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DETERMINANTS OF THE STORAGE SEASON CORN BASIS IN SOUTH CAROLINA

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Much research on the corn basis has specified a single basis equation rather than a system of structural equations (e.g., Garcia and Good; Kahl and Curtis; Martin et al.; Powers and Johnson; Taylor and Tomek). Tomek criticizes the ad hoc specification of a "quasi-reduced form" equation for the basis and suggests using a simultaneous system consisting of supply and demand equations. Stein has specified a system of equations in which cash prices and basis were simultaneously determined. However, Stein's model includes unobservable variables and thus is of limited use for direct empirical analysis.

The purpose of this analysis is to modify Stein's model to determine factors which have a significant effect on the corn basis (defined as the difference between cash and futures prices) during the storage season.[1] The paper begins with the development of a theoretical model that is used to derive a reduced form equation for the basis. An empirical model consistent with the reduced form equation is estimated using South Carolina data. The paper concludes with a discussion of the empirical results and a summary of the research findings.

Theoretical Model

The system of structural equations used in this analysis consists of a market model similar to Stein's model. Following Stein, the market model is developed assuming two time periods, the current period and a specific future period. The market model consists of a demand and supply for corn in the local area (i.e., South Carolina) in the current period and an expected demand and supply for corn in the national market in the future period.

The first equation in the model represents the current demand for corn in the local area. Although some corn in South Carolina is demanded for the export market during the first few months of the marketing year, corn is demanded primarily for livestock feed. The demand for corn consumption is derived from the demand for livestock which in turn is derived from the retail demand for meat and poultry. As such, the demand for corn consumption is inversely related to the price of corn and related to the expected retail price of meat and poultry. Because of difficulties in obtaining relevant data on retail prices, a current relevant local farm livestock price was used in this model. Current demand (for consumption) in the local area is specified as

$$q^D_1 = a + b P_1 + c M_1, \qquad (1)$$

where

q^D_1 = quantity of corn demanded in the local area for consumption in period 1 (i.e, the current period),

P_1 = local cash price of corn in period 1, and

M_1 = local farm price of relevant livestock in period 1.

Theory suggests that coefficient b is negative. The sign of coefficient c cannot be determined from the theory, without knowing whether the livestock price change resulted from a shift in the demand or supply of livestock.

The second equation represents the current supply of corn for consumption in the local area. Current production is assumed to be zero, because this analysis focuses only on the storage season (i.e., the period between harvests). Thus, the supply of corn for consumption equals initial local corn stocks (which represent the total local stocks in existence) minus local stocks demanded for storage. By subtracting a downward-sloping demand for storage curve from the fixed initial corn stocks, a typical upward-sloping supply curve is derived (Figure 1). Storage demand is assumed to be a linear function, positively related to the expected profits from storage, i.e., the expected cash price minus the current cash price minus storage (or carrying) costs. Based on the definitional formula for the basis, the expected cash price equals the expected futures price plus the expected basis. If one assumes that futures markets are efficient, then the current futures price equals and can be substituted for the expected futures price. The substitution of the futures price plus the expected basis for the expected cash price still leaves storage demand dependent on an expected price variable (the expected basis). However, estimates of the expected basis are generally easier to obtain and more accurate predictors than estimates of the expected cash price (Working, 1953). Current supply for consumption in the local area can thus be expressed as

$$q^S_1 = S_0 + d + e\,[F_{1,2} + E_1(B_2) - C_1 - P_1], \qquad (2)$$

where

q^S_1 = quantity of corn supplied for consumption in the local area in period 1,

S_0 = initial local corn stocks (i.e., at the end of period 0 or the beginning of period 1),

$F_{1,2}$ = price in period 1 of a corn futures contract maturing in period 2 (the future period),

$E_1(B_2)$ = expectation in period 1 of the local corn basis in period 2, and

C_1 = costs of storing corn from period 1 to period 2.

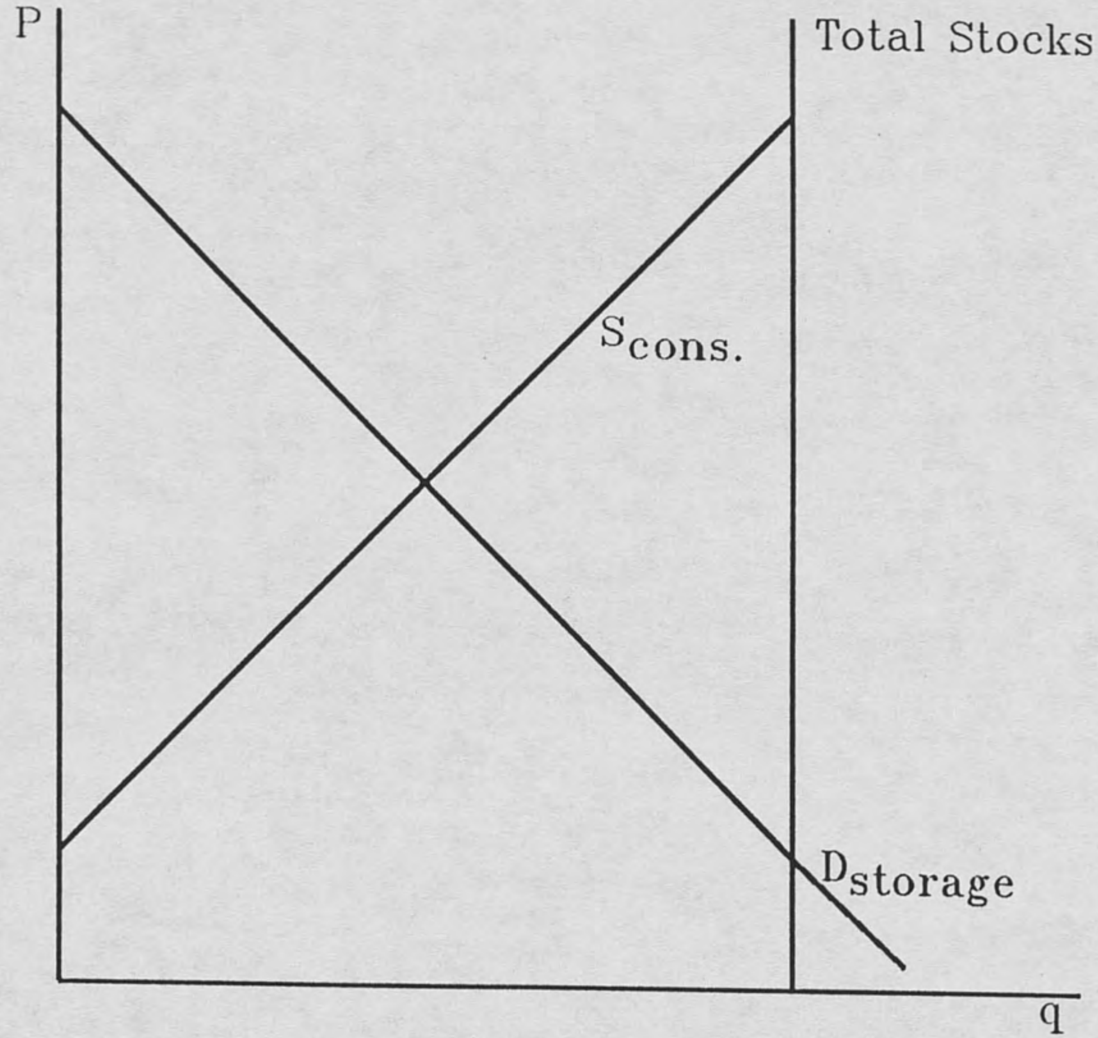

Figure 1. Supply of Corn for Consumption

According to theory, coefficient e is negative. As expected profits from storage increase, more stocks will be demanded for storage and fewer stocks will be supplied for consumption. Thus, the quantity supplied for consumption is inversely related to the expected price (as measured by the futures price and the expected basis) and directly related to storage costs and the current price.

The third and fourth equations represent the expected demand and expected supply of corn in the future period in the national market. The expected demand for corn is the expected demand for corn consumption which is primarily a derived demand dependent on the retail demand for meat and poultry, the final product. Economic theory indicates that the expected demand for corn would be negatively related to the expected cash price (i.e., the current futures price)[2] and related to the expected retail price of a relevant meat in the national market. Again, because of difficulties in obtaining relevant data on expected retail prices, an expected farm price for livestock was used in the equation specification. Expected demand in the national market is specified as

$$E_1(Q^D{}_2) = f + g\, F_{1,2} + h\, E_1(N_2), \qquad (3)$$

where

$E_1(Q^D{}_2)$ = expectation in period 1 of the quantity of corn that will be demanded in the national market in period 2, and

$E_1(N_2)$ = expectation in period 1 of the national farm price of relevant livestock in period 2.

According to theory, coefficient g is negative. The sign of coefficient h is indeterminate without knowing whether a supply or demand curve shift caused the livestock price change.

The final equation represents the expected supply of corn in the national market in the future time period. Expected supply should be positively related to the expected national cash price and expected national corn stocks in the future period. One would expect more corn to be supplied for consumption in the future if there were more total corn stocks in existence in the future. Expected supply should be negatively related to the percent of corn stocks owned by the government, if government stocks are less likely to be supplied than private stocks. In that case, for a given level of total corn stocks, the quantity supplied for consumption would be larger if the percentage of stocks owned by the government was smaller. Again, the current futures price represents the expected cash price. Expected supply in the national market is specified as

$$E_1(Q^S{}_2) = i + j\ F_{1,2} + k\ E_1(T_2) + m\ E_1(G_2), \quad (4)$$

where

$E_1(Q^S{}_2)$ = expectation in period 1 of the quantity of corn that will be supplied in the national market in period 2,

$E_1(T_2)$ = expectation in period 1 of total corn stocks in the United States in period 2, and

$E_1(G_2)$ = expectation in period 1 of the percent of total U.S. corn stocks owned by the government in period 2.

Theory indicates that coefficients j and k should be positive and coefficient m should be negative.

The equations specified for current demand and supply in the local area incorporate national market conditions through the inclusion of the futures price. However, the equations for expected demand and supply in the national market do not include the cash price or other variables reflecting current local market conditions. Thus, national market conditions are assumed to influence local market variables. However, local market conditions are assumed to have no effect on national market variables, because the local market represents such a small percentage of the total national market (Powers and Johnson).

This model[3] (equations (1) - (4)) can be solved to obtain a theoretical expression for the basis. In equilibrium, the quantities of stocks demanded and supplied in the current period must be equal (i.e., the right-hand sides of equations (1) and (2) must be equal). Simultaneously, the quantities expected to be demanded and supplied in the future period must be equal (i.e., the right-hand sides of equations (3) and (4) must be equal). The model then collapses to two equations and two endogenous variables, the current cash and futures prices. The two equations can be solved for the cash and futures prices as functions of only exogenous variables.[4] By definition, the basis in period 1 (i.e., B_1) equals the cash price minus the futures price in period 1. Thus, by subtracting the expression for the futures price from the expression for the cash price, one can obtain the following theoretical expression for the basis consistent with the model:

$$B_1 = r + s\ S_0 + t\ M_1 + u\ E_1(B_2) + v\ C_1 + w\ E_1(N_2) + x\ E_1(T_2) + y\ E_1(G_2), \qquad (5)$$

where

$r = [(d-a)(g-j) - b(i-f)]/[(b+e)(g-j)]$,

$s = +\ 1/(b+e)$,

$t = -\ c/(b+e)$,

$u = +\ e/(b+e)$,

$v = -\ e/(b+e)$,

$w = +\ hb/[(b+e)(g-j)]$,

$x = -\ kb/[(b+e)(g-j)]$, and

$y = -\ mb/[(b+e)(g-j)]$.

The signs of five of the above coefficients can be determined, based on the theoretical signs of the coefficients in the expressions on the right-hand side of the definitional formulas. The expression (b+e) is negative, since both coefficients b and e are negative. Thus, coefficient s is negative, indicating unequivocably that the basis is inversely related to initial local corn stocks. This inverse relationship between the basis and the level of stocks is consistent with basis literature (e.g., Working (1948, 1949); Brennan; Telser (1958); and Cootner).[5]

It is impossible to determine the sign of coefficient t because the sign of coefficient c is indeterminate. Thus, the model does not indicate the theoretical relationship between the corn basis and the farm price of relevant livestock in the local area.

Coefficient u is positive and v is negative, because coefficient e is negative. Equation (5) thus indicates that the basis is directly related to the expected basis and inversely related to storage costs in the local area. Other researchers have argued that the basis is inversely related to storage costs (e.g., Working (1948, 1949); Brennan; Telser (1958); and Cootner).

The sign of coefficient w cannot be determined because the sign of h is indeterminate. Thus, the relationship between the corn basis and the expected national farm price of livestock cannot be determined theoretically.

Coefficient x is positive, given that coefficient k is positive, coefficient b is negative, and the expression (g-j) is negative. Thus, the local corn basis is positively related to expected national corn stocks. As expected national stocks increase, one would expect both futures and cash prices to decrease. The positive relationship between the local basis and expected national stocks indicates that the futures price should decline more than the cash price, making the basis stronger (i.e., larger).

Coefficient y is negative, given the negativity of coefficient m. The local corn basis is thus inversely related to the expected percent of stocks owned by the government. If government stocks are less likely to be sold than private stocks, government stocks would be less bearish on prices than private stocks. The negative relationship between the local basis and the expected percent of stocks owned by the government indicates that the futures price would be more responsive than the cash price to changes in government stocks.

Previous basis research has generally not included expected national stocks and the expected percent of stocks owned by the government as explanatory variables. However, Garcia and Good, citing Thomson, argued and showed empirically that the basis is dependent on price levels, being stronger when prices were low than when prices were high.[6] These theoretical findings given above, that the basis is positively related to expected national stocks and negatively related to the expected percent of stocks owned by the government, are consistent with the observed negative relationship between the basis and the price level. As expected national stocks increase, the price level decreases and the basis strengthens (i.e., increases). Similarly, as the expected percent of government stocks increases, ceteris paribus, free stocks decrease, the price level increases, and the basis weakens (i.e., decreases).

Data and Empirical Model

Monthly data were collected to estimate equation (5). The current period (i.e., period 1) was assumed to be October for observation 1, November for observation 2, etc. In all cases, the future period (i.e., period 2) was assumed to be the following July.

The period of analysis covered the storage season of October through June for crop years 1974/75 through 1983/84. Corn harvest in South Carolina often begins in mid-July. Data for July, August and September were excluded to limit the analysis to the time period between harvests. As Martin et al. found, the corn basis in August and September is determined primarily by the size of the forthcoming crop, a variable not included in this model.

The basis was calculated as the average monthly cash price received by South Carolina farmers minus the closing price for the July futures contract at mid-month (i.e., on the fifteenth day or the business day closest to the fifteenth), both measured in dollars per bushel.

Initial local corn stocks, S_0, were measured as corn stocks (in billion bushels) held both on and off farms in South Carolina. The reported data, available only four times per year, were converted into monthly data by assuming that (1) consumption was equal during each month between the available data points, (2) production occurs on September 1, and (3) the stocks reported for October 1 represent carryover.

Monthly average prices received by South Carolina producers of eggs and broilers in South Carolina were used as alternative measures of the local livestock price, M_1. These commodities were selected because these industries are major consumers of grain, and presumably corn, in the state. In 1984, for example, hens and pullets represented 23 percent, broilers represented 19 percent, and chickens raised 7 percent of the grain-consuming animal units in the state (Bauer et al.). Egg prices were dollars per dozen and broiler prices were dollars per pound.

The average basis during July (period 2) of the most recent three years, measured in dollars per bushel, was used as the expected basis, $E_1(B_2)$. Agricultural economists (e.g., Hieronymus, pp. 207-208) often recommend using a historical average basis as the expected basis. Thus, expectations are assumed to be formed following a distributed lag model of length three with equal weights given to each previous year.

Storage costs, C_1, were measured as the opportunity cost of storage which is probably the most volatile component of total storage costs. Storage costs were estimated as the product of the monthly 90-day Treasury bill rate and the number of months until contract maturity. The Treasury bill rate was used as the interest rate because it represents a reasonable rate of return that producers can receive on their capital. The interest rate was not multiplied by the cash price to avoid statistical problems caused by having the cash price incorporated on both sides of the equation.

Livestock futures prices were used as the measure of the expected national livestock price, $E_1(N_2)$. Mid-month closing prices for the August live beef cattle futures contract and for the July hog futures contract, both in dollars per pound, were used as alternative measures of this explanatory variable.

A measure of expected national corn stocks, $E_1(T_2)$, in trillion bushels, was calculated from data on corn stocks held both on and off farms in the U.S. The data, available only four times per year, were initially converted into monthly corn stock data by making the same assumptions as for South Carolina stocks except that U.S. production was assumed to occur on October 1. To obtain an estimate of expected stocks from the monthly corn stock data, consumption was assumed to be equal each future month of the crop year and expected carryover was assumed to equal expected consumption for two months. Expected stocks were estimated as current stocks multiplied by five (the number of months between futures contract maturity (July) and the beginning of the crop year (October) plus two (expected carryover)) and divided by the sum of two and the number of months between the current period and October. (In March, expected stocks were March stocks multiplied by 5 and divided by 9.)

Monthly data on government stocks were unavailable to use in determining the percent of stocks expected to be owned by the government, $E_1(G_2)$. Two alternative measures of expected government stocks were used -- the percent of carryover stocks owned by the government and the national loan rate divided by the U.S. monthly average price received by farmers.[7]

Empirical Results

Equation (5) can be specified in various ways, depending on how the independent variables are measured. In this analysis, four versions of Equation (5), called Models, are discussed. The four models include identical measures of South Carolina corn stocks, expected U.S. corn stocks, storage costs, and expected basis. However, Model 1 uses the percent of carryover stocks owned by the government as expected government stocks while Models 2-4 use the loan rate divided by the U.S. average cash price as a proxy for government influence. Models 1 and 2 use the hog futures price as the expected farm price of livestock, while Models 3 and 4 use the live cattle futures price. Models 1 and 2 use the S.C. broiler cash price as the local livestock price, while Models 3 and 4 use the S.C. egg cash price. Models 1-3 use real data (adjusted by the consumer price index for all items), while Model 4 uses nominal data.

The four models were estimated using ordinary least squares (Appendix Table 1).[7] However, estimation using ordinary least squares is inappropriate if autocorrelation is present. In addition, the typical procedures for testing and correcting for autocorrelation are inappropriate for a discontinuous data set (Ward and Dasse). The data are not evenly spaced through time because of the exclusion of July, August, and September observations each crop year. Even though the error in one month might be highly correlated with the error in the previous month of the same crop year, the error in October would not be expected to be highly correlated with the previous calculated error (i.e., the error in June of the previous crop year).

To test for first order autocorrelation, the correlation coefficient was calculated between errors in consecutive months within the same crop year (i.e., between errors in November and October, December and November, etc., but not between October and June). Each estimated correlation coefficient (given in Appendix Table 1) was significantly different from zero at the 99 percent confidence level indicating the presence of autocorrelation.[8]

The estimated correlation coefficients, given in Appendix Table 1, were used to adjust for first order autocorrelation. The data for October were multiplied by the square root of the quantity 1 minus the correlation coefficient squared. For months November through June, the data used in estimation equaled the current observation less the product of the correlation coefficient and the lagged observation.

The results, after adjusting for first-order autocorrelation, are similar for the four models (Table 1). The coefficients of determination (R^2) are close, ranging from 0.60 to 0.66. In general, the results of two-tailed t-tests indicate that coefficients of the same variables are significantly different from zero (at the 95 percent confidence level) and have identical signs across models. Thus, the general empirical findings seem to hold, regardless of which measure of government influence and which livestock prices are used in the estimation and regardless of whether the data are adjusted for inflation.[9]

Although the explanatory power of each model is relatively high, only three coefficients are significantly different from zero. The coefficients of South Carolina corn stocks, storage costs, and the expected South Carolina corn basis are significant at the 90 percent confidence level, with the first two having negative signs and the last having a positive sign. These estimated signs are consistent with theory. The results indicate that the July corn basis in South Carolina is negatively related to South Carolina corn stocks and storage costs, and positively related to the expected South Carolina corn basis.

Table 1. Estimation of the July Corn Basis in South Carolina, Adjusted for Autocorrelation, October to June, 1974/75-1983/84[a]

Explanatory Variable	Estimated Coefficients			
	Real Basis Model 1	Real Basis Model 2	Real Basis Model 3	Nominal Basis Model 4
Intercept	0.0005 (1.40)[b]	0.0004 (1.18)	0.0003 (0.70)	0.1034 (1.23)
SC Stocks	-0.0396*[c] (-2.29)	-0.0444* (-2.73)	-0.0466* (-2.31)	-8.0893* (-2.17)
SC Broiler Price	0.3639 (0.54)	0.4500 (0.67)		
SC Egg Price			0.1294 (0.59)	0.2178 (0.99)
Expected Basis	1.2016 (1.97)	1.1168** (2.66)	1.2341** (2.88)	1.8781** (3.49)
Storage Costs	-0.0306* (-2.09)	-0.0309* (-2.23)	-0.0323* (-2.10)	-0.0349* (-2.38)
US Hog Price	-0.1889 (-0.59)	-0.1893 (-0.60)		
US Cattle Price			-0.0038 (-0.02)	-0.2545 (-0.94)
Expected US Stocks	0.1115 (0.62)	-0.0184 (-0.08)	0.0377 (0.15)	60.3974 (1.00)
Govt. % of Stocks	0.0000 (0.03)			
Loan/Cash		0.0006 (0.98)	0.0005 (0.80)	-0.0013 (-0.01)
ρ[d]	0.066	0.097	0.003	-0.021
R^2	0.634	0.655	0.632	0.596

[a]To correct for first order autocorrelation, the data were adjusted using the correlation coefficient calculated between consecutive monthly errors within the same crop year (given in Appendix Table 1).

[b]The values in parentheses are the calculated t-values.

[c]One asterisk denotes significance at the 95 percent confidence level for a two-tailed t-test. Two denote significance at the 99 percent confidence level.

[d]The correlation coefficient between errors in consecutive months within the same crop year is denoted by ρ.

The empirical results also indicate that expected U.S. corn stocks, the expected national livestock price, the current local livestock price, and the government corn program (as measured for this analysis) do not have significant effects on the July corn basis in South Carolina. Some previous empirical research has indicated that the basis can be explained best by variables measuring local market conditions (Martin et al.). The results obtained in this analysis support those findings in that two of the three variables having significant effects on the July corn basis in South Carolina (i.e., South Carolina corn stocks and the expected South Carolina corn basis) are unique to South Carolina.

Several additional models were estimated to determine the sensitivity of the results. In one model, expected U.S. corn stocks were calculated assuming that carryover from one crop year to the next would be zero. Again, equal consumption was assumed for each future month of the crop year. In another model, a trade-weighted real dollar index (obtained from Cox) was added as an explanatory variable in an attempt to incorporate expected foreign demand for consumption which could have been included in Equation (3). In a third model, storage costs were measured as the cash price in the previous month multiplied by the product of the Treasury bill rate and the number of months until contract maturity. Still another model used the number of grain-consuming animal units in South Carolina instead of the price of local livestock as a shifter of the local demand curve (Equation (1)). The results of these additional models are not presented in this paper because of their similarity with the presented results.

Concluding Remarks

In this study, a reduced form equation for the South Carolina corn basis is derived from supply and demand equations for local corn in the current period and for national corn in a future period. The implications from the reduced form equation are consistent with basis theory. In addition, the reduced form equation offers some theoretical justification for the observed inverse relationship between the basis and price levels.

The empirical results support the hypothesis that the July corn basis in South Carolina is negatively related to South Carolina corn stocks and storage costs, and positively related to the expected basis. The estimated signs of the coefficients of these three variables are consistent with the theoretical model developed to explain the basis and, in general, are consistent with previous research. Thus, this empirical analysis supports the general theory of the basis.

The empirical results presented in this paper are only for South Carolina. However, similar empirical models should be applicable for other locations as well.

FOOTNOTES

[1] The basis has been defined in some academic literature as the futures price minus the cash price. The definition used in this analysis is consistent with industry practice (Taylor and Tomek) and with some academic studies (e.g., Martin et al.; Powers and Johnson).

[2] As Telser (1967) and others have recognized, the futures price should represent the market estimate of the future cash price at a delivery point. In general, analysts believe the corn futures price (before the delivery period) represents expected national or world market conditions. Thus, the futures price represents the intersection of expected demand and supply in the national (or world) market.

[3] Although this model is based on Stein's model, important differences exist. First, Stein's model focuses on temporal differences without incorporating locational differences. Second, Stein specifies current demand as the demand for storage, defined as the demand for hedged and unhedged stocks. He specifies current supply as the supply of storage, defined as total stocks plus current production less current consumption. Third, Stein specifies the third and fourth equations as the current demand and supply of futures contracts that mature in the future time period. He specifies the demand for futures contracts as speculative demand, dependent on the profit expected by speculators from buying futures contracts. The supply of futures contracts is identical to the demand for hedged stocks. Finally, Stein's model includes three unobservable variables representing expectations (i.e., expected cash price, futures price expected by hedgers, and futures price expected by speculators).

[4] This technique conveniently eliminates the necessity of having to estimate the quantity of corn stocks demanded and supplied currently in the local area and the expected quantity of corn demanded and supplied in the national market. Data on these quantities are not available.

[5] Because these authors defined the basis as the futures price minus the cash price, they actually argued that the basis was directly related to stocks.

[6] Kahl and Curtis, however, found a positive relationship between the basis and the lagged cash price.

[7] The data sources are as follows: <u>Agricultural Prices</u> for S.C. and U.S. corn cash prices; Chicago Board of Trade <u>Statistical Annuals</u> for corn futures prices; <u>South Carolina Crop Statistics, State and County Data</u> for S.C. corn stocks; <u>Cash Receipts from Farm Marketings</u> for egg and broiler prices; <u>Survey of Current Business</u> for T-bill rates and consumer price indices; Chicago Mercantile Exchange <u>Yearbooks</u> for cattle and hog futures prices; <u>Agricultural Statistics</u> for U.S. corn stocks, government stocks, and loan rates.

[8] Tests for ninth order autocorrelation (i.e., correlation between errors for the same month across years) were also conducted. The estimated correlation coefficients between such errors for Models 1 and 2 were 0.054 and -0.015, respectively. These correlation coefficients were not significant at the 70 percent confidence level.

[9] After adjusting for first-order autocorrelation, the correlation coefficients between errors in consecutive months within the same crop year were calculated again for each model (Table 1). None is significantly different from zero at the 70 percent confidence level. In addition, the correlation coefficients between errors for the same month across years were calculated again for Models 1 and 2. The estimated coefficients of 0.027 and 0.021 were not significant at the 70 percent confidence level.

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Appendix Table 1. Estimation of the July Corn Basis in South Carolina Using Ordinary Least Squares, October to June, 1974/75-1983/84

Explanatory Variable	Estimated Coefficients Real Basis Model 1	Real Basis Model 2	Real Basis Model 3	Nominal Basis Model 4
Intercept	-0.0017 (-1.30)[a]	-0.0016 (-1.69)	-0.0012 (-1.45)	-0.0745 (-0.40)
SC Stocks	-0.0464**[b] (-3.90)	-0.0505** (-4.47)	-0.0581** (-4.59)	-9.5786** (-3.63)
SC Broiler Price	2.2467** (2.94)	2.0461** (2.90)		
SC Egg Price			0.3792* (2.17)	0.4660* (2.62)
Expected Basis	1.2270** (2.96)	1.2617** (4.16)	1.2845** (4.56)	1.3693** (3.84)
Storage Costs	-0.0422** (-3.75)	-0.0377** (-3.56)	-0.0414** (-3.62)	-0.0530** (-4.71)
US Hog Price	-0.3052 (-1.02)	-0.0023 (-0.80)		
US Cattle Price			0.3593 (1.81)	0.0983 (0.41)
Expected US Stocks	0.4735* (2.43)	0.1552 (0.84)	0.0073 (0.04)	6.0176 (0.14)
Govt. % of Stocks	0.0008 (0.70)			
Loan/Cash		0.0012* (2.51)	0.0013** (2.66)	0.1572 (1.44)
ρ[c]	0.521**	0.469**	0.535**	0.559**
R^2	0.734	0.752	0.749	0.732

[a] The values in parentheses are the calculated t-values.

[b] One asterisk denotes significance at the 95 percent confidence level. Two denote significance at the 99 percent confidence level.

[c] The estimated correlation coefficient between errors in two consecutive months within the same crop year is represented by ρ.