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An Empirical Model of the Basis for Live Beef Cattle

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Fundamental to understanding and studying the futures market is the basis. The basis is typically defined as the difference between a futures contract price and the cash price at a particular time and place. Many commercial firms and traders buy in one of these cash or futures markets and sell in the other, known as arbitrage. Since this simultaneous trading in the two markets means that the basis is essentially being bought or sold, of interest to the users of the market is what economic factors affect or influence the basis. With such economic knowledge, the behavior of the various traders in the futures market may be more readily explained, and this knowledge should provide them with additional background information about the market for intelligent decision making.

It is commonly accepted for grains that at the par-delivery point the basis reflects a payment for storage, called the carrying charge, which results from the demand for and supply of storage.[1] The futures-cash price differences for local markets include this carrying charge, a transportation charge, possibly a quality difference and maybe other market imperfections. The theories of carrying and inverse carrying charge markets are well understood and accepted [10,11].

Unfortunately, there is not a similar development and level of understanding of the intertemporal price relationships for nonstorable commodities. The primary reason is that nonstorable commodities change in form over time and supplies cannot be held for long periods of time, so there is no necessary tie between today's cash price and the price for deferred delivery. Implied for nonstorable commodities is that there can be little to no inventory demand. Also, trading of futures contracts for nonstorable commodities is relatively new and published analysis has been slow to emerge.

It is the purpose of this article to develop and empirically test a theoretical model indentifying the variables which affect the futures-cash price spreads for live beef cattle. It is hypothesized that the basis for cattle is a function of the expected shift in supply. This investigation should lead to better understanding of the price spreads for nonstorable commodities and an evaluation of futures market performance.

Background and Definition

An initial problem in analyzing price relationships for nonstorable commodities is to establish which of several cash-future price relationships is being investigated. For this paper, we will define the basis in the standard format of futures price minus cash price and develop that concept. However, other researchers have analyzed alternative price relationships which are also important to understanding futures markets.

Probably the first published attempt at analyzing the price relationships for nonstorable commodities was by Paul and Wesson in 1967 where they hypothesized for cattle that subtracting the value of the feeder animal plus feed from the value of the fed animal deliverable at the end of the feeding period creates a market determined price of feedlot services. With 1965-1966 quarterly data and using fed-cattle futures prices as the expected output price, they found that feedlot placements plotted against the feeding margin traced a positively sloped supply response. That is, apparently feedlot operators were responding to futures prices in their placements [9].

Ehrich extended this concept by examining the behavior of the price difference between fed-cattle futures and spot feeder calves and found that the latter adjust to changes in fed-cattle futures prices [3].

Miller and Kenyon have provided additional support for the Paul and Wesson model, using data for 1965-1976. They found that placements were positively related to feeding margins when deferred futures prices for fed animals were used as expected cash prices. They questioned the direction of causality, and demonstrated that feedlot operators may use fed-cattle futures prices as forecasts and not for forward pricing, which in turn affects the course of feeder-cattle prices [8].

This notion of the feeding margin being a market determined price of feedlot services follows from Working's concept that the basis for grains is a market determined charge for storage and not just a residual between futures and cash prices [10]. These relationships are important in their own right, but providing an economic explanation of the cash-futures price relationships for live-beef cattle can also be important for understanding trader behavior and for evaluating market performance. These price spreads can be a major factor in critical decisions by commercial-firm operators and traders, so knowledge of the economic variables affecting the spreads is important.

Ehrich was the first to publish an analysis of cash-futures price relationships for live cattle, but he concerned himself only with the period shortly before delivery, and in general had poor statistical results [2]. Erickson also empirically tested two monthly basis models for cattle and obtained encouraging results with regard to the signs of the coefficients and their level of significance. However, his models contain as independent variables a futures and cash price ratio and several lagged variables making interpretation difficult. His models also provide only moderate explanatory power of the dependent basis variables [4].

Crowder observed in 1976 that . . . "trading of nonstorable commodities caught the profession completely by surprise, and to date I have yet to see an acceptable theoretical or practical analysis of the live-cattle or live-hog futures markets" [1, p. 996]. He added that the basis is fundamental to understanding futures markets and hedging, and people do not have sufficient knowledge of it. Basis risk requires management just like cash or futures positions.

Basis

It is argued here that the basis for livestock is not a market determined value in the same sense as the case for grains, but more reflects the residual of futures and cash prices. This implies independence between the two markets. Certainly to the extent that expectations become involved, feeders can alter feeding programs and market weights, and livestock can be held for breeding or prepared for slaughter, some independence is lost. This is usually more the situation for nearby contracts than for distant contracts. Yet for the purpose of the analysis here, it is felt that the independence assumption is not limiting. Forward pricing on the futures market theoretically ought to be quite independent of current cash-market conditions. To the extent that they are not independent, some simultaneous equations bias may enter a single equation model.

To provide an interpretation of the basis requires an interpretation of the cash and futures prices. The meaning of the cash price is straightforward: a result of current demand and supply conditions. The futures price for a nonstorable commodity is interpreted here as reflecting the consensus of what traders expect the cash price to be at a particular time in the future, given currently available information [6]. It is an expected price which can be used for forward pricing, and assumes that in a high volume market expectations of traders tend to balance out so that the resulting price reflects a weighted average of their expectations.

The futures price for cattle then is essentially a result of expected demand and supply conditions. So, the difference between futures and cash prices is an indication of the expected movement in cash price over time, which will occur because of shifting demand and supply conditions. Knowledge of the basis, therefore, may offer insights about the forthcoming changes in cash price if the market is operating as hypothesized. Presumably, the major factors beyond those noted above which would make cash and futures prices move together would be external to the whole beef sector, causing changes in expectation.

As a result, the basis for a nonstorable commodity can be positive or negative, depending upon whether cash prices are expected to rise or fall.[2] The size of the basis should reflect the expected movement in cash prices. And, as with all commodities, the basis is expected to close near zero during the delivery month. How well the market acts in accordance to those expectations is a question of performance.

Basis Models

Since the basis is defined at a particular point in time as a futures price minus the cash price ($BAS_t = FP_t^{t+i} - CP_t$), explanation of the basis involves explaining the futures and cash prices themselves, given the arguments presented earlier. Both of these variables are, respectively, results of expected and current demand and supply conditions.

We assume here that the markets for these two sets of demand and supply functions are virtually independent of each other, except for the ability to vary feeding periods and rates. The cash-futures price spread for beef cattle should vary in correspondence with the difference between current demand and supply conditions and expected conditions. Since we are dealing in time spans which never exceed seven months in length, it is assumed that the current demand and expected demand functions are the same. That is, over short time periods taste and preferences are assumed constant, and any changes in incomes and prices of substitutes are assumed to have a negligible effect on the difference between cash and futures prices. Changes in these variables would likely affect current and expected demand conditions similarly.

Hence, the resulting price spread comes mainly from the difference between current and expected supply conditions. Price becomes an adjusting mechanism for shifting supply. Substituting both current and expected price-dependent supply equations into the basis equation results in the basis becoming a function of current supply, expected supply and other variables. The basis is a function primarily of the expected shifts in supply.

The variable chosen in this monthly model to represent current quantity supplied is the number of cattle slaughtered. As slaughter increases, cash price would decrease causing the (positive) basis to get larger. Thus, slaughter is hypothesized to have a positive sign. A second variable hypothesized as possibly influencing cash price is cattle on feed, 900 to 1100 pounds. This serves as a proxy for the stock available for slaughter. Since this variable is measured only quarterly, while slaughter is measured monthly, it was felt that the heavy cattle on feed would represent some of the variation not explained by slaughter. Cattle feeders have a reservation demand to hold cattle off the market, but only for a short period of time. Thus, cattle on feed, 900 to 1100 pounds, is hypothesized to have a positive sign for the same reasons as the slaughter variable.

Two approaches are possible for generating expected quantity supplied. One would be to estimate a supply function and use it for forecasting future quantities. The second approach, which is used here, is to substitute directly into our basis equation factors which would affect future quantity levels.

Three fundamental variables are hypothesized as influencing future quantities supplied: the current beef-corn price ratio, the number of cattle on feed, and the current price of feeder steers.

For this model, the beef-corn price ratio was split into two separate variables, the price of beef and the price of corn. Although empirical evidence in the case of beef does not to my knowledge exist, Meilke has demonstrated in the case of hogs that additional explanation and better model fits and predictions are obtained when the two variables are split [7]. He also cites earlier literature which examines the deficiencies from using the ratio, especially when corn prices fluctuate. That is, corn is a relatively less important input than it used to be, and the ratio can be the same at different price levels, which has different implications about profitability. Similar logic applies to beef. Hence, higher prices for corn will discourage feeding, causing higher futures prices, giving a positive sign for the price of corn. Higher cash cattle prices may attract entry into feeding, which will lower futures prices and cause the basis to become smaller. Thus, the cash price is hypothesized to have a negative sign.[3]

The more cattle there are currently on feed at lighter weights, the lower the futures price should be and hence, the smaller the basis. Cattle on feed are hypothesized to have a negative sign. As the price of feeder animals rise, feedlot operators are less inclined to buy stock, reducing cattle on feed, making the basis larger. The sign for the price of feeder animals is hypothesized as positive.

To account for potential seasonality in the basis, three dummy variables representing the last 3 quarters of the year are included. Preliminary runs with monthly dummy variables offered no advantages over the quarterly variables.

Since the data used are monthly observations, and the futures contracts for cattle are listed for every alternate month, two consecutive months were combined into one model.[4] The most nearby basis model, labeled BAS0-1, refers to all those observations when futures contracts are in their delivery month or the month preceding delivery. During a delivery month the next contract is two months away, so all those basis observations involving futures contracts two and three months prior to delivery were combined. This model is labeled BAS2-3. Similarly, the basis observations for contracts four and five months out in time were combined as were those for six and seven months out. These models are designated as BAS4-5 and BAS6-7, respectively.

Also, for the hypothesized cattle on feed variable, different weight groups were selected to represent this variable in different basis models depending upon the time length involved in the price spread. Cattle on feed of heavier weights were used for the more nearby basis, while cattle feed in lighter weights groups were used for the distant basis.

The hypothesized basis models used for estimation are:

$BASi_t = f(SLBF_t, PC_t, CP_t, FDRP_t, COF5\text{-}7_t, COF7\text{-}9_t, COF9\text{-}11_t, Q2, Q3, Q4)$

where:

$BASi_t = FP_t^{t+i} - CP_t$; i=0-1, 2-3, 4-5, 6-7 indicating the number of months until delivery or contract maturity. A zero represents the month of delivery. FP is the monthly average of daily closes for the respective futures contract. CP is defined below.

SLBF = number of beef slaughtered commercially each month, United States, 1000 head

PC = price of corn, U.S., monthly

CP = monthly average price of choice slaughter steers, 900 to 1100 pounds, Chicago until May 1970, then Omaha, dollars per hundredweight. When using this price for computing the spread involving a maturing futures contract, only the prices for the first three weeks of the month are included in the average.

FDRP = monthly average price of choice feeder steers, 600-700 pounds, Kansas City, dollars per hundredweight

COF5-7 = number of cattle on feed, 500 to 700 pounds, quarterly, 23 states, 1000 head

COF7-9 = number of cattle on feed, 700 to 900 pounds, quarterly, 23 states, 1000 head

COF9-11 = number of cattle on feed, 900 to 1100 pounds, quarterly, 23 states, 1000 head

Q2 = 1 if the second quarter of the year
= 0 otherwise

Q3 = 1 if the third quarter of the year
= 0 otherwise

Q4 = 1 if the fourth quarter of the year
= 0 otherwise.

The equations are linear in the original variables, and ordinary least squares were used for estimating each equation. The data are monthly for the period 1965-1977. Data for all the livestock variables were obtained from the U.S. Department of Agriculture annual publication, Livestock and Meat Statistics, while the price of corn was obtained from USDA Agricultural Prices. Futures prices were obtained from the annual Chicago Mercantile Exchange Yearbook for early observations and the Wall Street Journal for more recent observations.

Results

Table 1 presents the regression coefficients and their t-ratios for the four models. Summary statistics are given at the bottom. At first glance one can see that the statistical fit for the nearby basis model is not nearly as good as for the models reflecting the more distant contracts.

Table 1. Results of Regressing Cattle Basis on Independent Variables, Monthly Data, 1965-1977[a]

Independent Variable / Dependent Variable	BAS 0-1	BAS 2-3	BAS 4-5	BAS 6-7
Constant	1.75 (1.64)	3.52** (2.78)	4.79** (4.00)	5.20** (3.99)
SLBF	-.0001 (-.45)	.0006 (1.55)	.0002 (.57)	.0003 (.83)
PC	1.33** (5.78)	4.28** (14.74)	6.19** (22.58)	6.85** (21.10)
CP	-.17** (-5.24)	-.69** (-17.89)	-.98** (-26.92)	-1.07** (-27.53)
FDRP	.16** (5.50)	.51** (14.25)	.68** (19.85)	.73** (21.26)
COF5-7				-.0008* (-2.11)
COF5-9		-.001** (-3.69)	-.001** (-3.03)	
COF9-11	-.001** (-2.87)	-.0003 (-.56)	-.0002 (-.51)	-.001* (-2.32)
Q2	-.08 (-.36)	-.82** (-2.84)	-1.64** (-6.00)	-1.09** (-3.09)
Q3	-.30 (-1.34)	-.29 (-.94)	-.61* (-2.07)	-1.61** (-4.31)
Q4	.26 (1.16)	-.04 (-.14)	-.25 (-.95)	-.31 (-.73)
R^2	.26	.78	.89	.90
Durbin-Watson	2.14	1.61	1.60	1.40

[a]The t-ratios are in parentheses below the regression coefficients.

*Significantly different from zero at the 95 percent confidence level.

**Significantly different from zero at the 99 percent confidence level.

The nearby basis is more random and difficult to explain with economic variables. During delivery, items traded in the cash and futures markets become nearly interchangeable at the delivery point, and the difference between the prices reflects short run conditions and liquidity of the market. It is a time for speculative arbitrage as cash and futures prices should be close together. Thus, it is not surprising that an economic model designed to depict shifting supply conditions cannot explain intertemporal price relationships during or very close to delivery month. Cash and nearby futures prices are not independent as this model has assumed. However, the coefficients of determination trend higher as the models involve more distant futures contracts. Logically, the assumptions of the model fit most closely the conditions relating to those price spreads involving more distant futures contracts.

Looking at the coefficients of the independent variables for all the models, the signs are generally as hypothesized. Slaughter beef has positive signs in three cases, although the coefficients are not significantly different from zero. The coefficients for the prices of corn and feeder steers have positive signs as expected, and the cash price coefficients are negative as hypothesized. The coefficients for all three of these variables are significant at the 99 percent confidence level.

The cattle on feed variables gave mixed results. Cattle on feed, 500 to 700 pounds, has a negative sign in the BAS6-7 model as hypothesized and is significant. Similarly, the cattle on feed, 700-900 pounds, coefficients in BAS2-3 and BAS4-5 are negative and significant. The coefficient for cattle on feed, 900-1100 pounds, is negative, opposite to the hypothsis, in all four models and significant in two of the models. The correlation coefficients of this variable with the dependent variables were positive, but apparently its relationship with other variables in the multiple regression model caused the sign to change.

Five of the twelve coefficients representing quarterly dummy variables were significant, indicating only moderate seasonality to the basis. The significant variables came only in the second and third quarters, a result somewhat at variance with Erickson's results where December was identified as having distinctly larger price spreads [4].

The R^2s for the distant basis models indicate a good fit. The Durbin-Watson statistics suggest either no autocorrelation or the tests were inconclusive except for the most distant basis model. In this latter case autocorrelation may be present, but the coefficients would still be unbiased.

Conclusions

The empirical results presented here demonstrate that a high proportion of the variation of the live-beef cattle basis anywhere from two to seven months prior to contract delivery can be explained by the factors which determine and shift the supply curve. The results are better than one might expect, given the early poor performance of the market [6]. It was argued that the basis reflects the expected change in cash prices from the current time until the relevant futures contract matures, and the model developed hypothesized that most of this price difference would result from shifts in supply. The results presented confirm this paradigm.

Consequently, the ability to explain the basis in logical economic terms should give commercial users and traders more confidence in the market, more information for intelligent decision making, add to their understanding of futures-cash price spreads, and aid them in managing basis risk. Also, it gives us one measure that suggests the market is performing closely to expectations.

Finally, this study was an initial attempt to explain price spreads and leaves the opportunity to future investigators to expand the analysis from a single equation approach to a multi-equation system. It further suggests the possibility of investigating futures-futures price spreads for cattle, relating such spreads to cattle on feed variables. This latter study would be analogous to investigating grain price spreads and stocks, and may offer further insights into arbitrage possibilities for cattle feeders who can vary feeding rates and marketing times.

Footnotes

*The author acknowledges helpful comments on earlier drafts from Anne Peck, Lee Schrader and Lyle Fettig.

[1] Par delivery refers to the location where the commodity defined in the futures contract may be delivered at the specified price in fulfillment of the contract.

[2] The basis for grains can also be positive or negative, depending on whether the market reflects a carrying charge or an inverse carrying charge. In addition, this discussion has looked at only price differences over time, and has not concerned itself with geographic price differences which adds another dimension to the basis. The empirical section below investigates the basis at the par delivery point.

[3] Use of cash price as an exogeneous variable may cause concern that the least squares estimates would be biased. Such effects are considered minimal in this case as the largest correlation coefficient between cash price and a dependent variable is 0.17, with the rest being 0.05 or less. Correlation coefficients between the dependent variables and the beef-corn ratio are much higher, ranging from -.19 to -.46. Furthermore, estimation of relationships similar to those estimated here does have some precedent [5].

[4] The recently added January contract was not included in this analysis.

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