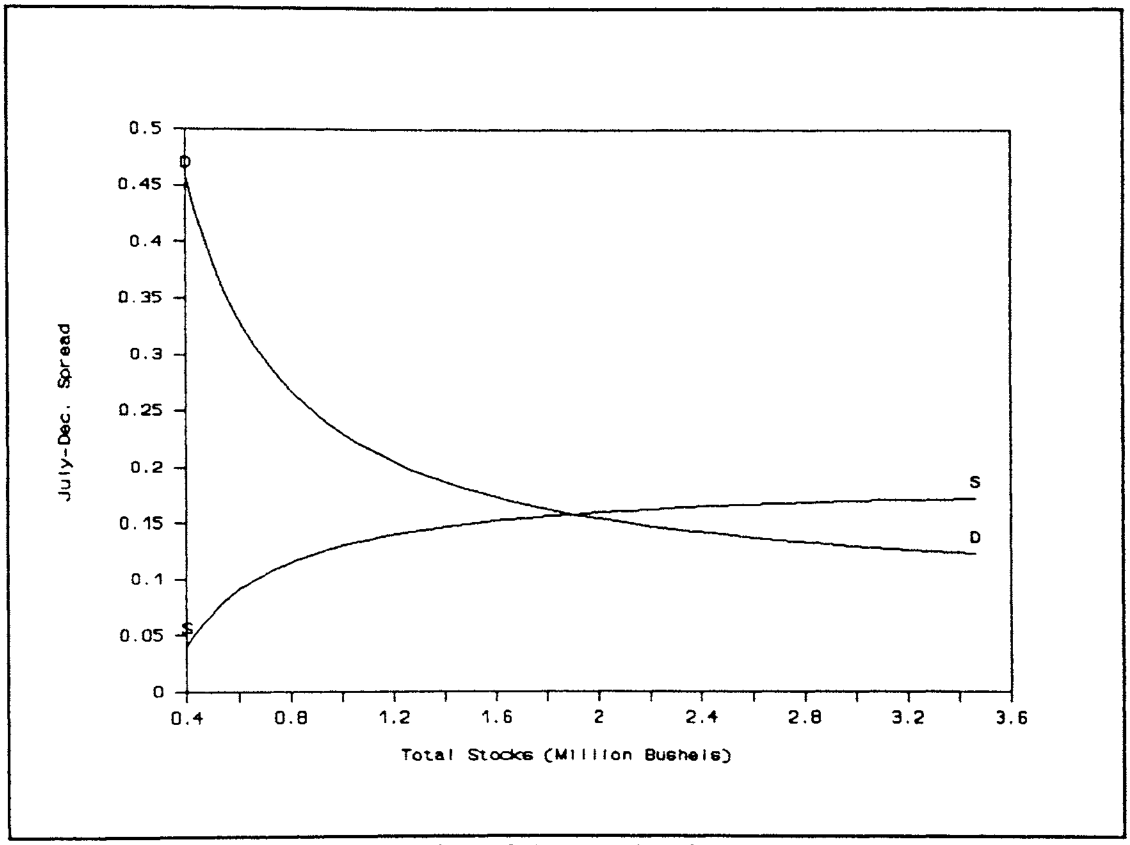

Figure 8. Graphical Representation of the Supply of and Demand for Storage Curves Estimated in Table 1, Harvest to November Storage Period.

$1/S_t$

The inverse of total stocks is the functional form of the stocks variable that gives the best fit to the data and allows for a nonlinear supply of storage curve.
The coefficient of $1/S_t$ is -59.89 with a significant t-value of -2.06. This reflects an upward-sloping supply of storage curve and suggests that as the spread increases (decreases) more (less) stocks are stored.

GS_t

Telser argues that as the proportion of stocks controlled by the government increases, the convenience yield of a given level of free stocks increases, reducing spreads. However, results from this analysis suggest that the proportion of stocks controlled by government does not significantly affect the supply of storage curve for an early crop year storage period. This should not be surprising since the marginal convenience yield approaches zero at higher levels of stocks. The government storage variable exhibits the hypothesized sign and has a coefficient of -0.0836, but the t-value of -0.87 is insignificant.

$CC_{t\ to\ t+1}$

Much research has assumed that the supply of storage function is stable. However, Sexauer argues that in some cases the supply curve is shifting significantly over time. Tomek and Robinson (pg. 228) state that the supply of storage function may shift during periods of fluctuating interest rates, or rising prices of the commodity going into storage. Results of this analysis tend to support these views.

The variable $CC_{t\ to\ t+1}$ exhibits the hypothesized sign with a coefficient of 0.9689 and a significant t-value of 4.23. During the early to mid-1980's, the interest rate and the price level were falling, decreasing carry costs. This shifted the supply curve to the right, decreasing the market-determined price of storage. This suggests that the supply of storage curve does shift due to changes in carry costs brought about by changes in interest rates and the price of the commodity going into storage.

$1/C_t$

As consumption during t (C_t) increases (decreases) the spread is expected to decrease (increase) due to the increasing convenience yield of a given level of free stocks. In other words, as the demand for free stocks increases (decreases) the convenience yield of the remaining free stocks increases (decreases) and, consequently, the spread decreases (increases). Results suggest that this is the case for the harvest to November supply of storage function. $1/C_t$ has a coefficient of 292.19 and a significant t-value of 1.97.

The question that presents itself is "since increases in both government storage and consumption in time t are expected to increase the marginal convenience yield of a given level of stocks, why is consumption significant but government storage not?" One possible explanation is that once stocks are consumed, they are not available to the market. However, government-controlled stocks, although not readily accessible to the market, are available to the market once released. This explanation implies that consumption increases convenience yield more than does the same amount of the commodity put into government storage.

Harvest to November Storage Period: Demand Equation

A graphical representation of the estimated demand for storage function for the harvest to November storage period appears in figure 8. The variables in this function are discussed below.

$1/S_t$

The demand for storage curve is expected to be negatively sloped with respect to stocks (S_t). This is the case, and is seen in figure 8. The inverse of total stocks exhibits the hypothesized sign and has a coefficient of 151.86, with a significant t-value of 1.88. This indicates that as the spread increases (decreases), less (more) storage is demanded.

GS_t

Thompson (1986) implies that government controlled stocks may also affect the demand for storage; i.e. as the government's demand for storage increases, private demand for storage decreases, reducing the incentive for private firms to store. Results of the analysis suggest that Thompson is correct. Although government storage does not have a significant impact on the supply of storage curve for the harvest to November storage period, in the demand curve the variable has the expected sign with a coefficient of -0.5092 and a significant t-value of -2.36.

$1/S_{t-1}$

The variable $1/S_{t-1}$ has the hypothesized sign, with a coefficient of -220.28, and a significant t-value of -1.97. This suggests that as stocks carried out of the previous period increase (decrease), spreads increase (decrease).

$1/X_t$

Production in period t (X_t) is expected to behave in a similar manner to stocks carried out of the previous period (S_{t-1}). $1/X_t$ exhibits the hypothesized sign, and has a coefficient of -1413.7, with a significant t-value of -2.55. This suggests that as production in period t increases (decreases), spreads in the current period increase (decrease).

$1/S_{t+1}$

Stocks carried out of t+1 are expected to behave similarly to production in t and stocks carried out of t-1, in that they are expected to have a positive relationship with the spread. However, for the harvest to November storage period the variable $1/S_{t+1}$ does not exhibit the hypothesized sign. The coefficient is 344.11, but the t-value of 1.15 indicates that the coefficient is not significantly different from zero, which suggests that stocks carried out of t+1 do not significantly impact the demand for storage. The results may differ if a forecast of stocks carried out of t+1 is used, as opposed to the actual values used here.

Harvest to February Storage Period

The results of the supply of and demand for storage functions for the harvest to February storage period are very similar to the results discussed above for the harvest to November storage period. Figure 9 shows a graphical representation of the estimates from table 1. The most notable difference is the coefficient on the variable $1/C_t$, in the supply equation, which is insignificant with a t-value of 1.59. Also the larger coefficient on $1/C_t$ indicates that the effect of C_t is smaller. This suggests that the convenience yield for longer storage periods does not impact the supply of storage to the same extent it does for shorter storage periods. This contradicts the findings of Ward and Dasse (1977), however. They found that as the duration of the storage period increases, the convenience yield for frozen concentrated orange juice increases.

December to February Storage Period: Supply Equation

Because of lower stock levels during this period, a portion of the supply curve extends into negative prices of storage. This is seen in figure 10 which is a graphical representation of the estimated supply of and demand for storage functions in table 1 for storage period III.

In contrast to estimations for the other two storage periods, the coefficient on the government storage variable in the supply equation is significant with a t-value of -3.23 and a coefficient of -0.3840. This suggests that as the crop season progresses, and stock levels diminish, the influence of government storage on the spread, by way of the marginal convenience yield, begins to take effect. However, the coefficient on $1/C_t$ does not exhibit the hypothesized sign and is insignificant with a t-value of -0.80.

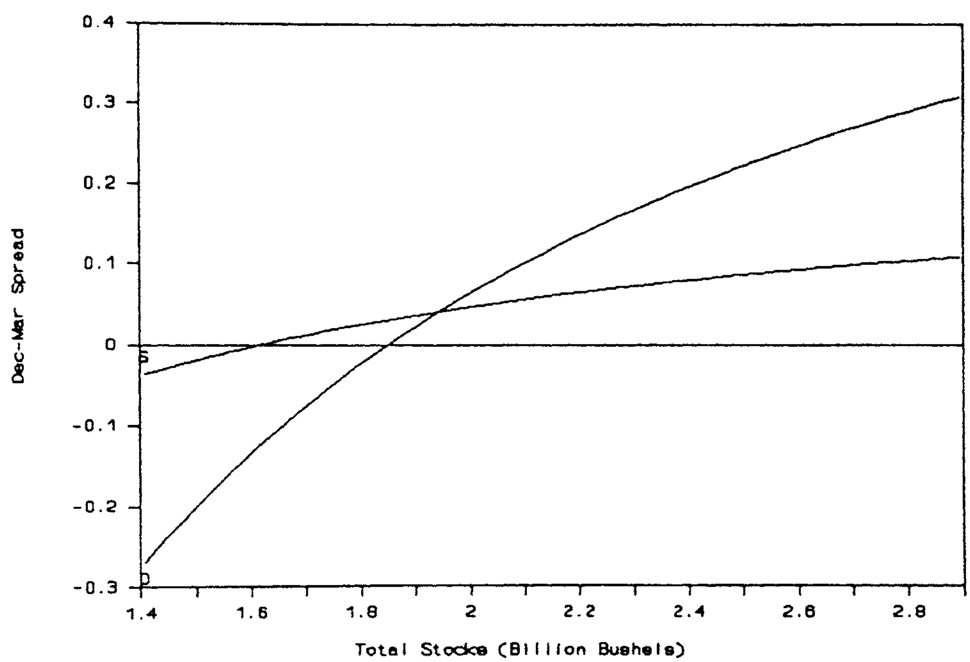

Figure 9. Graphical Representation of the Supply of and Demand for Storage Curves Estimated in Table 1, December to February Storage Period.

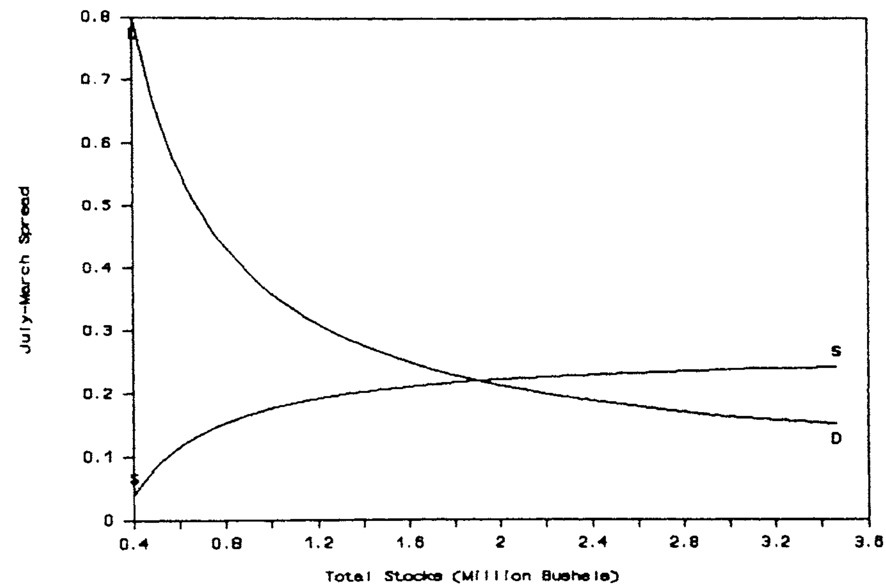

Figure 10. Graphical Representation of the Supply of and Demand for Storage Curves Estimated in Table 1, Harvest to February Storage Period.

This suggests that C_t during later crop year storage periods does not impact the spread by way of the marginal convenience yield. This is contrary to the findings for the other two storage periods which suggest that consumption has a greater impact on the spread through the marginal convenience yield.

$CC_{t\ to\ t+1}$ for the December to February storage period is insignificant with a t-value of 0.38. This may be because carry costs for the December to February storage period only cover 2 months, while for the harvest to November and harvest to February carry costs cover 5 and 8 months, respectively. Thus, on a per bushel basis, storage costs are less important for the December to February storage period than for the other two storage periods. Also, the greater importance of convenience yield in this storage period may overshadow the importance of storage costs.

<u>December to February Storage Period: Demand Function</u>

On the demand side, the coefficient on the stocks variable $1/S_t$ indicates a positive relationship between stocks and the spread. However, the coefficient on this variable is not significantly different from zero, suggesting that the demand curve is perfectly elastic for storage periods later in the crop year.

As with the previous storage periods an increased proportion of stocks under government control reduces the private demand for storage as indicated by the coefficient on the government storage variable of -0.4344, and a t-value of -2.91.

Of the remaining variables, $1/S_{t-1}$ and $1/S_{t+1}$, neither exhibits the hypothesized sign. However, both are insignificant with t-values of 0.54 and 0.94, respectively, suggesting that stocks carried into t and stocks carried out of t have no impact on the demand for storage for this storage period.

Results of the Simultaneous Estimation of the Supply of and Demand for Storage System (Model II)

The supply of and demand for storage system for the harvest to November storage period using model II is estimated and presented in the following section. Model II addresses and attempts to correct several problems associated with Model I. Simultaneous equations estimation procedures discussed in Chapter III are used in the analysis.

Table 2 shows the endogenous and predetermined variables along the top row with the structural parameter estimates and their t-statistics in parenthesis in the following rows. Equation 1 is the supply of storage equation, equation 2 is the demand for storage equation, and equation 3 is the technical identity. The coefficients in table 2 are the structural parameters of the system. Each of the coefficients of the model is significant at the 10% level or better.

Equation 1 (supply of storage) exhibits the hypothesized signs for the variables involved. Equation 1 shows that decisions about the level of stocks to be carried over a storage period (S_t) are based on the spread (Sp_t), the ratio of government storage to total stocks (GS_t), and estimated carry costs ($CC_{t\ to\ t+1}$) of storing grain over the period. All three variables have a statistically significant impact on the quantity of stocks stored through the supply equation.

Equation 2 (demand for storage) in table 2 exhibits the hypothesized sign for each of the explanatory variables. The basis change (BC_t) is negatively related to ending stocks (S_t), which through the identity equation (equation 3), means that it is positively related to consumption in period t (C_t). Equation 2 shows that production

Table 2. Estimated Coefficients of the Harvest to November Supply of and Demand for Storage Model II.

	Endogenous Variables			Predetermined Variables								
Equation	S_t	BC_t	C_t	Sp_t	GS_t	CC_t^{t+1}	X_t	S_{t-1}	S_{t-1}^2	FC_{t+1}	Constant	D75
1	-1			2416.6	1342.4	-3371.0					1623.4	
				(1.85)	(4.46)	(-1.89)					(5.64)	
2	-0.0017	-1			-0.6420		0.0017	0.0023	-0.34E-06	-0.0036	-0.1967	-0.7597
	(-2.62)				(-1.68)		(2.79)	(2.90)	(-1.90)	(-3.06)	(-0.52)	(-2.89)
3	-1		-1				1	1				

t statistics are in ( ).

(X_t), stocks entering period t (S_{t-1}), the ratio of government storage to total stocks (GS_t), and forecasted consumption in period t+1 (FC_t^{t+1}) all have statistically significant impacts on the basis change through the demand equation. In the initial estimation using equation 2 in this model, it was noticed that 1975 had an unusually large error term compared to other years in the data set. The reason may be due to the small ratio of government controlled stocks to total stocks (GS_t) for 1975 and 1976. The ratio for 1975 was 4 percent and for 1976, 3 percent. The average ratio for the data series was 59 percent, with the smallest ratio, excluding 1975 and 1976, being 25 percent. A dummy variable (D75) is used in equation 2 to take out the effects of this outlying observation on government storage. Squared terms were used on several of the predetermined variables to determine if any nonlinearities existed. The only variable that was statistically significant and added any explanatory power to the model was the squared term on beginning stocks (S_{t-1}^2).

Equation 3 in table 2 is simply the technical relationship between stocks in t and consumption in t. The equation states that consumption in t is equal to stocks coming into the period plus production minus stocks leaving the period ($C_t = S_{t-1} + X_t - S_t$)

Table 3 shows the reduced form parameters for equations 1 and 2 in table 2. Reduced form parameters are considered the long run multipliers of the model (Kennedy pg. 127) and are calculated using the formula presented in Chapter IV. The top section of table 3 shows the reduced form parameters for the endogenous variable ending total stocks (S_t). Notice that the reduced form parameters for ending total stocks are the same as the structural parameters of the supply equation in table 2. This results from the supply equation having only one endogenous variable, ending stocks, and thus no simultaneity exists in the supply equation. In other words, no

Table 3. Harvest to November Supply of and Demand for Storage System Reduced Form Parameters and Supply Elasticities.

Supply Equation

Predetermined Variable	Reduced Form Parameters Dependent Variable S_t	Supply Elasticity	% Change in S_t Due to a 10% increase in Predetermined Variable	Change in Average Stocks Due to 10% Increase in Predetermined Variable (million bushels)
Sp_t	2416.6	0.19%	1.9%	38.6
GS_t	1342.4	0.39%	3.9%	79.3
$CC_{t\ to\ t+1}$	-3371.0	-0.38%	-3.8%	-77.3
Constant	1623.4	-	-	-

Demand Equation

Predetermined Variable	Reduced Form Parameters Dependent Variable BC_t
X_t	0.0017
S_{t-1}	0.0001
FC_{t+1}	-0.0036
GS_t	-2.8981
Sp_t	-4.0616
$CC_{t\ to\ t+1}$	5.6656
Constant	-2.9252
D75	-0.7597

variables from the demand equation impact ending stocks through the supply equation. If two stage least squares would have been used to estimate the supply curve in this model, the results would have been exactly the same as results from ordinary least squares procedures. However, since three stage least squares uses the residuals from two stage least squares estimation as additional information, the estimates of the supply curve in this analysis are more efficient.[5] The reduced form parameters for ending total stocks suggest that a 1 cent increase in the spread (Sp_t) will induce a 24.2 million bushel increase in stocks stored. A 1% increase in the ratio of government storage (GS_t) will induce a 13.4 million bushel increase in ending total stocks, and a 1 cent increase in the estimated cost of carry ($CC_{t\ to\ t+1}$) will cause a 33.7 million bushel decrease in stocks.

Since the reduced form parameters for ending stocks are equal to the structural parameters of the supply equation, elasticities can be calculated. Table 3 shows the supply elasticities for ending stocks which are calculated at the mean. The elasticities measure the percent change in ending total stocks as a result of a 1 percent change in the independent variable under consideration. The elasticity of stocks with respect to the spread is 0.19 indicating that for a 10 percent increase in the spread, average ending stocks will increase 1.9 percent, or 38.6 million bushels. A 10 percent increase in the ratio of government storage will increase average ending total stocks by 3.9 percent, or 79.3 million bushels. A 10 percent increase in estimated carry costs will reduce average ending stocks by 3.8 percent or, 77.3 million bushels.

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[5] See Appendix I for the ordinary least squares results of the supply of storage curve.

The reduced form parameters for the basis change (BC_t) in period t are presented in the lower section of table 3. The parameters in this equation are the long run multipliers of the model for the basis change. In other words, they are the impacts from both the supply and demand variables of the system on the basis change. According to the reduced form parameters of this equation, a 1 million bushel increase in production (X_t) will induce a 0.17 cent basis increase. A 1 million bushel increase in beginning stocks (S_{t-1}) will induce a 0.01 cent basis increase.[6] A 1 million bushel increase in forecasted consumption (FC_t^{t+1}) induces a 0.36 cent decrease in the realized price of storage. A 1 percent increase in the ratio of stocks held by the government (GS_t) causes a 2.9 cent basis decrease. A 1 cent increase in the spread (Sp_t) causes a 4.1 cent basis decrease, and a 1 cent increase in estimated carry costs ($CC_{t\ to\ t+1}$) induces a 5.7 cent increase in the realized price of storage, the basis change. Since the reduced form parameters in this equation are the long run impacts of the total system on the basis change, price flexibilities are not calculated.

[6] The reduced form parameter for beginning stocks presented in table 3 is calculated by taking the derivative of the basis change (BC_t) in the reduced form equation with respect to S_{t-1}, since S_{t-1} has a squared term. The reduced form parameter for S_{t-1} is 0.002319 and -0.3374E-06 for S_{t-1}^2. Thus, the overall impact of a 1 unit change in S_{t-1} is 0.0001.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The supply of and demand for storage models estimated in this study, for the most part, support the theory of the supply of and demand for storage. Simultaneous equations estimation procedures were used in this analysis to account for the simultaneous determination of the price of storage and the quantity of stocks to be stored. Three stage least squares procedures were used to provide more efficient estimates of the structural parameters.

Summary of Model I

Results indicate that the supply of storage curve, which was thought to be stable, may indeed shift over time due to changes in consumption, carry costs, and government storage depending on the storage period under analysis.

Government storage was found to be insignificant during harvest time storage periods when stocks are high and the convenience yield is near zero. However, for storage periods later in the crop year, results suggest that government storage has a significant impact on the price of storage by way of the marginal convenience yield. Government storage was also found to be significant in the demand for storage equation in all three storage periods analyzed.

Consumption in period t gave conflicting results. In the harvest to November storage period, consumption was found to be significant and negatively related to the spread, however, for the harvest to February storage period consumption was insignificant but exhibited the correct sign. These results suggested that consumption may have a greater impact on storage periods of shorter durations, or that consumption varied more during harvest to November than during other periods. Consumption for the December to February storage period did not have the hypothesized sign and was insignificant suggesting that consumption does not impact the supply of storage during storage periods later in the crop year. This also supports the conclusion that consumption does not have as great an impact on shorter storage periods. Storage period III was the shortest period analyzed.

Carry costs were found to be significant and positively related to the spread for storage periods I and II. For storage period III, however, carry costs were insignificant, suggesting that the marginal convenience yield component outweighs the marginal physical storage component during later crop year storage periods.

The demand for storage was estimated and found to be compatible with economic theory. For storage periods I and II the demand curve was downward sloping. For storage period III the demand curve was upward sloping, but the coefficient on the stocks variable was found to be insignificant suggesting that the demand curve is perfectly elastic during storage period III.

Stocks carried into t and production in t both had the hypothesized relationship to the spread and were significant for storage periods I and II. Stocks carried into t for storage period III, was found to be insignificant.

These results suggest that increases in government storage and in consumption played a large part in decreasing spreads during the mid-1980s. Results also suggest that spreads would have been lower if stocks had not increased during this same time period.

Overall results from model I suggest that firms that hold stocks should be concerned about variables that shift the demand for storage in later crop year storage periods when the slope of the supply curve is greater, and in variables such as consumption and carry costs that shift the supply of storage.

Summary of Model II

Results of model II tend to agree with the results of model I for the most part. On the supply of storage equation total ending stocks in period t, and through the identity, consumption in t are determined by the spread, ratio of government storage to total stocks, and estimated carry costs of storing grain. Each of these variables was significant and exhibited the hypothesized sign. These results, like the results for Model I, suggest that the supply of storage curve is not stable, but that it shifts over time.

In this model, the ratio of government storage to total stocks is positively related to total ending stocks. In other words, as the percentage of total stocks made up by government controlled stocks at the beginning of the storage period increases, period t ending total stocks are expected to increase. This suggests that less free stocks will be available to the market, which increases the convenience yield of the remaining free stocks.

The demand equation in model II is also compatible with economic theory. Each of the variables exhibited the hypothesized sign and was statistically significant. The demand equation in this model uses the basis change from harvest to November to represent the realized price of storage, as opposed to assuming that the realized price of storage on average equals the expected price of storage. This demand equation states that the basis change for storage period t, ending total stocks in t, and consumption in t are simultaneously determined by each other and the exogenous variables: stocks entering t, production in t, forecasted consumption in t+1, and the ratio of government storage to total stocks in t.

Reduced form parameters which are the long run impacts of the model were calculated and discussed. The reduced form parameters for ending total stocks were equal to the structural parameters of the supply equation since only one endogenous variable was present in the supply equation. Because of this, only the elasticities of supply were calculated. It was found that given a 10% change in each of the independent variables, the ratio of government controlled stocks to total stocks had the greatest impact on ending total stocks. Carry cost had the second largest impact with the spread having the smallest impact. These parameters also show that in the long run, the spread and the ratio of government stocks to total stocks impact total ending stocks positively, while estimated carry costs impact total ending stocks negatively.

The reduced form parameters for the basis change show that over the long run production, stocks entering period t, and estimated carry costs all have positive impacts on the basis increase. Forecasted consumption in t+1, the ratio of government controlled stocks to total stocks, and the spread all have negative impacts on the basis increase over the long run.

Conclusions

The results of model I and model II suggest that increases in government controlled stocks in the mid-1980s may have played a large part in decreasing returns to storage hedges. The results also suggest that policy makers should consider the impacts that changes in the amount of government storage, changes in interest rates, affects of various farm policies on commodity prices, or changes in stock levels will have on the profitability of private storage firms before implementing such changes.

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APPENDIX

APPENDIX A

ORDINARY LEAST SQUARES ESTIMATION OF THE SUPPLY OF AND DEMAND FOR STORAGE EQUATIONS IN MODEL II

APPENDIX A

ORDINARY LEAST SQUARES ESTIMATION OF THE SUPPLY OF AND DEMAND FOR STORAGE EQUATIONS IN MODEL II

The results of the ordinary least squares estimation of the supply of and demand for storage equations used in model II are presented in table 4 to show the importance of using simultaneous equations estimation procedures with price and quantity data. The supply equation has been corrected for first order autocorrelation.

Table 4. OLS Estimation of the Supply of Storage Equation in Model II

Independent Variable	Coefficient	Standard Error	T-Ratio (15 df)	p-value (Prob > |t|)
Sp_t	2166.0	1190.0	1.82	0.09
GS_t	1215.2	439.0	2.77	0.01
$CC_{t\ to\ t+1}$	-3076.1	1645.0	-1.87	0.08
Constant	1668.0	397.3	4.20	0.00
Adj. R^2	0.61			
DW	1.97			

Table 4 shows that the OLS coefficients of the supply of storage equation are comparable to the three stage least squares coefficients presented in Chapter V. However, the three stage least squares results are more efficient (larger t-ratios) than the OLS results because of the additional information used in three stage least squares estimations. This additional information consists of the two stage least squares residuals.

The OLS results of the demand for storage equation are presented in Table 5. The OLS results are lest efficient than the three stage least squares results presented in Chapter V. Although the OLS parameters exhibit the correct sign for each of the variables, parameter estimates are noticably different from the three stage least squares results. This suggests that the OLS results are biased and that the demand equation is in fact a part of a simultaneous system.

Table 5. OLS Estimation of the Demand for Storage Equation in Model II

Independent Variable	Coefficient	Standard Error	T-Ratio (15 df)	p-value (Prob > |t|)
S_t	-0.00026	0.00023	-1.13	0.28
GS_t	-0.19322	0.2339	-0.83	0.43
X_t	0.00050	0.00024	2.08	0.06
S_{t-1}	0.00089	0.00042	2.14	0.06
S_{t-1}^2	-0.31E-06	0.15E-06	-2.09	0.06
FC_t^{t+1}	-0.00163	0.00069	-2.36	0.04
D75	-0.33365	0.1535	-2.17	.052
Constant	-0.02999	0.2793	-0.11	0.92
Adj. R^2	0.42			
DW	2.03			

V

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