Cash and Futures Price Relationships for Nonstorable Commodities: An Empirical Analysis Using a General Theory

Gopal Naik and Raymond M. Leuthold

Empirical analysis examines the presence of basis risk, speculative component, and expected maturity basis component in basis relationships for nonstorable commodities. The results indicate that all three above components exist in both cattle and hog markets. The basis risk and speculative components vary across contracts. Hog markets showed seasonality, which helps explain the hog basis more accurately. Flexibility in making the marketing decision strengthens the explanation of intertemporal price relationships for both cattle and hogs beyond that previously attributed to only feed prices.

Key words: basis, futures markets, livestock, nonstorable commodities.

The success of hedgers in the futures market depends on how well they can anticipate basis (futures price minus cash price) relationships. Understanding the mechanism and identifying the factors influencing such relationships can assist market participants in making successful production and marketing decisions. A better understanding of basis relationships may also help policymakers in evaluating market performance by identifying unnecessary movements in prices.

The two major theories about basis relationships are Keynes' (1923, 1930) theory of normal backwardation and Working's (1949, 1953) theory of price of storage. However, the nonstorable nature of livestock commodities, which have traded successfully on the futures market since the 1960s, and their production and supply characteristics prevent direct application of the general theory of the price of storage to these commodities. Paul and Wesson utilized the theory of the price of storage to explain the relationships between the distant fed animal futures contract price and the current cash price of feeder animals, and they called this the price of feedlot services. This means in the case of livestock, if the production (placing animals on feed) decision is made at a particular age of animal, then the relationship between the price of feeder animals and the price of output (fed animal) exists only during that time. Once the production decision is made, unless there exists flexibility in choosing feeder animals of a different age, the relationship is only a one-time phenomenon. This is contrary to storables, where the whole constellation of prices interrelate.

Livestock producers are also interested in understanding intramarket price relationships, that is, the relationships between cash and futures prices of output. It was generally believed that no relationships exist between two intertemporal prices of a nonstorable commodity (Ehrich; Futrell; Leuthold 1977) because stocks cannot be carried over time. However, empirical investigation of intramarket intertemporal price relationships in livestock markets (Purcell, Flood, and Plaxico; Leuthold 1979; Tomek) have indicated that the cash and nearby futures prices are related. Cash and futures prices for distant contracts are not necessarily related (Tomek).

Kendall examined theoretically and empir-

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ically the intertemporal price relationships for nonstorable commodities and concluded that positive correlation among intertemporal prices of a commodity such as live cattle can arise. This relationship is caused by the mutual dependency of current and future-dated supplies of beef cattle on the common input market for current and future-dated corn where prices relate intertemporally.

Naik and Leuthold recently expanded on these concepts and examined theoretically basis relationships considering the time flexibility for the producer in making marketing decisions during which the quality of meat of these animals stays relatively unchanged. They develop a model of intertemporal price relationships for nonstorable commodities utilizing expected utility theory and then derive a basis model for estimation using market equilibrium conditions and rational expectations. The purpose of this paper is to test empirically these theoretically suggested basis relationships for cattle and hogs. The results of this paper demonstrate that flexibility in making the marketing decision improves our understanding of and ability to explain intertemporal price relationships for nonstorable commodities beyond that previously attributed to only feed prices.

Theory and Models

Assuming market participants have a negative exponential utility function and profits are normally distributed, Naik and Leuthold examined the basis relationships for nonstorable commodities such as livestock in an expected utility maximization framework. Considering the flexibility for the producer in making marketing decisions, they argue that producers make supply decisions twice in the life of an animal. The first decision is made at the beginning of the production process and concerns the quantity to produce. The second decision is made when the animals reach the marketing stage. This latter case involves whether to sell the animals immediately or withhold them until the next period. At both times, a producer can participate in the futures market and hence may hold futures positions. They show that it is this marketing flexibility that strengthens the basis relationships for livestock.

Assuming that the producer has the flexibility in marketing the animals either in period $t-1$ or in the next period t, Naik and Leuthold used a profit function for withholding the animals and offering them for supply in the next period in the presence of a futures market, which is

$$(1)\quad \begin{aligned}\Pi_{it} = {} & (1 - \lambda_{t-1})Q_{it-1}[(1 + \delta)P_t \\ & - (1 + \gamma_{t-1})P_{t-1}] \\ & - k(1 + \gamma_{t-1})PF_{t-1}(1 - \lambda_{t-1})Q_{it-1} \\ & - b_1(1 + \gamma_{t-1})(1 - \lambda_{t-1})Q_{it-1} \\ & - \tfrac{1}{2}b_2(1 + \gamma_{t-1})(1 - \lambda_{t-1})^2Q^2_{i\,t,t-1} \\ & + A_{1it-1}(F_{t,t} - F_{t,t-1}),\end{aligned}$$

where Π_{it} is the profit of the producers, $(1 + \delta)$ is the growth rate of animals from period $t - 1$ to t $(\delta \geq 0)$, $(1 - \lambda_{t-1})Q_{it-1}$ is that part of output Q_{it-1} withheld in period $t - 1$ $(0 \leq \lambda_{t-1} \leq 1)$ for marketing in period t, γ is the risk-free interest rate, P_{t-1} is the price of animals as output in period $t - 1$, PF_{t-1} is the price of feed, k is the amount of feed required to feed one unit of Q_{it-1} from period $t - 1$ to t, $F_{t,t-1}$ is the futures price formed at $t - 1$ for time t, b_1 and b_2 are components of the quadratic cost function, and A_{1it-1} is the futures position ($A_{1it-1} < 0$ indicates sales). Costs are entered in a quadratic framework.

Using a mean-variance framework, producers' expected utility of profit, Ω, for the marketing decision can be written as

$$(2)\quad \Omega_{it} = E_{t-1}\Pi_{it} - \tfrac{1}{2}\mu_i\sigma^2_{\Pi t,t-1},$$

where μ is the Arrow-Pratt measure of risk aversion ($\mu > 0$ (<0) indicates the decision maker is risk averse (loving)), $\sigma^2_{\Pi t,t-1}$ is the conditional variance of profit for time t formed at time $t - 1$, which is (see Naik and Leuthold)

$$(3)\quad \begin{aligned}\sigma^2_{\Pi t,t-1} = {} & \sigma^2_{pt,t-1}((1 + \delta)(1 - \lambda_{t-1})Q_{it-1})^2 \\ & + \sigma^2_{ft,t-1}A^2_{1it-1} + 2\,\mathrm{cov}_{t-1}(P_t,F_t) \\ & (1 + \delta)(1 - \lambda_{t-1})Q_{it-1}A_{1it-1},\end{aligned}$$

where σ^2_p and σ^2_f are the variances of cash and futures prices, respectively. Substituting the expected value of equations (1) and (3) in equation (2), Naik and Leuthold derive the following basis equation

$$(4)\quad \begin{aligned}F_{t,t-1} - P_{t-1} = {} & b_1(1 + \gamma_{t-1}) \\ & + b_2(1 + \gamma_{t-1})(1 - \lambda_{t-1})Q_{it-1} \\ & + k(1 + \gamma_{t-1})PF_{t-1} + \gamma_{t-1}P_{t-1} \\ & + (1 + \delta)E_{t-1}BS_t \\ & + \mu_i\,\sigma^2_{p,t,t-1}(1 - r^2)(1 + \delta)^2 \\ & \cdot(1 - \lambda_{t-1})Q_{it-1} - x(1 + \delta) \\ & \cdot[E_{t-1}F_{t,t} - F_{t,t-1}] \\ & - \delta F_{t,t-1},\end{aligned}$$

where $F_{t,t-1} - P_{t-1}$ is one period basis, r is the expected correlation coefficient between cash and futures prices, x is one minus the ratio of covariance between cash and futures price to variance of futures price and BS_t is the basis in time t. This result indicates that if there exists flexibility in making marketing decisions, and if the time betweeen successive production streams is less than or equal to the duration of this flexibility, then the one-period basis (the difference between the cash and one-period ahead futures) is the sum of the cost of maintaining the animal, opportunity cost, expected maturity basis, basis risk ($\mu_1\sigma^2_{pt,t-1}(1 - r^2)(1 + \delta)^2(1 - \lambda_{t-1})Q_{it-1}$), adjusted speculation ($x(1 + \delta)[E_{t-1}F_{t,t} - F_{t,t-1}]$) and the income due to the gain in the weight of the animals ($\delta F_{t,t-1}$).[1]

Equation (4), derived elsewhere, shows those factors important in explaining the one-period basis for livestock assuming flexibility exists in marketing decisions. The key to this equation is measuring the size of r and x and assessing whether factors exist to determine the expected basis. That is, everything else is lagged or known. The purpose of this paper is to investigate and measure these three unknowns, giving insight into intertemporal (basis) relationships for livestock.

Naik and Leuthold suggest that the absolute value of a correlation coefficient r between cash and futures prices during maturity month different than one for any contract indicates there exists maturity basis risk for that contract.[2] That is, if the correlation coefficient equals (absolute) one, the basis risk component of the equation goes to zero, meaning basis risk does not affect the basis.

To test whether the speculative component affects the basis, cash price is regressed on the futures price during maturity month. A coefficient different than one will indicate that a speculative component affects the basis.[3]

Because cash and futures prices are endogeneous in the overall model, Naik and Leuthold use market equilibrium conditions and rational expectations to derive a model to study the impact of expected maturity basis. They suggest that the maturity basis (BS) be regressed on the previous period demand shifters (Z), feed price, basis, supply of animals, and two-periods-previous feed price, cash price, and futures price, as follows

$$(5)\qquad BS_t = f(Z_{t-1}, P_{t-2}, PF_{t-1}, PF_{t-2}, BS_{t-1}, F_{t,t-2}\ Q_{t-1}).$$

Because the arbitrage possibility exists only for one-period ahead when explicitly examining the marketing stage, determining the length of lag can be important. The length of lag varies from animal to animal. In the case of hogs, a producer is usually flexible in making marketing decisions for about a month, whereas in the case of cattle this period may extend up to two months.

The (un)biasedness of futures prices can be observed from the results obtained from the above three tests, the correlation coefficient, the regression coefficient and basis equation. The results will help better understand the basis relationships for nonstorable commodities. They will also help us gain insights into relationships among intertemporal prices for nonstorables as suggested by Kendall.

The theoretical results also show that when the time length of flexibility in marketing the animals is equal to or greater than the time between successive maturity periods (futures contracts), then the cash and futures prices are related beyond the flexibility period. For two periods ahead the futures price is a function of expected demand shifters one period ahead (E_tZ_{t+1}), current cash price (P_t), expected feed price one period ahead (E_tPF_{t+1}), current feed price (PF_t), futures price one period ahead ($F_{t+1,t}$), expected basis for one period ahead (E_tBS_{t+1}) and expected supply (E_tQ_{t+1}), as follows:

$$(6)\qquad F_{t+2,t} = (E_tZ_{t+1}, P_t, E_tPF_{t+1}, PF_t, F_{t+1,t}, E_tBS_{t+1}, E_tQ_{t+1}).$$

The difficulty in estimating the above equation lies in obtaining the data on expected values, i.e., data on E_tZ_{t+1}, E_tPF_{t+1}, E_tBS_{t+1} and E_tQ_{t+1}. E_tZ_{t+1} is the expected value of demand shifters such as income, price of related commodities, and the season. The per capita income follows a fairly well-defined trend and hence is easily estimated. Futures prices of a related commodity, if available, can be used as an expected price for that commodity. And season is relatively easy to predict. If the feed used is traded on the commodity futures market, then its one-period-ahead futures price can

[1] The expression for basis risk can actually be referred to as a risk premium. Theoretically, risk premium equals risk times the risk aversion coefficient. In the basis risk expression, μ_i is the risk aversion coefficient and $\sigma^2(1 - r^2)$ is the basis risk. The remaining terms are weights. Because variance is in monetary terms, the basis risk expression is in monetary terms. To avoid confusion we refer to this expression as basis risk, although basis risk premium is equally applicable.

[2] This assumes traders are not risk neutral, i.e., $\mu_i \neq 0$.

[3] For the speculative component to exist, this also assumes that the expected futures price does not equal the final futures price, or there is a bias in the market. We do not explicitly test this latter hypothesis.

be used as a proxy for E_tPF_{t+1}. Because Q_t is known any time after period $t - q$ (the time when young animals were placed on feed), E_tQ_{t+1} can be estimated from that information. The value of E_tBS_{t+1} can be obtained from the basis equation (5).

Assuming Z_t follows a first-order autoregressive process, i.e., $Z_t = \rho Z_{t-1} + v_{zt}$, we can obtain $E_tZ_{t+1} = \rho Z_t$. Utilizing these expected values we can express futures price for two periods ahead in terms of predetermined variables except for expected supply, E_tQ_{t+1}.[4] That is,

$$(7) \qquad F_{t+2,t} = (Z_t, P_t, P_{t-1}, BS_t, PF_{t+1,t}, PF_t, PF_{t-1}, F_{t+1,t}, E_tQ_{t+1}, Q_t).$$

The hypothesis that current cash price and the current futures price for two periods ahead are related can be tested by estimating the above equation. That is, tests can be conducted by regressing two-periods-ahead futures prices on current demand shifters, current cash price, current basis, current feed price, previous period cash price and feed price, one-period-ahead futures price, one-period-ahead futures price of feed, current supply, and expected supply for the next period. The futures price of feed can be used as proxy for E_tPF_{t+1}. The demand shifters used are per capita income and prices of other products. The simultaneity between the cash and futures price can be avoided by using their difference.

Daily cash prices for the Omaha market and futures prices from Chicago Mercantile Exchange for the period 1966 through 1986 are used to estimate the correlation coefficient and the ratio of covariance between cash and futures price to the variance of futures price for nonstorable cattle and hogs. Only data during the maturity month of each contact during the twenty-one-year period are used (cattle has 6 contracts/year, hogs 7 contracts/year). The data were supplied by Iowa State University, and we averaged the reported daily high and low prices for both cash and futures. The cash prices for cattle up to 1973 are for Choice slaughter steers, 1,100–1,300 pounds. From 1973 onwards the cash prices for cattle are slaughter steers, Choice 2–4, 1,000-1,200 pounds. The cash prices for hogs up to mid-1972 are barrows and gilts 200–220 pounds, and beyond mid-1972 are barrows and gilts, 200–240 pounds. If either a cash or futures price was not available for any particular day, such as no cash market for cattle on Thursday and Friday in recent years, that observation was omitted.

[4] Expressing futures price in terms of predetermined variables helps us empirically estimate this relationship. The data on animals of different weight groups on feed can be used as a good proxy for the expected supply variable.

Results

Correlation Coefficients

The correlation coefficients between maturity month cash and futures prices for all individual cattle and hog contracts are grouped into three categories (table 1). The coefficients for cattle varied from −.641 in August 1975 to .984 in April 1981. Out of the 126 coefficients, 35 are less than .5 and only 26 are greater than .9. No definite pattern in correlation coefficients is observed either with respect to contracts or over time, although February has the largest number exceeding .9 and June the lowest number. The correlation coefficients for hogs ranged from −.313 in April 1978 to .992 in June 1975 contract. Out of 144 coefficients, 41 are less than .5 and only 25 coefficients are greater than .9. February and April contracts have the lowest correlations, whereas June and August contracts have the highest correlations. For both cattle and hogs the majority of the coefficients are less than .9.

The upper confidence limit is greater than .95 for 54 coefficients for cattle and 39 coefficients for hogs.[5] The number of observations used for each coefficient ranged from 7 to 13 for cattle and from 12 to 15 for hogs.

In order to examine the impact of contracts on the correlation coefficient, correlation coefficients were regressed on dummy variables representing contract maturity months. For cattle no dummy variable was significant, suggesting there is no seasonality. However, the regression estimates for hogs show June and April contract correlation coefficients significantly different (higher and lower, respectively) than February coefficients. This suggests the correlation coefficients for hogs are affected by seasonality.

The majority of the correlation coefficients in both the cattle and hog markets are less than the upper confidence limit of .95, and they vary

[5] Procedures do not exist to test whether a correlation coefficient is equal to one. However, upper confidence levels are calculated for the 95% level.

Table 1. Correlation Coefficients between Cash and Futures Prices of Maturity Months of Individual Contracts at Omaha during 1966-86

Correlation Coefficient r	Futures Contract						
	February	April	June	July	August	October	December
	Number of Contracts						
Cattle							
$0 \leq \|r\| \leq .5$	8	5	6		6	9	4
$.5 < \|r\| \leq .9$	7	11	14		11	7	12
$\|r\| > .9$	6	5	1		4	5	5
UCL > .95[a]	8	11	9		8	8	10
Hogs							
$0 \leq \|r\| \leq .5$	6	12	1	6	3	8	5
$.5 < \|r\| \leq .9$	13	7	13	13	12	9	11
$\|r\| > .9$	1	1	6	2	6	4	5
UCL > .95	2	2	9	4	10	5	7

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

widely. This indicates basis risk exists in the livestock markets, and it varies from contract to contract and from commodity to commodity. While no definite pattern over time or contracts in the cattle coefficients is evident, correlation coefficients for hogs show seasonality. Therefore, it is possible that the predictability of the correlation coefficient between cash and futures prices of hogs may be better than for cattle.

Closer examination of the cash and futures price movements indicates that when the change in the price range is small, the movement of cash and futures prices are not always well coordinated. Therefore, a band of cash and futures price changes exists within which arbitraging between cash and futures markets appears unattractive. That is, there is more randomness in price relationships.

Low correlation coefficients may be from several causes. First, there may be weak integration between cash and futures markets because of thinness in the markets, local supply and demand conditions, and/or low arbitrage possibilities. Second, either one of these markets may lead or lag the other. Third, the cash and futures markets may converge from different directions, or there may exist outliers in one of the markets. Fourth, measurement errors in price series can cause low correlation. Fifth, the results may be caused by the small sample size in each case indicating that the estimates are not reliable. Last, lack of adequate transportation and imprecise and insufficient market information may also cause low correlation between cash and futures prices.

The physical distance between the markets may cause weak integration when there are uncertainties (bottlenecks) in transportation. Correlation coefficients were also obtained using leads and lags of futures prices. In both the lead and lag cases, some coefficients improved marginally but others did worse than those summarized in table 1. Overall, no gains were noticed. Therefore, leads or lags did not seem to be the reason for small coefficients for some maturity months.

The continuation of cash and futures price convergence during the maturity months creates profit opportunity from arbitrage. Gradual convergence can exist only in weakly integrated or thin markets due to lack of information or insufficient number of arbitragers. Visual examination of daily basis did not reveal any convergence pattern.

No extreme outliers existed for cattle. For hogs an absolute value of the basis greater than $5 per hundredweight is considered as an outlier and is removed. There were only six such outliers, so small correlation coefficients are not caused by the presence of extreme outliers.

The data on cash and futures prices are an average of high and low prices. The correlation of average prices may be different than the actual prices. It is possible that correlation of only high or low prices would yield higher correlation coefficients.

In the above analysis small-sample problems arise since all coefficients are based on fifteen or less observations. Therefore, the data are grouped into two different types, yearwise and contractwise. These groupings help us ex-

Table 2. Yearwise Correlation Coefficients between Daily Cash and Futures Prices of Maturity Months at Omaha during 1966-86

	Cattle			Hogs		
Year	*r*[a]	*N*[b]	*UCL*[c]	*r*	*N*	*UCL*
1966	.450	68	.621	.190	54	.435
1967	.184	68	.405	.243	98	.421
1968	.462	67	.632	.316	93	.488
1969	.130	69	.356	.384	97	.542
1970	.341	69	.534	.322	98	.490
1971	.164	67	.389	.370	96	.531
1972	.673	67	.786	.603	97	.716
1973	.428	70	.602	.618	98	.727
1974	.609	68	.740	.587	98	.703
1975	.543	61	.699	.622	97	.731
1976	.804	64	.876	.569	97	.690
1977	.667	58	.789	.570	96	.692
1978	.528	65	.684	.286	97	.459
1979	.802	61	.877	.302	97	.473
1980	.565	57	.720	.702	97	.790
1981	.758	54	.853	.512	96	.646
1982	.683	49	.809	.530	96	.660
1983	.517	49	.697	.649	97	.751
1984	.233	51	.478	.367	96	.529
1985	.717	51	.829	.450	97	.596
1986	.555	51	.721	.729	98	.810

[a] *r* refers to correlation coefficient.
[b] *N* is the number of observations.
[c] *UCL* is the upper confidence limit of the correlation coefficient.

amine the pattern of correlation coefficients among years and among contracts, as well as increase sample size.

Correlation coefficients based on raw grouped data may yield a high correlation, not only because of the synchronous movements of cash and futures prices during maturity months but also because of the large changes in price levels from one contract to another.[6] In order to remove the impact of different levels of prices, the mean of the individual contract cash price is subtracted from all the cash and futures prices of that contract. The yearwise correlation coefficients are given in table 2. These tables show that the yearwise correlation coefficients range from .130 in 1969 to .804 in 1976 for cattle and .190 in 1966 to .729 in 1986 for hogs. For cattle the coefficients are relatively higher during the period 1972–83, and for hogs the coefficients are relatively higher during 1972–77 and 1980–83.

[6] The large changes in price levels between contract months can be so high as to completely swamp the variation in the movement in cash and futures prices during the maturity months. The correlation coefficient obtained in such cases does not reflect the synchronous movement between cash and futures prices during maturity months.

Table 3. Contractwise Correlation Coefficients between Daily Cash and Futures Prices of Maturity Months at Omaha during 1966–86

	Cattle			Hogs		
Contract	*r*[a]	*N*[b]	*UCL*[c]	*r*	*N*	*UCL*
February	.537	204	.628	.403	270	.498
April	.656	215	.726	.276	271	.383
June	.569	218	.652	.783	282	.824
July				.491	276	.576
August	.501	212	.595	.656	298	.716
October	.634	213	.708	.493	296	.575
December	.569	222	.652	.604	297	.672

[a] *r* refers to correlation coefficient.
[b] *N* is the number of observations.
[c] *UCL* is the upper confidence limit of the correlation coefficient.

The contractwise correlation coefficients for cattle did not fluctuate very much, whereas for hogs the fluctuation in contractwise correlation coefficients are relatively high (table 3). The lowest correlation coefficient for hogs is observed for the April contract and the highest for the June contract. Correlation coefficients were also calculated for all contracts in three-year groups and individual contracts in five-year groups. The former set of correlation coefficients showed results similar to the yearwise correlation coefficients. The five-year contractwise correlation coefficients were similar to table 1. All coefficients were substantially less than one.

Overall, the correlation coefficients are substantially lower than one and fluctuate. In the case of cattle, seasonality is not noticed, whereas for hogs seasonality is a factor in determining the magnitude of the correlation coefficient. These results provide evidence of maturing basis risk (premium) in cattle and hog markets.

Speculative Component

The number of ratios of the covariance between cash and futures prices to the variance of the futures price during the maturity months of individual contracts that are equal to or significantly different from one are presented in table 4. The August contract has the highest number of coefficients equal to one at the 5% level for cattle and the October contract has the highest number for hogs. The lowest number of coefficients equal to one is found for the February contract for cattle and the April contract for hogs. Overall, hogs have a higher per-

Table 4. Ratios of Covariance between Cash and Futures Prices to the Variance of Futures Price of Maturity Months of Individual Contracts at Omaha for the Period 1966–86

	Futures Contract						
	February	April	June	July	August	October	December
Cattle				Number of Ratios			
Ratio = 1[a]	7	12	8		13	8	9
Ratio ≠ 1	14	9	13		8	13	12
Hogs							
Ratio = 1	11	6	10	10	12	14	11
Ratio ≠ 1	9	14	10	11	9	7	10

[a] The ratio is tested at the 5% level using *t*-statistic.

centage (51%) of coefficients equal to one than cattle (45%).

As outlined above, data were grouped to increase sample size. Table 5 shows that the yearwise regression coefficients range from .060 in 1969 to .853 in 1981 for cattle, and .082 in 1966 to .780 in 1983 for hogs, respectively. All coefficients are significantly less than one except for cattle in 1981. The contractwise coefficients fluctuate less in the case of cattle than for hogs (table 6). Nevertheless, all are significantly less than one. Also, the coefficients obtained for three-year and five-year grouped data indicate that all the coefficients are significantly less than one.

These results indicate that the speculative component exists in both cattle and hog markets unless the expected price is equal to the current futures price. The speculative component seems to vary widely across contracts and commodities, and in the hog market it seems to exhibit seasonality.

Expected Maturity Basis

To test whether the expected maturity basis exists in the basis, theoretical results suggest to regress basis on its lag basis, lag demand shifters, two-period lag cash and futures prices, lag price of feed one and two periods, and lag total quantity supplied using monthly data [equation (5)]. Empirical results suggest that a high degree of dependence exists between the independent variables suggested by theory, especially in the case of hogs. Therefore, a re-

Table 5. Yearwise Ratios of Covariance between Daily Cash and Futures Prices to the Variance of Futures Price of Maturity Months at Omaha During 1966–86

	Cattle		Hogs	
Year	Ratio	*t*-Statist.[a]	Ratio	*t*-Statist.
1966	.248	−12.38	.082	−15.54
1967	.102	−13.42	.159	−12.96
1968	.160	−22.04	.219	−11.34
1969	.060	−16.74	.178	−18.76
1970	.163	−15.26	.237	−10.72
1971	.121	−9.75	.239	−12.26
1972	.565	−5.65	.514	−6.97
1973	.316	−8.44	.482	−8.28
1974	.484	−6.64	.629	−4.19
1975	.330	−10.08	.452	−9.40
1976	.650	−5.73	.502	−6.68
1977	.454	−8.06	.367	−11.63
1978	.462	−5.74	.178	−13.40
1979	.485	−10.93	.152	−17.20
1980	.335	−10.10	.618	−5.93
1981	.853	−1.44	.408	−8.38
1982	.521	−5.88	.421	−8.33
1983	.307	−9.34	.780	−2.34
1984	.072	−21.49	.265	−10.63
1985	.583	−5.16	.353	−8.98
1986	.513	−4.44	.572	−7.81

[a] The *t*-statistic tests the hypothesis that the ratio is equal to 1.

Table 6. Contractwise Ratios of Covariance between Daily Cash and Futures Prices to the Variance of Futures Price of Maturity Months at Omaha during 1966–86

	Cattle		Hogs	
Contract	Ratio	*t*-Statist.[a]	Ratio	*t*-Statist.
February	.407	−13.20	.346	−13.64
April	.487	−13.28	.161	−24.59
June	.392	−15.80	.788	−5.68
July			.431	−12.34
August	.310	−18.63	.465	−17.22
October	.459	−14.06	.388	−15.31
December	.356	−18.56	.525	−11.77

[a] The *t*-statistic tests the hypothesis that the ratio is equal to 1.

duced version of the theoretical model is used to estimate the relationships. The selection of variables to be included in the reduced version is made by eliminating variables which are highly correlated with other variables. Lagged cash and futures prices are differenced to form a lagged basis. However, an effort is made to retain the important variables in the model. In the case of cattle, two-period-previous feed price is not considered, and in the case of hogs both one-period and two-periods lag feed prices are not considered. Variables selected as demand shifters include per capita income and prices of hogs (in cattle equation) and cattle (in hog equation). Pork cold storage is used as a component of supply. Monthly data are used for estimation. Prices and income variables are deflated using the consumer price index.

The estimated models are as follows (*t*-ratios are in parentheses):[7]

<u>When One Period is Equal to One Month</u>

Cattle

$$BAS = \underset{(-3.38)}{-2.34} + \underset{(6.39)}{0.41}\ L1BAS - \underset{(-1.76)}{0.07}\ L2BAS + \underset{(2.44)}{0.0005}\ L1PCI + \underset{(3.10)}{0.03}\ L1HOGCSH - \underset{(-0.81)}{0.14}\ L1PRCORN + \underset{(0.14)}{0.00002}\ L1TOTCAT,$$

$R^2 = 0.47$ D-W = 1.75 Condition No. = 60.

The estimated model shows that one-month lag basis, one-month lag per-capita income, and one-month lag hog cash prices are significantly affecting the maturity basis of cattle, and that 47% of the variation in the expected maturity basis can be explained one month before maturity. The Durbin-Watson (D-W) statistic indicates an absence of autocorrelation.[8] The condition number is high, suggesting that there is a multicollinearity problem. By removing the multicollinearity, it is possible that some of the variables which are not significant can become significant.[9]

The estimated model for hogs is as follows:

Hogs

$$BAS = \underset{(-2.35)}{-1.37} + \underset{(4.62)}{0.24}\ L1BAS - \underset{(-0.45)}{0.02}\ L2BAS + \underset{(3.25)}{0.0005}\ L1PCI - \underset{(-1.46)}{0.001}\ L1CLDHG - \underset{(-3.56)}{0.48}\ APRIL - \underset{(-4.17)}{0.47}\ JUNE - \underset{(-0.82)}{0.10}\ AUGUST - \underset{(-2.47)}{0.34}\ OCTOBER - \underset{(-3.31)}{0.38}\ DECEMBER,$$

$R^2 = 0.57$ D-W = 1.83 Condition No. = 47,

where months refers to contract maturity months.[10]

The estimated model for hogs shows that 57% of the maturity basis can be explained. The one-month lag basis, one-month lag per-capita income, and most of the seasonal (contract) dummy variables are significant. The D-W statistic indicates the absence of autocorrelation, and the condition number indicates that there may be a slight multicollinearity problem.

The results of these models when one period is equal to two and three months are given below.[11]

[7] In the following regressions, the letter *L* preceding the variable name means it is lagged, and the number following indicates the number of months lagged. Then *BAS* represents basis (cents per hundredweight, cwt), *PCI* per capita income ($/year), *HOGCSH* is cash price of hogs in Omaha (¢/cwt), *PRCORN* is U.S. price of corn (¢/bushel), *TOTCAT* is the total cattle supply which is sum of the number of animals slaughtered and the number of animals which are heavier than 1,100 pounds (1,000 head), *CLDHG* is pork cold storage (million lbs.). All data are monthly. The dependent variable is maturity basis. Basis is determined by taking the average of daily closing prices in month t for $t + i$, and subtracting from it monthly average cash price for cattle (Omaha) or hogs (Omaha).

[8] The data on lagged basis is the basis prevalent one period before maturity, not the maturity basis of the previous contract. Therefore, the Durbin-Watson statistic is still used to determine approximately the presence of autocorrelation.

[9] The signs of the coefficients are difficult to determine a priori. Hence, the evaluation of signs is not considered here.

[10] The dummy variable for the July contract is not given because its impact (at least most of it) is taken care of by either the June or August contract.

[11] The maturing contract is still used in *BAS*.

When One Period Is Equal to Two Months

Cattle

$$\begin{aligned} BAS = {} & \underset{(-3.02)}{-2.57} + \underset{(3.25)}{0.14\,L2BAS} \\ & \underset{(-0.77)}{-\,0.03\,L4BAS} + \underset{(1.94)}{0.0005\,L2PCI} \\ & + \underset{(0.73)}{0.0083\,L2HOGCSH} \\ & + \underset{(0.88)}{0.18\,L2PRCORN} \\ & + \underset{(0.58)}{0.00009\,L2TOTCAT}, \end{aligned}$$

$R^2 = 0.18$ D-W = 2.09 Condition No. = 59.

With the increase in the length of the lag to two months, observe that only the two-month lag basis is significant. The explanatory capacity of the model dropped to 18%.

For hogs the results are as follows:

Hogs

$$\begin{aligned} BAS = {} & \underset{(-2.34)}{-1.55} + \underset{(1.31)}{0.06\,L2BAS} \\ & + \underset{(0.86)}{0.03\,L4BAS} + \underset{(3.11)}{0.0005\,L2PCI} \\ & \underset{(-1.07)}{-\,0.001\,L2CLDHG} \\ & \underset{(-3.87)}{-\,0.55\,APRIL} \underset{(-4.51)}{-\,0.60\,JUNE} \\ & + \underset{(1.55)}{0.20\,AUGUST} \\ & \underset{(-2.06)}{-\,0.33\,OCTOBER} \\ & \underset{(-4.94)}{-\,0.65\,DECEMBER}, \end{aligned}$$

$R^2 = 0.48$ D-W = 1.53 Condition No. = 48.

With the increase in the lag length to two months lagged per capita income is significant along with most of the dummy variables. The R^2 dropped from .57 to .48. Autocorrelation in this and subsequent equations is not a problem.

When One Period Is Equal to Three Months

The results for cattle when one period is equal to three months are as follows:

Cattle

$$\begin{aligned} BAS = {} & \underset{(-2.97)}{-2.50} + \underset{(3.81)}{0.12\,L3BAS} \\ & \underset{(-1.49)}{-\,0.04\,L6BAS} + \underset{(2.88)}{0.0007\,L3PCI} \\ & + \underset{(1.39)}{0.0157\,L3HOGCSH} \\ & + \underset{(1.09)}{0.22\,L3PRCORN} \\ & \underset{(-1.02)}{-\,0.00018\,L3TOTCAT}, \end{aligned}$$

$R^2 = 0.21$ D-W = 2.12 Condition No. = 59.

Only three-month lag basis and three-month lag per-capita income are significant. The R^2 remains low.

The results for hogs, when one period is equal to three months, are as follows:

Hogs

$$\begin{aligned} BAS = {} & \underset{(-2.24)}{-1.57} + \underset{(2.90)}{0.10L3BAS} \\ & \underset{(-0.13)}{-\,0.003\,L6BAS} + \underset{(3.13)}{0.0006\,L3PCI} \\ & \underset{(-0.71)}{-\,0.0007\,L3CLDHG} \\ & \underset{(-4.24)}{-\,0.60\,APRIL} \underset{(-5.93)}{-\,0.74\,JUNE} \\ & + \underset{(1.26)}{0.16\,AUGUST} \\ & \underset{(-2.23)}{-\,0.41\,OCTOBER} \\ & \underset{(-4.80)}{-\,0.72\,DECEMBER}, \end{aligned}$$

$R^2 = 0.48$ D-W = 1.57 Condition No. = 49.

Three-month lag basis, three-month per capita income and April, June, October, and December dummy variables are significant. The R^2 is the same as in the two-month lag model.

For cattle, as the length of lag increases the first lagged basis is always significant and income maintains a fairly high t-ratio. However, the R^2 dropped considerably. For hogs, income is the only variable which remains significant, while the first lagged basis is significant in the first and third regressions. The explanatory power of the hog model remains almost unchanged. This is probably because the seasonal dummy variables in the hog model explain a large part of the variation in the basis.

From the above analysis, we have observed that there exists a maturity basis risk and a speculative component in both the hog and cattle markets. We have also observed that in both markets a substantial portion of the maturity basis can be explained one month before the maturity. These results suggest that the maturity basis for livestock contains a risk component, a speculative component, and expected maturity basis. We noticed seasonality affecting all three of these factors for hogs. These results facilitate better understanding of the components of the livestock basis.

Cash and Futures Price Relationships Beyond One Period

To test whether current cash price is related with the futures price beyond one period ahead, theoretical results suggest [equation (7)] to regress futures price on current demand shifters, current cash price, current basis, current feed price, previous period cash price and feed price, one-period-ahead futures price, one-period-ahead futures price of feed, current supply, and expected supply for the next period. Once again a trimmed version of the model is used to reduce the multicollinearity problem. A similar procedure as mentioned in the previous subsection is used to trim the model, i.e., eliminating the variables that are highly correlated with other predetermined variables in the model. Current feed price, previous period feed price, one-period-ahead futures price of feed, and expected supply are removed for both cattle and hog models. In the case of the hog model one-period-ahead future price is also removed. These models utilize monthly data, same as those described above.

The estimated models are as follows (t-ratios are in parentheses):

Cattle

$$\begin{aligned} FUTTP = &\; \underset{(-2.18)}{-8.56} - \underset{(-8.84)}{2.84}\, BAS \\ &+ \underset{(3.09)}{0.003}\, PCI - \underset{(-3.09)}{0.06}\, MCASH \\ &+ \underset{(2.39)}{0.00614}\, ONPFUT \\ &+ \underset{(23.37)}{1.028}\, L1MCASH \\ &- \underset{(-1.15)}{0.0007}\, TOTCAT, \end{aligned}$$

$R^2 = .90$ D-W = 1.75 Condition No. = 104,

where *FUTTP* is futures price two-periods ahead (¢/cwt),[12] *MCASH* is the current cash price (¢/cwt), *ONPFUT* is the one-period-ahead futures price of corn (¢/bushel), and other variables and notations were defined previously. All the variables above except total supply are significantly different from zero at the 5% level. The cash price variable is highly significant and is negative. This means the current cash price inversely affects the two-months-ahead futures prices in the case of cattle. The R^2 suggests that 90% of the variation in the futures price is explained by the independent variables used. The D-W statistic suggests no autocorrelation. However, the condition number is high and suggests strong dependence between independent variables still exists.

The estimated model for hogs is as follows:

Hogs

$$\begin{aligned} FUTTP = &\; \underset{(0.81)}{5.45} - \underset{(-7.55)}{2.19}\, BAS \\ &+ \underset{(2.14)}{0.06}\, MCASH - \underset{(-1.85)}{0.0032}\, PCI \\ &+ \underset{(15.66)}{0.90}\, L1MCASH \\ &+ \underset{(1.33)}{0.00057}\, HOGM18, \end{aligned}$$

$R^2 = .91$ D-W = 1.75 Condition No. = 111,

where *HOGM*18 is the number of animals above the 180 pounds, and all other variables are defined above. The coefficients of cash price, basis, and lagged cash price are significantly different than zero. The cash price coefficient is positive suggesting that the cash price and two-months-ahead futures prices are directly related. Note that the lag cash price is highly significant, which suggests that cash price may be related with even three-months-ahead futures price. The model explains 91% of the variation of two-period-ahead futures price of hogs. The D-W statistic indicates no autocorrelation. As in the case of cattle, high multicollinearity exists.

The estimated model for four-periods-ahead futures price is presented below:

Cattle

$$FUTFP = \underset{(-5.56)}{-\,8.79} + \underset{(0.75)}{0.11}\, BAS$$

[12] Here one period is equal to one month. The futures contract is the nearby contract.

$$+ \underset{(2.88)}{0.002\, PCI} - \underset{(-4.34)}{0.059\, MCASH}$$
$$- \underset{(-3.21)}{2.10\, PRCORN}$$
$$+ \underset{(4.68)}{0.012\, TWPFUT}$$
$$+ \underset{(27.74)}{1.007\, FUTTP}$$
$$+ \underset{(1.64)}{0.05\, L2MCASH}$$
$$- \underset{(-0.39)}{0.0001\, TOTCAT}$$
$$+ \underset{(6.50)}{0.001\, COF911}$$
$$+ \underset{(1.19)}{0.65\, L2PRCORN},$$

$R^2 = .98$ D-W = 1.48 Condition No. = 130.

Hogs

$$FUTFP = \underset{(-0.05)}{-0.38} - \underset{(-3.82)}{1.35\, BAS}$$
$$+ \underset{(1.07)}{0.03\, MCASH} - \underset{(-1.71)}{0.003\, PCI}$$
$$+ \underset{(14.79)}{0.93\, L1MCASH}$$
$$+ \underset{(3.95)}{0.00018\, HOGM18},$$

$R^2 = .86$ D-W = 1.28 Condition No. = 105,

where, *FUTFP* is the futures price four-period ahead, *COF*911 is the number of cattle on feed weighing between 900 and 1,100 pounds (1,000 head), *TWPFUT* is the two-period-ahead futures price of corn (¢/bushel), and other variables are as described above. In the above estimated models, observe that the cash price is significantly and negatively affecting futures prices four periods ahead in the case of cattle, whereas for hogs the cash price is not influencing futures price four periods ahead. We expect this result because cattle have longer flexibility in marketing than hogs. The R^2 for cattle model is also higher indicating better explanation of the four-months-ahead futures price of cattle than hogs. Autocorrelation was not a severe problem in these latter equations.

Conclusions

Empirical analysis examines the component of basis relationships for livestock using the theoretical results of Naik and Leuthold. The results indicate there exists a maturity basis risk (premium) and a speculative component in both cattle and hog markets.[13] We also observe that both the basis risk and speculative component vary from contract to contract. For both markets the expected maturity basis is nonzero, and thus it is included in the basis. Hog markets showed seasonality with respect to the basis risk, speculative component, and maturity basis. The variation in the synchronous movement between cash and futures prices makes the participation in the futures market less attractive to hedgers.

It is possible to anticipate a part of the maturity basis well ahead of time, although the fits beyond one month for cattle are very low. Higher predictability of the hog basis is probably due to seasonality. These results in aggregate could explain the bias in futures prices that is often detected. Finally, we observe that the cash prices and futures prices are related beyond one period. This relationship exists not only through feed price relationships, as Kendall has suggested, but also through the inventory effect resulting from the flexibility in marketing the animals. The role of inventory and marketing has not previously been empirically confirmed as influencing livestock basis pattern. For cattle, the cash price seems to influence far distant futures prices more than for hogs. This makes sense since cattle have a longer marketing horizon than do hogs. Flexibility in making the marketing decision strengthens the explanation of intertemporal price relationships for nonstorable commodities. These results help us understand better the cash and futures price relationships for livestock.

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References

Ehrich, R. L. "The Role of Market Prices." *Futures Trading in Livestock,* ed., H. H. Bakken, pp. 83–94. Madison WI: Mimir Publishers, 1970.

Futrell, G. A. "Characteristic Variances of Live Animal Futures Contracts." *Futures Trading in Livestock,* ed., H. H. Bakken, pp. 133–38. Madison, WI: Mimir Publishers, 1970.

Kendall, D. L. "Intertemporal Price Relationships in Noninventory Futures Markets." Ph.D. thesis, North Carolina State University, 1981.

[13] The speculative component will not be important if the expected futures price is equal to the current futures price.

Keynes, J. M. *A Treatise on Money,* vol. 2. London: Macmillan & Co., 1930.

———. "Some Aspects of Commodity Markets." *Manchester Guardian Commercial: European Reconstruction Series,* section 13, 1923.

Leuthold, R. M. "An Analysis of the Basis for Live Beef Cattle," Illinois Agricultural Economics Staff Paper No. 77 E-25, Urbana, Illinois, 1977.

———. "An Analysis of the Futures-Cash Price Basis for Live Beef Cattle." *N. Cent. J. Agr. Econ.* 1(1979):47–52.

Naik, G., and R. M. Leuthold. *Cash and Futures Price Relationships for Nonstorable Commodities: A Theoretical Analysis.* Dep. Agr. Econ. Staff Pap. No. 88 E-403, University of Illinois, Feb. 1988.

Paul, A. B., and W. T. Wesson. "Pricing Feedlot Services through Cattle Futures." *Agr. Econ. Res.,* 19(1967): 33–45.

Purcell, W. D., D. Flood, and J. S. Plaxico. "Cash-Futures Interrelationships in Live Cattle: Causality, Variability, and Pricing Process." *Livestock Futures Research Symposium,* ed., R. M. Leuthold and P. Dixon, pp. 135–56. Chicago: Chicago Mercantile Exchange, 1979.

Tomek, W. G. "An Analysis of the Futures-Cash Price Basis for Live Beef Cattle: Comment." *N. Cent. J. Agr. Econ.* 2(1980):81–82.

Working, H. "Futures Trading and Hedging." *Amer. Econ. Rev.,* 43(1953):314–43.

———. "The Theory of Price of Storage." *Amer. Econ. Rev.* 39(1949):1254–62.