A NOTE ON THE FACTORS AFFECTING CORN BASIS RELATIONSHIPS

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Abstract

Empirical tests were made of components of the corn basis in the U.S. utilizing a general theory of intertemporal price relationships for storable commodities. These tests showed that the basis consists of a risk premium, a speculative component, and a maturity basis apart from other factors such as storage costs for storable commodities. The results provide insights into factors affecting basis patterns for corn.

Key words: corn basis, risk premium, speculative component, storable commodities

INTRODUCTION

The success of hedgers' participation in the futures market depends on how well they can predict basis relationships.[1] Understanding the mechanism and identifying the factors influencing the basis assists market participants in making successful production and marketing decisions. Keynes' theory of normal backwardation (risk premium) and Working's theory of price of storage are the two major, but contradictory, theories that researchers use to examine basis relationships. Recently, Naik and Leuthold (1988) expanded on these theories and provided further insight on understanding basis relationships. This paper empirically examines basis relationships for corn using these recent theoretical developments.

Keynes (1923, 1930) and other British economists (Blau 1944-45; Hicks 1953) believed that hedgers participate in the futures market to shift the risk of price change. That is, hedgers want to shift the risk of price change to speculators by paying a premium, selling contracts at a price lower than the expected price, while speculators accept the risk from hedgers in return for keeping the premium. Therefore, providing that short hedging exceeds long hedging, futures prices will be downward biased estimates of the expected future cash price, the bias reflecting the risk premium. The fundamental assumption of this theory is that both hedgers and speculators are risk-averse, and that the possibility of risk-shifting motivates hedgers to participate in the futures market.

Working (1949, 1953) disagreed with the hypothesis that the main motivation behind the hedger's participation in the futures market is risk shifting, or that a risk premium exists. Introducing multipurpose concepts of hedging, he stressed that the main motivation of hedgers is the pursuit of profits arising out of changes in the movements of cash and futures prices. In his view, hedging is done when there is a possibility of making a profit by arbitraging in cash and futures markets. That is, when the difference between futures and cash prices (basis) is greater than the net carrying cost (including storage cost, insurance, opportunity cost, and convenience yield) of stocks, then arbitrage possibilities exist. Therefore, in long-run equilibrium, the basis should be equal to the net carrying cost which is determined by the supply of storage. According to this theory, the futures price is not affected by the risk premium and the arbitrage possibilities eliminate any bias in futures prices.

The legitimacy of these theories has been widely debated in the literature. Empirical investigations on the topic have produced mixed results, and the question of whether a risk premium exists in the futures market remains unresolved. Telser (1958, 1960) found no risk premium in the wheat and cotton markets. However, Cootner (1960a, 1960b) using Telser's data reported the existence of a risk premium. Gray (1960, 1961) reported the absence of a risk premium for high trade volume markets such as corn, but suggested that risk premiums could exist in unbalanced markets. Using a large number of commodities, Rockwell (1967) found risk premiums for only some commodities. These studies examined the risk premium hypothesis by analyzing actual time series of spot and futures prices.

Using the capital asset pricing model (CAPM), Dusak (1973), Grauer (1977), and Bodie and Rosan-

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[1] Basis is defined as the difference between futures and cash prices.

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sky (1980) found no risk premium, whereas Breeden (1980), Carter et al. (1983), and Lee and Leuthold (1983) found risk premiums in commodity futures markets. Kahl (1978) first applied portfolio theory to study the changes in the corn basis during the 1970s as compared with the decade of the 1960s. Her results showed that lagged basis and increased demand for bin space affected the basis pattern. Johnson (1960) contended that both the theory of normal backwardation and the theory of the supply of storage taken separately are inadequate because inventory holders' motivations to hedge in the futures markets are both risk reduction and the pursuit of profits. He then combined these conflicting notions in one paradigm.

Naik and Leuthold (1988) theoretically examined cash and futures price relationships utilizing a mean-variance framework of expected utility theory. Market equilibrium conditions and rational expectations were used to derive a model of basis relationships for estimation. This paper provides an empirical test of those theoretical developments.

Theoretical Model[2]

Assuming a negative exponential form of utility function, and utilizing a mean-variance framework, expected utility of profit, ω, can be expressed as (Freund, 1956):

$$(1) \quad \Omega = E\Pi - \frac{1}{2} \mu \, Var(\Pi)$$

where E is the expectation operator, Π is profit, μ is the Arrow-Pratt measure of risk aversion [$\mu \geq 0$ (<0) indicates that the decision maker is risk-averse (loving)], and Var (Π) is the variance of profit. An individual inventory holder's profit function is represented as:

$$(2) \quad \Pi_t = I_{t-1}\{P_t - (1 + \gamma) P_{t-1} \} - (1 + \gamma) \{-b_0$$
$$+ b_1 I_{t-1} + \frac{1}{2} b_2 (I_{t-1})^2 \} + H_{t-1} (F_t - F_{t-1})$$

where I_{t-1} is the inventory held at the end of the period t-1, P_t is the cash price prevailing in period t,

γ is the discount rate (risk-free interest rate), H_{t-1} is the number of bushels held as futures contracts bought ($H_{t-1} > 0$) or sold ($H_{t-1} < 0$) by the individual inventory holder in period t-1, and F_{t-1} is the futures price formed at period t-1 for period t. The second term in equation (2), i.e.,

$$- b_0 + b_1 I_{t-1} + \frac{1}{2} b_2 (I_{t-1})^2$$

is a quadratic inventory cost function (convex to the origin) which takes into account both the cost due to loss in convenience yield and increase in cost due to storage capacity limits.[3]

Substituting expected value and variance of profit into equation (1) and maximizing with respect to the individual's level of inventory, I_{t-1}, and futures position, H_{t-1}, we obtain:

$$(3) \quad E_{t-1}P_t - (1 + \gamma)P_{t-1} - (1 + \gamma) [\, b_1 + b_2 I_{t-1} \,]$$
$$- \mu \, [\sigma_p^2 I_{t-1} + Cov_{t-1} (P_t, F_t)H_{t-1}] = 0$$

$$(4) \quad E_{t-1}F_t - F_{t-1}$$
$$- \mu [\, \sigma_f^2 H_{t-1} + Cov_{-1}(P_t, F_t) I_{t-1}] = 0$$

where $\sigma_p{}^2$ and $\sigma_f{}^2$ are conditional variances of cash and futures prices, respectively, E_{t-1} is the expectation operator in t-1, and Cov is covariance.

Equations (3) and (4) can be solved for inventory (I) and futures positions (H) of inventory holders and then aggregated across individual holders to obtain market level inventory and futures positions. At the market level, cash and futures prices are endogenous. Therefore, assuming equations (3) and (4) are obtained for a representative firm, we can solve for P_t and F_t and in turn for the basis[4], which is (Naik and Leuthold, 1988):

$$(5) \quad BS_t = (1 + \gamma) [b_1 + b_2 I_t] + \gamma P_t + E_t BS_{t+1}$$
$$- x (E_t F_{t+1} - F_t) + \mu \sigma_p^2 (1 - r^2) I_t$$

where BS is basis, as is F - P, $x = 1 - [\sigma_f^2]^{-1} Cov(P_t, F_t)$, r is the correlation coefficient between cash and futures prices, and $\sigma_p^2 (1 - r^2)$ is basis risk. Equation (5) states that basis consists of storage cost, opportunity cost, expected basis at maturity, speculation (which is $E_t F_{t+1} - F_t$) adjusted by

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[2] A complete model underlies the abstracted version presented here (Naik and Leuthold 1988). The spot market demand for storable commodities is comprised of consumption demand and inventory demand. Consumption demand is in turn reflected by changes in the inventory level. Because only intraseasonal basis relationships are analyzed, meaning production is exogenous, the intraseasonal supply in the spot market comes from the inventory that was held during the previous period. In the futures market, the demand for futures contracts comes from speculators, and supply comes from inventory holders (hedgers). In this analysis, inventory holders are allowed to take speculative positions through their buying or selling of futures contracts. Thus, these various market forces can all be represented in an inventory holder's profit function as shown below in equation (2). This approach is similar to others, e.g. Holthausen (1979), and Feder, Just, and Schmitz (1980), except that the market participant being modeled here is the inventory-holder rather than the producer.

[3] The negative sign before b_o reflects convenience yield.

[4] Equation (5) is obtained by solving equation (4) for H_{t-1} and substituting the result into equation (3), which then can be rearranged to get an expression for BS_t.

one minus a regression coefficient obtained from regressing cash price on futures price (x), and basis risk premium $(\mu \sigma_p^2 (1 - r^2) I_t)$. The term $\sigma_p^2 (1 - r^2) I_t$ is basis risk, and is inversely related to the absolute value of correlation between cash and futures prices. If we assume that expected maturity basis $E_t BS_{t+1} = 0$, $x = 0$, and $|r| = 1$, then equation (5) becomes

(5a) $BS_t = (1 + \gamma) [b_1 + b_2 I_t] + \gamma P_t$

which says basis is equal to storage and opportunity cost. This is the same as the carrying charge theory by Working. In this case there is no basis risk premium.

Equation (5) provides a general theory of the basis relationship for storable commodities. This paper empirically examines the components of the basis relationship. Specifically, the following questions are examined:

(1) Does a maturity basis risk premium exist for storable commodities?

(2) Does the basis include a speculative component?

(3) Does the basis include an expected maturity basis component?

In equation (5) the basis risk premium $[\mu \sigma_p^2 (1 - r^2) I_t]$ will be zero for the market as a whole when the absolute value of r, the correlation coefficient between cash and futures prices during maturity, is equal to 1. If the absolute value of the correlation coefficient is not equal to one, it can be concluded that a basis risk premium exists.[5] Below, the hypothesis about the existence of a maturity basis risk premium is tested by examining the correlation coefficient between cash and futures prices during the maturity period of the contract.[6]

The role of the speculative component $(x(E_t F_{t+1} - F_t))$ in determining the magnitude of the basis can be examined by testing whether x is equal to zero. The value of x is zero when the regression coefficient (the coefficient obtained by regressing cash price of futures price) is equal to one.[7] Such a regression coefficient is estimated using the data on cash and futures prices during the maturity month. If the regression coefficient is equal to one, then we can conclude that speculation by the inventory holders does not affect basis.[8]

There is no convenient way to test whether expected maturity basis is equal to zero. If actual maturity basis is consistently zero, then we could assume that expected maturity basis may also be zero. Otherwise, it is difficult to make any conclusion, even if actual maturity basis averages zero. Testing whether expected maturity basis equals zero involves identifying factors affecting the basis and examining whether one could predict it from previous period(s). If it can be predicted with reasonable accuracy, then chances are high that an expected maturity basis exists. Naik and Leuthold (1988) used the following market equilibrium conditions of cash and futures markets to establish a procedure to test whether the expected maturity basis is zero:

Consumer Demand (D_t)

(6) $D_t = f_1 (P_t, Z_t)$

Inventory Demand

(7) $I_t = f_2 (E_t F_{t+1}, F_t, P_t, E_t BS_{t+1})$

Cash Market Clears when

(8) $I_{t-1} = D_t + I_t$

Futures Position of Inventory Holders

(9) $H_t = f_3 (E_t F_{t+1}, F_t, P_t, E_t BS_{t+1})$

Futures Position of Speculators (S_t)

(10) $S_t = f_4 (E_t F_{t+1}, F_t)$

Futures Market Clears when

(11) $-H_t + S_t = 0$

where Z refers to demand shifters and other variables which were defined previously. Naik and Leuthold (1988) obtained a reduced form expression for basis by solving for inventory demand and futures positions of inventory holders and speculators, which then led to reduced form expressions for cash and futures prices. In this framework they assumed $E_t F_{t+1} = f_5(F_t)$. Using the rational expectations hypothesis, this reduced form solution for basis is solved in terms of the following variables.

(12) $BS_t = f(BS_{t-1}, P_{t-2}, F_{t-2}, Z_{t-1})$

where BS_t is the basis at time t, P_{t-2} is the two-periods previous cash price, F_{t-2} is the two-periods previous futures price, and Z_{t-1} is the one-period previous demand shifters. One potential problem that may arise is the simultaneity and thus multicollinearity between P_{t-2} and F_{t-2}. This can be solved by using them in a difference form (basis).

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[5] This assumes traders are not risk neutral.

[6] Examining correlation coefficients for delivery months only is an outcome of the theoretical model. Equation (15) applies to any period, so BS_t can be for any period during the contract. However, the expected basis term is only for the maturity period, irrespective of the period for BS.

[7] Recall that b in a regression equation of $P_t = a + bF_t$ is determined from $Cov(P_t, F_t) / \sigma_f^2$ (see the definitions with equation (5)).

[8] Even if the ratio is not equal to 1, the speculative component does not exist if the expected futures price is equal to current futures prices. The latter issue is not addressed here.

DATA AND EMPIRICAL RESULTS

The corn market was used to assess the components suggested by the above theoretical framework. Daily data during each corn contract maturity month for the period 1966 through 1986 were used to estimate, from equation (5), the correlation coefficient and the ratio of covariance between cash and futures price to the variance of futures price. Futures (settlement) prices originated from the Chicago Board of Trade. Cash prices were those prevailing at an East Central Illinois elevator as collected by the Department of Agricultural Economics, University of Illinois.[9]

Monthly basis models as in equation (12) were estimated using data for the years 1970 through 1985. Chicago cash prices were collected from the *Feed Outlook and Situation*. Monthly futures prices were obtained by averaging daily settlement prices. Quarterly data on exports, inventory, and domestic disappearance and annual production data were also collected from the *Feed Outlook and Situation*.

Correlation Coefficients

A summary of the correlation coefficients between daily East Central Illinois cash and Chicago futures prices during the maturity months of individual contracts for 1966-1986 is reported Table 1. The correlation coefficients varied from -0.525 for the 1986 September contract to 0.998 for the 1978 March contract. Out of the 102 coefficients, 34 are 0.9 or higher, but there are 15 correlation coefficients with a value less than 0.5, and seven coefficients are negative. The remaining 53 coefficients fall between 0.5 and 0.9. No definite pattern was obtained with respect either to contract months or time. The upper confidence limit is greater than .95 for 48 coefficients.[10] These results are mixed, but indicate that

there existed a maturity basis risk premium in the corn futures market in approximately one-half of the contracts tested.

When correlation coefficients were regressed on contract dummy variables, no significant relationship was found. However, the correlation coefficients for the period 1971 through 1983 seemed to be higher compared with the coefficients for other years. Out of 65 coefficients during this period, 41 coefficients were higher than .8 and only 4 had a value less than .5. Examination of cash and futures prices plotted by individual contract also revealed that the correlation between these two prices was higher when the change in prices was larger. In order to confirm this hypothesis, the correlation coefficient obtained for individual contracts was regressed separately on the cash price range and futures price range during the maturity month. These regression coefficients were positive and significant at the 5 percent level, indicating that higher ranges of price changes have a positive impact on the magnitude of the correlation coefficient. These results suggested that when there were small changes in prices, the participants may not have looked for arbitrage opportunities, probably because opportunities were not readily apparent, and because there may have been other uncertainties in the physical delivery of the grain.

Speculative Component

Theoretical results (equation 5) revealed that the speculative component will not have any impact on the basis if the ratio of the covariance between daily cash and futures prices to the variance of daily futures price during maturity month is equal to one. This ratio is the same as the regression coefficient obtained by regressing daily cash price on futures

Table 1. Correlation Coefficients Between Cash and Futures Prices of Maturity Months of Individual Contracts at an East Central Illinois Elevator During 1966-1986

Correlation Coefficient r	Futures Contracts				
	March	May	July	September	December
$0 \leq |r| \leq .5$	4	0	3	4	4
$.5 \leq |r| \leq .9$	10	12	10	11	10
$|r| > .9$	6	8	7	6	7
UCL[a] $> .95$	10	10	9	10	9

[a] UCL is the upper confidence limit of the correlation coefficient.

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[9]Data were also available for elevators near Chicago and in Northern Illinois. Empirical results were similar among the elevators, so only the East Central Illinois results are discussed.

[10] Our primary interest was to test whether the correlation coefficients were equal to one. However, it was not possible to derive such a test because the distribution of a correlation coefficient does not exist when the value is equal to plus or minus one. As a close approximation of such a test, the upper confidence level was calculated at the 95 percent level.

price. A summary of the regression coefficients for individual contracts for each year is reported in Table 2. The regression coefficients varied widely, from -0.832 for the 1985 September contract to 4.25 for the 1969 September contract. Most of the coefficients were less than one, and slightly more than 50 percent were significantly different from one.

These results are also mixed, but suggest that a speculative component existed in the corn basis for approximately one-half the contracts tested. Of course, as noted in footnote 4, this speculative component does not exist if the expected futures price is equal to current futures price. The high degree of fluctuation in the regression coefficients also indicates that the speculative component can vary widely from contract to contract without a predictable pattern.

Expected Maturity Basis

The third component of the basis model (equation 5) is the expected maturity basis. In order to examine whether it exists, the theoretical model (equation 12) suggests a regression of the basis on one-period lag basis, two-period lag cash futures prices, and one-period lag demand shifters. Since exports are very important in the case of corn, the percent of supply exported was used as a demand shifter.[11] To reduce the multicollinearity between cash and futures prices in this model, two-period lag futures prices were replaced by two-period lag basis.[12] The regression estimates considering one month as one period are as follows:

$$BAS = -2.59 + 0.59 \text{ L1BAS} + 0.24 \text{ L2BAS}$$
$$\quad\quad (-1.64)\ (4.76) \quad\quad\quad (2.22)$$

$$+ 0.05 \text{ L2CASH} - 0.48 \text{ L1PXPORT}$$
$$\quad (4.57) \quad\quad\quad\quad (-1.97)$$

$$- 0.57 \text{ MAY} - 2.92 \text{ JULY}$$
$$\quad (-0.55) \quad\quad (-2.82)$$

$$- 3.81 \text{ SEPTEMBER} + 2.85 \text{ DECEMBER}$$
$$\quad (-2.87) \quad\quad\quad\quad\quad (2.62)$$

$$R^2 = 0.63 \quad DW = 1.58$$
$$\text{CONDITION } \# = 11.54 \quad N = 105$$

where BAS is the Chicago basis (cents/bushel). L1BAS is the one-month lag basis, L2BAS is two-month lag basis, L2CASH is two-month lag Chicago cash price (cents/bushel), and L1PXPORT is one-month lag percentage of supply exported (t-ratios are in parentheses). Contract dummy variables were used to account for seasonality. The estimates indicated that all the variables except the May dummy variable and the percentage of supply exported were significantly different from zero at the 5 percent level. L1PXPORT was significant at the 10 percent level. It was difficult to determine the sign of the coefficients *a priori* because each coefficient was a function of several parameters whose magnitudes were not known. The R^2 indicated that 63 percent of the variation in the basis was explained by the independent variables. A low condition number suggested that the dependency between the independent variables was not strong.[13] The DW statistic was in the inconclusive range which indicates that autocorrelation was not serious.[14] This regression estimate

Table 2. Ratios of Covariance Between Cash and Futures Prices to the Variance of Futures Price of Maturity Months of Individual Contracts at an East Central Illinois Elevator During 1966-86

	Futures Contract				
	March	May	July	September	December
	- Number of Ratios -				
Ratio = 1[a]	12	8	9	12	9
Ratio ≠ 1	8	12	11	9	12

[a] Tests were conducted on whether ratios were significantly different from one.

[11] Other feasible variables were not found to be significant.

[12] The lagged cash prices were retained as a separate variable because the theoretical model suggests that the coefficients of cash and futures prices are different.

[13] The condition number is the square root of the ratio of the largest eigenvalue of X'X, where X is the regressor matrix, to the smallest eigenvalue of X'X, where X has been properly scaled. See Belsley et al. (1980) for a discussion of scaling and the use of the condition number as a measure of multicollinearity. They reported that a condition number in excess of 30 indicates strong dependency in the X matrix.

[14] The data on lagged basis were the bases prevalent one period before maturity, not the maturity basis of the previous contract. Therefore, the DW statistic is still used to determine approximately the presence of autocorrelation.

suggests that it may be possible to predict expected maturity basis one month ahead of the maturity period. Therefore, this estimate allows the conclusion that, assuming rational expectations, the expected maturity basis one month before contract maturity is important in determining the maturity basis.

To assume one month as the appropriate period was arbitrary, so the model was also estimated under the assumption that one period is equal to two months. These results are:

$$BAS = 0.27 + 0.37 \text{ L2BAS} + 0.18 \text{ L4BAS}$$
$$(0.15) (2.49) \qquad (1.67)$$

$$+ 0.04 \text{ L4CASH} - 0.67 \text{ L2PXPORT}$$
$$(3.36) \qquad (-2.39)$$

$$- 0.07 \text{ MAY} - 3.05 \text{ JULY}$$
$$(-0.06) \qquad (-2.53)$$

$$- 5.47 \text{ SEPTEMBER} + 1.00 \text{ DECEMBER}$$
$$(-3.58) \qquad (0.55)$$

$$R^2 = 0.53 \quad DW = 1.64$$
$$CONDITION \# = 11.89$$

where, L2BAS is the two-month lag basis, L4BAS is four-month lag basis, L4CASH is four-month lag cash price, and L2PXPORT is two-month lag percentage of supply exported. The results were similar to the previous regression estimates except that the two-period lag basis was significant at the 10 percent level, and the lagged percentage of supply exported was significant at the 5 percent level. As the length of lag increased, the lag basis was expected to be less significant because it becomes more difficult to predict the maturity basis longer periods of time ahead. The R^2 suggested that the basis variability was not explained as well as in the previous case.

The estimates of the regression when one period is equal to three months are:

$$BAS = 1.42 + 0.32 \text{ L3BAS} + 0.12 \text{ L6BAS}$$
$$(0.76) (3.13) \qquad (1.86)$$

$$+ 0.03 \text{ L4CASH} - 0.73 \text{ L2PXPORT}$$
$$(2.14) \qquad (-2.50)$$

$$+ 1.58 \text{ MAY} - 1.79 \text{ JULY}$$
$$(1.29) \qquad (-1.47)$$

$$- 6.17 \text{ SEPTEMBER} + 0.87 \text{ DECEMBER}$$
$$(-4.69) \qquad (0.50)$$

$$R^2 = 0.49 \quad DW = 1.42 \quad CONDITION \# = 11.67.$$

The estimates were similar to the ones obtained in the previous regression. The three-month lag basis was significant whereas the six-month lag basis was not significant at the 5 percent level. These latter two regression estimates suggested that expected maturity basis could be predicted from two and three months before the maturity of the contract. However, as lags farther back in time are used, the precision of the prediction would decrease because the amount of variation explained decreases.

These results suggest that in the case of corn, the basis often includes a risk premium, a speculative component, and an expected maturity basis. The risk premium and speculative components vary widely across contracts.

CONCLUSIONS

The existence of some components of the corn basis were examined utilizing a general theory of intertemporal price relationships for storable commodities as proposed by Naik and Leuthold (1988). Their general theoretical model indicated that basis consists of basis risk premium, adjusted speculation, and expected maturity basis apart from cost of storage, opportunity cost, and convenience yield.

The empirical results on corn obtained in this study indicated that there often exists a maturity basis risk premium in the futures market. The basis consists of a risk premium, a speculative component, and a maturity basis apart from other factors such as storage cost for storable commodities. The existence of the futures market reduces price risk, but does not totally eliminate it. The variation in the synchronous movement between cash and futures prices makes participation in the futures market less attractive to hedgers. It may be possible to predict a part of the maturity basis well ahead of time.

Previous studies on the existence of the risk premium have been inconclusive. The results in this study support those studies that found a risk premium (e.g. Houthakker 1957; Cootner 1960). However, previous tests for the existence of a speculative component could not be identified, so results could not be compared. The results on the predictability of the basis and cash and futures price relationships are consistent with previous empirical results (e.g. Kahl, 1982).

These results are based on the assumptions that traders are not risk neutral and that futures markets are not always unbiased. The results could be affected by transportation bottlenecks and particular market-pricing procedures. Ideal data sets were not available. However, these general results held for

elevators in three different locations in Illinois. The general theoretical model outlined here and empirical tests of it offer insights into the factors affecting basis patterns for corn.

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