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The Effects of Government Storage Programs

on Supply and Demand for Wheat Stocks

by

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Research has suggested that profitability of wheat storage hedges has declined in the 1980s, and that part of this decline is attributable to the increased proportion of stocks under government control during the mid-1980s. This study measures the effect of market and government factors on supply/demand for storage of hard red winter wheat using simultaneous equations procedures. Results indicate that government storage is negatively related to price of storage, shifting both supply and demand functions.

Introduction

Storage activities are important for allocating a seasonally produced commodity's use over time. Research has suggested that profitability of storage hedges has declined since 1982, and that part of this decline is attributable to the increased proportion of stocks under government control during the mid-1980s (Adam, Anderson, and Olbert). Government storage activities may have reduced the need for privately-held stocks, as well as the monetary incentive for private firms to store (Tilley and Campbell). Profitability of storage hedges is related to the market-determined price of storage (spread) and changes in the basis. The primary objective of this study is to measure the effect of government storage programs on price of storage for hard red winter wheat. It expands on previous work by modeling the market for storage in a simultaneous system that measures the effects of market factors and government storage programs on both the supply and demand for storage.

Theoretical Model

A theoretical model for supply of and demand for storage is based on those introduced by Brennan, Telser, Sexauer, and Thompson. 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.

Supply

A firm seeks to maximize profit 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 during the same interval. 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. 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.[1]

Assume a firm wishes to determine the amount of stocks, S_t, that it should hold 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

$$(1) \qquad nc(S_t) = tc(S_t) + rp(S_t) - cy(S_t).$$

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, $Sp_t S_t$. The net profit then becomes:

$$(2) \qquad \Pi = Sp_t S_t - tc(S_t) - rp(S_t) + cy(S_t).$$

In order to find the quantity of stocks that maximizes profit, equation (6) is differentiated with respect to S_t and set equal to zero. This yields:

$$(3) \qquad Sp_t = tc'(S_t) + rp'(S_t) - cy'(S_t).$$

or maximum profit, marginal revenue must equal marginal cost plus a marginal risk premium minus a marginal convenience yield.[2]

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[1] Several authors (e.g. Working (1948), Telser, Paul) argue that the risk premium (if it exists) is small.

[2] 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 is derived by solving for S_t as a function of Sp_t.[3] Assuming no external economies or diseconomies of scale in the storage industry, the industry supply of storage curve can be derived by adding each firm's individual net marginal cost curve.

A variable that increases the marginal cost of physical storage or the risk premium of a given level of stocks increases the spread, while a variable that increases the marginal convenience yield of a given level of stocks decreases the spread.

Demand

Following Brennan, Telser, and Sexauer, inverse demand for consumption in period t can be written as:

(4)
$$P_t = f_t(C_t), \quad \frac{df_t}{dC_t} < 0.$$

If consumers desire to consume some of the commodity in the next period rather than in the current period, the demand for storage from period t to period t+1 can be written as:

(5)
$$P_t^{t+1} - P_t = f_t^{t+1}(S_t + X_t^{t+1} - S_t^{t+1}) - f_t(S_{t-1} + X_t - S_t).$$

where consumption (C_t) is rewritten as stocks carried into period t from period t-1 (S_t) plus production in period t (X_t) minus stocks carried out of t into period t+1 (S_t), and where the subscript denotes the period in which expectations are formed for the period denoted by the superscript. The expected price difference between period t and period t+1 is a function of expected consumption in period t+1, and consumption in period t.

Increases in stocks carried into t (S_{t-1}), production in t (X_t), or expected stocks in t+1 (S_t^{t+1}), and decreases in expected production in t+1 (X_t^{t+1}), increase consumers' demand for stocks to be carried to t+1, these changes cause rightward shifts in the demand for storage (Tilley and Campbell). Opposite movements of these exogenous variables will produce leftward shifts in demand for storage, decreasing the price of storage.

Thompson suggests that, in addition to the above variables, changes in government held stocks may shift the demand for storage curve. For example, as the government storage increases, demand for private storage decreases and a lower price results.

Working (1949), Telser, and Brennan assumed a stable supply of storage function, and a shifting demand for storage function. Thus, they assumed that their single-equation models estimated the supply curve. Sexauer, however, noted that in some cases both the supply and

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[3]The firm's net marginal cost curve is positively sloped, which can be seen by taking the derivative of net marginal cost with respect to S_t:

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. Also, Telser suggests that an increased fraction of government stocks shifts supply left by increasing the marginal convenience yield, and Tomek and Robinson note that supply may shift due to changes in interest rates and the price of the commodity. Thus, both supply and demand for storage may shift. However, none of the articles reviewed estimated a simultaneous equations model of supply and demand for storage. In this study it is hypothesized that, in addition to the factors noted above, government storage programs shift both the supply and demand curves. Simultaneous equation estimation procedures are necessary because the quantity stored and the price incentive to store wheat are jointly and simultaneously determined.

In addition to building on the work of previous studies by modeling supply and demand for storage in a simultaneous system, the system modeled here differs from previous work in several important ways. First, previous authors (e.g. Telser, Brennan, Sexauer) related the expected price of storage at the beginning of the storage period ($Sp_t = P_t^{t+1} - P_t$) to quantity of stocks held. It was assumed that the expected price of storage equals the realized price of storage. Thus, the spread was used to represent price of storage in both supply and demand equations. However, as Telser notes (p.237), 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.

In the system modeled here, the spread represents the expected price of storage in the supply function. Since the spread is provided by the market at the beginning of a storage period (price of a distant futures contract minus price of a nearby futures contract), it is assumed exogenous. In both the demand and supply equations, the realized price of storage, represented by basis change over the storage period, and ending stocks, are endogenous.[4]

Second, previous authors have assumed that use is exogenous. In this study, use is jointly and simultaneously determined along with price and the amount of storage.

Third, previous authors have specified an identity that price in the demand equation equals price in the supply equation. Since it is assumed here that the spread in the supply equation is given exogenously, while basis change in the demand and supply equations is determined jointly and simultaneously with consumption, this model specifies an identity that consumption equals stocks entering the period plus production in the period minus stocks leaving the period.

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[4]Basis is defined here as cash price minus futures price.

Procedures

In this analysis, the storage period is defined as the period from harvest (June 20) to the last trading day in November. The empirical supply of storage function is:

$$(6) \qquad\qquad S_D = f(Sp_J, BC_J^D, GS_J, CC_J^D)$$

where S_D is total stocks at the end of the storage period (December 1 total stocks, million bushel units); $Sp_J = P_J^D - P_J$, is the market's expectation of the price of storage at the beginning of the storage period, and is calculated as the December futures price minus the July futures price at harvest (June 20) in each year.

Sp_J 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 carried.

BC_J^D is basis change over the storage period June to December, the realized price of storage. Basis change is calculated as the basis (Gulf cash minus December futures) at the time the hedge is liquidated (November 30) minus the basis at the time the hedge is placed (June 20). While the July - December spread on June 20, Sp_J, provides an expected return to storage, BC_J^D provides a measure of incentive for firms to change amount of stocks held during the period. If cash price increases (decreases) relative to futures price (increasing BC_J^D), stock holders have increased (decreased) incentive to remove grain from storage and supply it to the cash market, reducing (increasing) quantity of stocks held to the end of the period.

GS_J is the ratio of Commodity Credit Corporation stocks plus Farmer-Owned Reserve (FOR) stocks plus outstanding loans to total stocks on June 1. Telser argues that the marginal convenience yield of a given level of stocks increases (decreases) as the proportion under government control increases (decreases). Therefore, for higher (lower) GS_D, period t ending total stocks are expected to be higher (lower) and ending free stocks lower (higher).

CC_J^D is estimated carry costs of storing grain from June 20 to November 30 (daily variable storage costs plus daily interest costs times the number of days the grain is stored). CC_J^D is hypothesized to have a negative relationship with December 1 stocks. If carry costs increase, the supply of storage curve shifts left reflecting the higher cost of storing grain. This causes the quantity of stocks stored to decrease.

The empirical demand for storage function is:

$$(7) \qquad\qquad BC_J^D = g(C_J^D, FC_D^M, GS_J)$$

where BC_J^D is basis change over the storage period, the realized price of storage. Basis change is calculated as the basis (Gulf cash minus December futures) at the time the hedge is liquidated (November 30) minus the basis at the time the hedge is placed (June 20).

C_J^D, consumption (use) from June to December, which equals domestic disappearance plus exports, is calculated as June 1 stocks (S_J) plus production from June 1 to December 1 (X_J^D) minus December 1 stocks (S_D). Increases in June 1 stocks (S_J) put downward pressure on cash price in June relative to price in November, which decreases the beginning basis and provides opportunity for larger basis gains over the storage period. Production over the period June to December (X_J^D) is hypothesized to have a positive impact on the basis change for the same reasons as June 1 stocks, since harvest (production) occurs at the beginning of the period. Larger production or stocks carried in would create more demand for storage, raising the realized price of storage. December 1 stocks (S_D) is hypothesized to be negatively related to basis change (realized price of storage). For a larger quantity of stocks to be held to December 1, basis (cash minus futures) must increase by a smaller amount (Tilley and Campbell).

The expectation in June of consumption in the period December to March (FC_D^M) is hypothesized to be negatively related to basis change. If consumption in the period following December 1 is expected to increase, futures price will rise relative to Gulf cash price (reducing basis) to induce more storage and less consumption in the period June to December.[5] A simple ARIMA model is used to forecast this variable.

Government storage (GS_J) is expected to have a negative impact on basis change. As Thompson states, as proportion of stocks held by government increases, the demand for private storage decreases, which reduces the price of storage.

The market for storage is analyzed in a three-equation system: a supply of storage equation, a demand for storage equation, and an identity ($C_J^D = S_J + X_J^D - S_D$) used to close out the system. In this model, basis change, the level of stocks carried to the next period, and consumption of the commodity from June to December are simultaneously determined.

According to order and rank tests, both the supply equation and the demand equation are over-identified. Consequently three stage least squares estimation procedures are used to provide more efficient estimates of the structural parameters.

Data used in this analysis are yearly observations from 1974 to 1992, consisting of harvesttime (June 20) and November 30 Kansas City Board of Trade closing (daily) wheat futures prices and Gulf cash bids (dollars per bushel). Interest rates are those charged by Bank for Cooperatives (Wichita, Kansas), and storage costs are an elevator's variable costs of maintaining wheat in storage (dollars per bushel), provided by commercial elevators. Total stocks, CCC stocks, FOR stocks, outstanding loans, production, and total disappearance data are from USDA, and are in million bushel units.

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[5]Note that if spread (the difference between distant and nearby contract futures prices) were the dependent variable, the expected sign on this variable would be positive. An increase in expected consumption in $t+1$ would cause the price of the distant contract to rise, reflecting the need for more grain in the future.

Results

As shown in table 1, each of the coefficients of the structural form of the model except one is significant at the 10% level or better, and the signs are as expected. In the supply equation, increases in the spread (Sp_I) are associated with higher ending stocks (S_D). Although the coefficient of BC_I^D is significant at only the 20% level, it indicates that an increase in cash price relative to futures price causes more stocks to be diverted to cash markets, resulting in smaller ending stocks. Increases in government storage (GS_I) shift the supply curve right, and increases in carry costs (CC_I^D) shift the supply curve left.

In the demand equation, basis change (BC_I^D) is negatively related to ending stocks (S_D), which, through the identity, implies that BC_I^D is positively related to consumption during the period (C_I^D).[6] Increases in production during the period (X_I^D) and beginning stocks (S_I) shift the demand curve right, while increases in government storage (GS_I) and forecasted consumption (FC_I^D) shift the demand curve left.

The reduced form coefficients, also shown in table 1, are the impact multipliers and measure the immediate response of the endogenous variables to changes in the predetermined variables (Kmenta, p.590). In the supply equation, the reduced form coefficients for the supply equation suggest that a 1-cent increase in the spread (Sp_I) induces a 19-million bushel increase in stocks stored, a percentage point (.01) increase in the ratio of government-controlled stocks (GS_I) induces a 9 million bushel increase in ending total stocks, and a 1-cent increase in the estimated cost of carry (CC_I^D) causes a 14-million bushel decrease in stocks.

Also, a given increase in stocks carried in (S_I) or in production (X_I^D) leads to a slightly greater corresponding decrease in December stocks. An increase in forecasted consumption in the period following December leads to an increase in stocks. The smaller effect of stocks carried in and production on December stocks likely is because a portion of these amounts will be consumed during the period.

The reduced form coefficients for the demand equation are interpreted similarly. A 1-cent increase in the June 1 spread leads to a nearly 4-cent decrease (reduced increase) in basis change.[7] Also, a percentage point increase in the ratio of stocks held by the government

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[6] In initial analysis of the demand equation, 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_I) for 1975 and 1976. The ratio for 1975 and 1976 was 1 percent, while the average ratio for the data series was 28 percent, and the smallest ratio, excluding 1975 and 1976, was 13 percent. A dummy variable (D75) is used in the demand equation to allow for this outlier.

[7] The increased spread, by signaling a greater return to storage, causes more wheat to be placed in storage. However, through the demand equation, the increased wheat placed in storage is associated with a smaller basis increase. If this variable were the initial basis, the coefficient would predict convergence in the basis. For example, if the coefficient on initial basis were 0.75, and the initial basis were \$0.20/bu., the predicted change in basis ("convergence" if cash price were less than futures price) would be \$0.15/bu. However, since the variable is June 1 spread, the results are interpreted differently. Whereas a large initial basis would suggest that the basis likely will not increase much more, a large initial spread indicates that the market is offering a large

(GS_I) causes a 1-cent decrease in basis change, a 1-cent increase in carry costs leads to a 3-cent increase in basis change, and a 100-million bushel increase in production or in stocks carried in leads to a 6-cent increase in basis change, as demand for storage increases. However, a 100-million bushel increase in forecasted consumption in the period following December leads to an 11-cent decrease in basis change. A greater demand for stocks in the future leads to a smaller increase in cash price relative to futures price, providing less incentive for stocks to flow to the cash market.

In the identity, the reduced form coefficients indicate that a 1-cent increase in the spread leads to a decrease in July-December consumption of nearly 19 million bushels. An increase in the government stocks ratio of 0.01 leads to a 900-million bushel decrease in consumption, while an increase in carry costs of $0.01/bu. leads to an increase in consumption of 1400 million bushels. Three-tenths of increases in production, and two-tenths of increases in stocks carried into the period, are consumed in the period. A 1-million bushel increase in expected consumption following December leads to a 2-million bushel decrease in consumption from July to December.

Conclusions

This model of the market for storage highlights the simultaneous relationship between basis change, use, and changes in stocks over the storage period. Specifically, the results suggest that increases in government controlled stocks in the mid-1980s played a large part in decreasing returns to storage hedges as measured by basis change. Increases in the proportion of stocks controlled by government shift the supply curve right and the demand curve left, reducing the price of storage.

The reduced form coeffients indicate that a 25% increase in the proportion of stocks controlled by government policy (e.g., an increase to 0.35 from the series average of 0.28) leads to a 61-million bushel increase in December stocks and reduces the realized price of storage (basis change) by nearly 7 cents per bushel. The results suggest that policy makers should consider the impacts that changes in government storage programs will have on the market for storage.

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return to storage. More wheat is placed into storage in response to this signal, so holding a given quantity of stocks until December does not require as large a basis increase as it would have otherwise. Thus, an increased spread leads to a reduced increase in basis change.

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Table 1. Estimated Structural Form and Reduced Form Coefficients of the Harvest (June) to December Supply of and Demand for Storage.

Equation	Endogenous Variables[a]				Predetermined Variables						
	S_D	BC_J^D	C_J^D	Sp_J	GS_J	CC_J^D	X_J^D	S_J	FC_D^M	Constant	D75
Structural Form											
Supply	-1	-2127.8 (-1.23)		6107.8 (1.79)	1183.1 (3.50)	-4455.9 (-2.24)				1843.1 (5.74)	
Demand	-0.0020 (-2.58)	-1			-0.80 (-1.77)		0.0020 (2.65)	0.0019 (2.29)	-0.0037 (-2.66)	0.034 (0.086)	-0.81 (-2.51)
Identity	-1		-1				1	1			
Reduced Form											
Supply	-1			1859.57	878.91	-1356.64	-1.3	-1.22	2.38	538.96	524.58
Demand		-1		-3.74	-0.97	2.73	0.0006	0.0006	-0.0011	-1.12	-0.25
Identity	-1		-1	-1859.57	-878.91	1356.64	0.31	0.22	-2.38	-538.96	-524.58

Note: t statistics are in ( ). N = 19

[a]

S_D = stocks on December 1, million bu.

BC_J^D = Gulf - KCBT basis change from June 20 to November 30 on December contract, $/bu.

C_J^D = consumption (use) from June 1 to December 1, million bu.

Sp_J = December - July KCBT spread on June 20, $/bu

GS_J = (CCC + FOR + outstanding loans)/Total Stocks on Dec 1, million bu.

CC_J^D = carry costs from June 20 to November 30, $/bu.

X_J^D = production from June 1 to December 1, million bu.

S_J = stocks on June 1, million bu.

FC_D^M = consumption (use) from December 1 to March 1, forecasted on June 20.

D75 = dummy variable, which equals 1 in 1975, 0 in other years