Feeder Cattle Price Differentials in Arizona Auction Markets

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This paper presents the results of an empirical study of price differentials for feeder cattle in Arizona auction markets. Emphasis is placed upon the estimation of price/weight relationships for steers and heifers. Estimation of a short-run feeder cattle price differential model resulted in an equation with a good empirical fit. The model also is in agreement with theoretical expectations. It is concluded that the model presented in the paper could be maintained and updated periodically to provide a useful supplement to market price information services commonly used by cattle producers.

Key words: cattle prices, feeder cattle, market information, price premiums.

Price determination in feeder cattle markets is a complicated process. Conceivably, price premiums and discounts on the basis of factors such as weight and sex should reflect quality and thus also reflect differences in the relative supply and demand for the different weights and grades of cattle (Marsh). In a long-run equilibrium, price differences would reflect differences in the value (as determined by quality factors) of the various types of cattle.[1] Buccola has determined that a mix of animal (e.g., weight, breed, sex, grade, and age) and market (e.g., lot size, market location, day of the week, auction sale order, and sale size) characteristics combine to determine feeder cattle price differentials. However, price/weight relationships are not static. Price differences between animal weights appear over time to display a dynamic adjustment process (Marsh, Schultz and Marsh).[2] That is, the movement from a short- to long-run equilibrium can be expressed in a distributed lag framework, influenced by the cost of gain, seasonality, and expectations about slaughter market prices.

The comparative statics of factors affecting market price differentials have been explicitly analyzed by Buccola using break-even analysis. Marsh's extension to a dynamic adjustment model illustrates the process by which changing economic conditions affect the magnitude of price premiums and discounts. However, as suggested by Buccola (p. 579), short-run price relationships cannot be accurately assessed using break-even analysis. Furthermore, available studies that evaluate factors affecting feeder cattle price relationships, in a static framework, contain several inherent problems that limit their usefulness to cattle producers (Madsen and Liu; James and Farris; Folwell and Rehberg).[3] Critical is the need to expand the analysis to include nonlinear relationships.

Because the magnitude of premiums and discounts for feeder cattle affects the decisions of ranchers (Marsh) and cattle feeders, it would appear that more detailed study of short-run price relationships is warranted. In particular, the allowance of nonlinear price/weight and price/lot size relationships could be expected to extend knowledge of price behavior in feeder cattle auction markets and help develop a market information system. It follows directly

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[1] A caveat is in order here. Viewing quality and product attribute differences in a spatial model is possible (Scherer; Benson). It follows that applying the theory of information (Stigler) in a spatial (i.e., product space) sense leads to the conclusion that price dispersions between cattle type could exist that do not reflect quality differences.

[2] In the information theory viewpoint (see footnote 1), this adjustment process might reflect the dissemination of information.

[3] The purpose here is not to be critical of previous work. Rather, these studies provide a background for additional study.

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from the model presented below that cattle producers (both buyers and sellers of feeder cattle) can use current information from auction markets to assist in the formulation of production decisions (such as weight at which to sell cattle) and marketing decisions (in particular, lot size determination).

A Short-Run Price Discount Model

Buccola analyzed feeder cattle price differentials using a general model of break-even feeder cattle prices. Break-even prices define the long-run reservation prices for feeder cattle buyers (sellers) since paying more (accepting less) than the break-even price would be inconsistent with a producer goal of earning profits. Animal (weight, breed, grade, age) and market (sales size, lot size, auction sale orders, market location, day) characteristics have been found to affect sales prices (Buccola; Buccola and Jessee).

Principal factors affecting the rate that break-even prices fall or rise with weight are expected slaughter prices, current feed and pasture costs, soil moisture conditions, and rates of inventory changes. For example, rising slaughter cattle price expectations cause buyers to bid up the price of light feeders relative to heavy feeders. However, the effects on steers and heifers are not symmetric because of the demand for heifers as herd replacements. During an expansionary period of the cattle cycle, young heifers tend to sell at smaller discounts relative to periods of contraction (Marsh).

Feeder cattle auction prices observed at specific points in space and time reflect animal characteristics, current economic conditions, and expectations about future conditions. General models that determine factors affecting price differentials (e.g., Buccola) or evaluate adjustment processes (e.g., Marsh; Schultz and Marsh) are useful for analyzing the economic structure of markets. They are not particularly well suited to providing guidelines for feeder cattle sellers and buyers. However, price/weight and price/lot size relationships based upon Buccola's model can be developed from auction market data to provide summary descriptions of current market characteristics.

In any particular auction day, supply is essentially fixed. For each transaction lot size is predetermined. Therefore, the supply curve is perfectly inelastic and individual lot prices reflect the intersection of a downward sloping demand curve and a vertical supply (see fig. 1). Given the characteristics of the lot (sex, breed, weight, lot size) the price will be determined. For example, in figure 1 demand curves D_1 and D_2 reflect the demands for different bundles of characteristics and hence intersect the supply curve (S_1) to result in different price levels (P_1 and P_2). However, note that the position of the demand curves is dependent upon the lot size. A smaller sized lot (S_2) with the same cattle attributes might have a demand curve below D_1 and D_2. It follows that a characteristics demand for feeder cattle during a specific auction can be estimated by regressing specific attributes of feeder cattle lots on realized price for each lot.

A price discount model for feeder cattle was explicitly designed along these lines to explore price premiums and discounts on the basis of cattle type (sex), weight, and lot size. In particular, nonlinear price discounting relationships for weight and lot size are directly modeled. This provision follows directly from Buccola who observes that, in the long run, price/weight lines for steers are generally convex from below while for heifers they are usually slightly concave from below.[4] Note that these observations are in conflict with Folwell and Rehberg who argue, on the basis of cross-section data for ten markets in eastern Washington, that the price/weight relationships for both calves and stocker/feeders are negative and linear.[5] Madsen and Liu also consider price/weight relationships but use a combination of discrete weight/sex variables to analyze price discounts. Their results are not readily comparable because the discrete weight categories they use for steers and heifers are not identical.

The statistical model is specified as follows:

$$P = f(W, W^2, H, H^2, B, S, SW, SW^2, Y[S, H, H^2, W, W^2, SW, SW^2], SALE_{ij}, U),$$

[4] In his analysis, Buccola uses linear approximations of price/weight relationships. Note also that we are using the term "feeder cattle" in a quite generic context, as have previous authors. Technically, replacement heifers cannot be regarded as feeders. But to avoid cluttering the discussion we will not explicitly differentiate the discussion below except to point out the effects that the demand for replacement heifers can have on the estimated relationships.

[5] One reason for these conclusions could appear to arise from the data. The weight ranges in their sample were generally quite small, largely because the data were stratified into calves and stockers/feeders. Given this stratification, it is quite possible that a linear function would fit the data well.

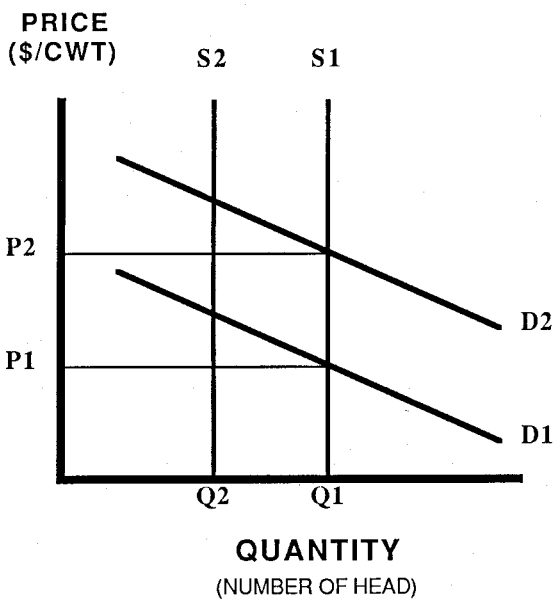

Figure 1. Illustrated supply and demand curves for auction sale price

where P is price of feeder cattle in $ per hundred weight; W, weight in pounds per animal; H, number of head in sale lot; S, sex of animal (binary: 0 = steer, 1 = heifer); B, breed (binary: 0 = hereford white face, 1 = crossbreed); $SALE_{ij}$, sale-year binary variable (sale = i, year = j) where $SALE_{ij} = 1$ if sale = i and year = j and 0 otherwise ($i = 0$ for Gila County and 1 for Mohave County, $j = 0$ for 1984 and 1 for 1985); Y, year (binary: 0 = 1984, 1 = 1985); and U, classical disturbance term with mean zero, constant variance, and serial independence.

The statistical model is nonlinear both in terms of weight and lot size (i.e., the squared terms W^2, H^2) and necessary interaction terms. This allows nonlinearities of weight and lot size, as suggested by Buccola, to enter the estimation procedure directly. A central focus of the model is to estimate price/weight and price/lot size relationships, so these variables are also interacted with the year dummy variable (i.e., note the brackets indicate multiplication) to determine if the relationships are variant over time. The animal-sex dummy variable is included to allow differential price/weight relationships between animal sexes. The sex variable is also interacted with the year dummy.

The breed variable is included to measure effects due to lots with crossbreed cattle. The

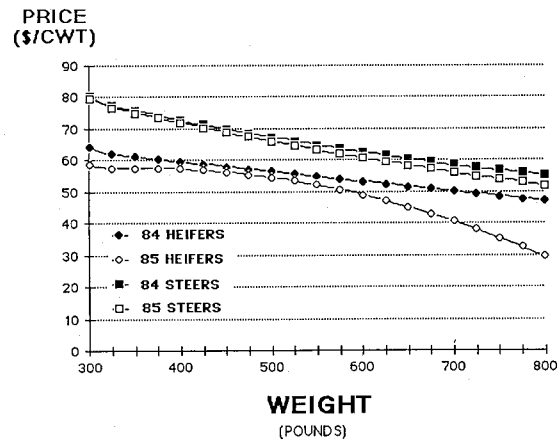

Figure 2. Influence of weight on price

binary breed variable is not interacted with time because we are specifically interested in estimating the price/weight and price/lot size relationships. Since B is an intercept shifter it would not affect the shape of these relationships.

Finally, three time- and auction-market specific dummy variables ($SALE_{01}$, $SALE_{10}$, and $SALE_{11}$) are included to account for price effects particular to individual markets by allowing shifts in the demand curves at the different markets and time periods (Folwell and Rehberg; Madsen and Liu). Factors such as sales size, sale date, and location can be expected to affect price levels, so inclusion of time- and location-specific dummy variables should summarize these effects. Other factors such as auction sale order may also help determine price levels and differentials, but they are largely out of the control of cattle producers. Because the primary purpose of the model is to determine price relationships that may aid decision making by cattle producers, no attempt to include variables beyond their control is made.

Notice that this functional form is quite flexible. It allows price/weight lines to be plotted separately for steers and heifers utilizing data for different years. Although the form estimated below utilizes data from two years (1984 and 1985), sales data for multiple time periods could be analyzed in the same manner to test for parametric differences.

Data

Data are collected from individual feeder cattle sale lots during the month of May 1984 and

1985 at the Gila and Mohave County cattle association sales. These auctions are the major producer-run sales in Arizona, and data on all transactions at these sales are routinely collected on microcomputers as part of an extension program on microcomputer applications. In total, data for over 400 lots were collected. Sale lots containing bulls and lots containing less than 5 head were discarded from the data set because they frequently displayed outlying price levels. Thus, 368 usable sale lot observations are available for analysis.

Empirical Results

The following feeder cattle pricing model is fitted to the data from the two Arizona auction markets using ordinary least squares:

$$
\begin{aligned}
P = {} & \underset{(17.91)}{99.94} - \underset{(4.44)}{.096W} + \underset{(2.13)}{.000036W^2} \\
& + \underset{(3.99)}{.15H} - \underset{(3.05)}{.0012H^2} - \underset{(2.09)}{.68B} \\
& - \underset{(2.79)}{29.41S} + \underset{(1.27)}{.05SW} - \underset{(.80)}{.000035SW^2} \\
& - \underset{(1.95)}{31.48YS} - \underset{(.42)}{.028YH} + \underset{(.28)}{.00032YH^2} \\
& + \underset{(.05)}{.0014YW} - \underset{(.24)}{.0000060YW^2} + \underset{(2.00)}{.13YSW} \\
& - \underset{(2.09)}{.00014YSW^2} + \underset{(.94)}{7.43SALE_{01}} \\
& - \underset{(4.89)}{2.45SALE_{10}} + \underset{(.45)}{3.57SALE_{11}}.
\end{aligned}
$$

Shown in parentheses below the estimated coefficients are the t-statistics. The $\bar{R}^2$ for the equation is .85 (349 degrees of freedom) and the F-ratio is 112.37, clearly a highly significant level. The residuals were inspected for heteroscedasticity, but no evidence was apparent.

In aggregate, the empirical model performs quite well. A large degree of the variation in the dependent variable is explained by the regressors, and the coefficients are generally significant. Insignificant coefficients are specifically associated with the interaction of two sex-weight variables, the year dummy to the number of head and weight variables for steers, and two *SALE* variables. This lack of significance indicates that the underlying price/weight and price/lot relationships for steers are not different in the two years, 1984 and 1985. The negative coefficient associated with the binary variable for breed (B) indicates that cross breeds are discounted relative to straight breeds.

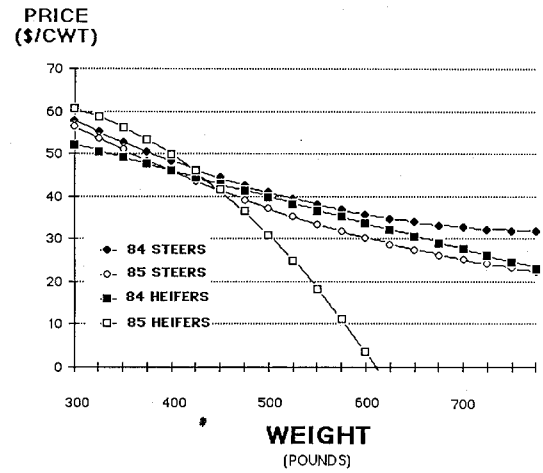

Figure 3. Marginal value

Weight Relationships

Notice that the coefficients of W and W^2 are both significant, indicating that the 1984 price/weight line[6]—a curve showing price adjustments for feeder cattle weight increases—for steers is quadratic and convex from below. Price/weight lines for steers and heifers are given in figure 2. The price/weight lines are plotted for both 1984 and 1985 steers, although it should be emphasized that no statistical difference between the two years turns up in the data. However, the plots are useful to illustrate that both curves are quite similar in shape and slope.

The 1984 heifer price/weight line is almost linear and differs substantially from the 1985 heifer price/weight line, which is highly concave to the origin. Significant 1985 heifer year-weight interaction terms (YSW, YSW^2) indicate that the relationships between price and weight are different for 1984 and 1985 heifers.

The price/weight lines for steers and heifers both display behavior consistent with Buccola's long-run analysis. He concludes that the price/weight line for steers is generally convex from below. In both cases (1984 and 1985) that is true in our data. Buccola also emphasizes that the price/weight line for heifers is usually slightly concave from below because

[6] The assumptions used to develop the price weight lines are (*a*) intercept equal $SALE_{00}$, (*b*) hereford cattle, (*c*) lot size of 20.

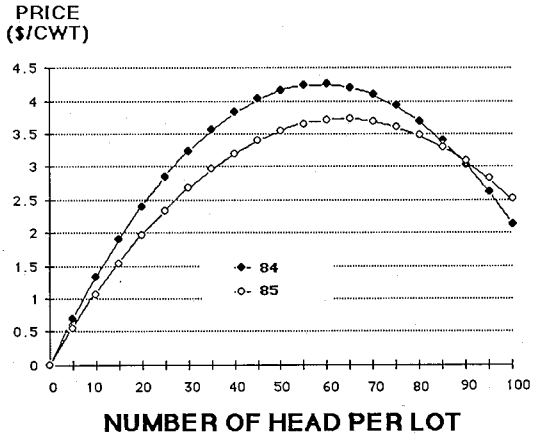

Figure 4. Influence of lot size on price

heifer prices at light weights (300–400 pounds) often rise before falling. Note that heifer prices in 1985 actually rise during this weight range then are heavily discounted (relative to steers and 1984 heifers) at higher weight ranges.

The price/weight relationships permit calculation of the gross value per head for steers and heifers. From the gross value functions marginal value relationships can be computed. Figure 3 provides the marginal animal value relationships for steers and heifers based on the price/weight relationships shown in figure 2. These marginal value/weight lines provide the marginal adjustment in animal value brought about by a change in weight and the associated change in price and assume an intercept term estimated for $SALE_{00}$ for hereford cattle.

The marginal value/weight lines for 1984 steers and heifers as well as 1985 steers are all quite similar in shape and slope. However, for 1985 heifers the marginal value/weight line is concave to the origin and becomes negative at a weight of approximately 615 pounds. This implies that increasing the weight of heifers past the 615-pound level actually reduces the total value of the animal. Note also that the 1985 heifer marginal value/weight line is much steeper in slope and falls below the other relationships shown in figure 3 at a weight of about 450 pounds. The sharp reduction in marginal value above 450 pounds could possibly influence ranchers' production decisions if they could predict these relationships (dynamic implications as discussed below).

Lot Size Relationships

The relationship between price received and lot size is significant and quadratic. The price/lot size line, measured in number of head (see fig. 4), reaches a maximum at approximately sixty head and is not significantly different between years. Thus, *ceteris paribus,* for these specific sales it pays to market feeder cattle in lots of approximately sixty head. These findings differ from Folwell and Rehberg, who determine a linear response of price to lot size. Madsen and Liu found that larger lots, up to eighty head, generally receive higher prices, although there is considerable variability in their results. In some months medium-sized lots receive price premiums.

In fact, there are good reasons to suspect variability in this relationship over space and time. Factors such as size of auction, market characteristics, and transactions costs can differ by region. Furthermore, weights for cattle marketed tend to vary across different months. Depending upon feeding costs, relative prices for different weights, and expectations about future fed cattle prices, the demand for certain weight cattle can differ. Since the price/lot size relationship is influenced by shipping costs—premiums are paid for lots that facilitate filling truck loads—it follows that premiums for certain sized sale lots will be influenced by truck capacity limits. Therefore, the empirical model is reestimated replacing H and H^2 with lot weight and squared lot weight variables. This results (not shown here) in an equation that is not qualitatively or quantitatively different from the equation given above. The same variables enter the model significantly and coefficient values are quite similar. A lot weight of 32,000 pounds results in price being maximized.

This result is somewhat unexpected (although not completely surprising given the results of Madsen and Liu reported above) since truck capacity is generally about 40,000 pounds. Possible explanations relate to ranges in the sales data collected and end-of-market buyer behavior. We note that the price/lot size relationship is relatively flat near the maximum point and relatively few sales occur with lot sizes greater than sixty head. Furthermore, it is customary at these sales for buyers to enact trades and off-market transactions with other buyers at the end of the auction day to fill truck loads. Thus, our empirical results may be due

to limited observations at the upper end of the lot size scale.

Implications

Ranchers can enhance price by breaking lots into smaller sizes if anticipated marketings are larger than the optimum size. Alternatively, it might be profitable to adjust production and marketing decisions to avoid unnecessarily small lot sizes. Price discounts up to $3 per cwt are possible in these Arizona auctions for small (less than 10 head) lots relative to lots of sixty cattle. Since these results are based upon feeder cattle marketed during the month of May only, it would be useful to follow the price/lot size relationships from month to month when determining the optimal lot size. (It may also be useful to follow price/weight relationships on a monthly basis to determine if seasonal influences exist in Arizona that are similar to those described by James and Farris.) Furthermore, optimal lot size may vary across regions so these specific empirical results may not hold in other locations.

Conceivably, cattle producers may forego profit opportunities by not considering alternative auction markets.[7] Estimating price relationships in the short-run price discount model given above provides information to farmers on the relative premiums and discounts being paid for different types of cattle. It might be possible to choose an auction market for delivery because prices generated in that market reward particular characteristics in cattle. Or, in the case where it is possible to sell subsets of total intended cattle marketings over a period of time, it might be possible to design a strategy that makes use of particular market opportunities as they arise. For example, heifers could be sold at light weights and steers held over a winter and sold as yearlings. The expected marginal value of additional gain (compared with the expected additional cost) could be useful information in making production decisions such as these.

Information is also provided that assists in describing the link between production and marketing decisions. For example, the 1985 price/weight line for heifers, relative to 1984, suggests that the market is rewarding light heifers in comparison to heavier weights where prices are discounted at an increasing rate for heavier animals. This could be interpreted to imply that the short-term fat cattle market outlook was unfavorable, but over the longer term expectations are for more favorable prices. Consultation of market commentary for May 1985, indicated that this was the case (*Drovers Journal* 1985a, b). At that time a backlog of cattle on feed ready for marketing in the Southwest, combined with higher cattle weights, appeared to be causing pessimism about prospective short-term (3–5 month) fat cattle prices. However, an anticipated attractive feed grain market for the fall assisted in generating optimism about fat cattle prices over the longer term (6–12 months). Thus, according to *Drovers Journal* market analysts, circumstances in the fat cattle market appeared to be affecting prices in the feeder cattle market.

However, this does not explain the difference between the price/weight relationships for steers and heifers. For this explanation, it is necessary to consider the fundamental difference in the demand for heifers as opposed to steers. Heifers are also demanded for herd replacement purposes. Therefore, long-run pessimism about future price levels can lead to a decreased demand for light heifers as herd replacements (Schultz and Marsh). The typical heifer price/weight line is concave from below (Buccola), as in the 1985 line shown in figure 2, so the almost linear 1984 price/weight line suggests atypical market behavior. During 1984 the dramatic U.S. cattle and calf liquidation continued (U.S. Department of Agriculture 1985b). The 1984 heifer price/weight line appears to reflect a reduced demand for heifers as beef herd replacements in conjunction with the general herd liquidation. The more normal price/weight relationship exhibited by the concave line for 1985 thus possibly reflects the more optimistic longer-term price forecasts during the first half of 1985 (Uvacek, U.S. Department of Agriculture 1985a).

Of course, it is unreasonable to expect many farmers to conduct this type of analysis individually. Because many farmers rely on public or private information sources for market analysis and information, we propose that this technique be utilized to augment these information sources. Currently, market commen-

[7] Of course, if the market is in spatial equilibrium, no opportunities for choice will appear. However, although livestock markets are probably quite closely linked in a spatial equilibrium sense, opportunities for profits may arise as markets are in the process of moving to spatial equilibrium. Unfortunately, there is not available evidence on the speed of spatial price transmission.

tary (daily, weekly, and monthly) tends to rely on the personal observation of reporters or crude numerical analysis. Market reports and outlook are often difficult to interpret for clear market signals. In contrast, diagrams such as figure 2 convey a considerable amount of information about current market conditions which reflect expectations by market participants about subsequent market conditions.

A critical component of many cattle producers' decisions relates to interlinked production/marketing decisions (Marsh). Whether or not to sell light feeders, use heifers as herd replacements, or fatten cattle are all decisions in which current market information programs may not provide much assistance. Other researchers have shown that price premiums and discounts for feeder cattle can be expressed in a dynamic framework (Marsh, Schultz and Marsh). A true forecasting model should be couched in a dynamic framework and account for variables such as feeding costs. However, information about current market conditions is summarized by the price discount model on a format that is relatively easy to interpret and visualize. We propose that market information based on this approach and provided on a regular basis could supply a useful information source to ranchers and cattle feeders. It is emphasized that continual updating and analysis is necessary for producers to identify extreme market conditions or current market opportunities.

Further, the actual computational demands of such a system are not severe, particularly as microcomputers and maintained databases are becoming increasingly utilized. It would be quite easy for state extension and private market information services systematically to collect auction market data to be input directly into computer files and regularly analyzed. In addition, the availability and versatility of computer graphic and plotting systems for microcomputers make it possible to produce graphs, such as those shown in figures 2, 3 and 4, from raw data in short periods of time. With current cutbacks in data collection budgets, market analysts are increasingly forced to utilize market information more efficiently. A systematic and regular report compatible with microcomputer technology, such as the one presented here, may provide some analysts with a cost-efficient method of providing market commentary.

Conclusions

Recent studies have emphasized analytical issues in studying long-run price differentials for feeder cattle characteristics and dynamic response relationships. This paper, in contrast, focuses on the use of static premium and discount analysis as an aid to rancher production and marketing decision making.

A static feeder cattle price differential model is estimated using data from two Arizona auction markets. The statistical results are quite strong and agree, for the most part, with previous research. It is argued that this technique is a potentially useful method of summarizing information to farmers about current market conditions. This may assist farmers in developing market strategies. Therefore, some private and/or public market information services may wish to utilize this type of analysis on a regular basis.

However, it should be pointed out that this model should not be viewed as a forecasting model providing complete information to farmers. Producers must also include an analysis of anticipated future product and input price levels in determining market and production plans. Rather, the price discount model is proposed as a method of summarizing current market conditions. This could assist farmers in their decision process by allowing for more complete analysis of current market conditions, thereby facilitating dynamic decision making.

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