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by

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CATTLE PRICE RELATIONSHIPS:

PROBABILISTIC CAUSALITY

Theodore D. Covey and David A. Bessler*

The purpose of this paper is to investigate the possible causal relationship between live cattle futures and slaughter cattle cash prices. Previous studies suggest that futures markets for non-storable commodities (such as cattle) may act as price forecasting agencies (Leuthold). Although slaughter cattle are referred to as non-storable, cattle feeders actually do have a limited marketing horizon after feeder cattle have reached the minimum market weights for choice slaughter steers. Cattle cash market experts have observed that cattle feeders rely on the nearby live cattle futures price in formulating their very short-term slaughter cattle price expectations (Hoffman, McCarty). This expected price can then be contrasted to the spot price for slaughter cattle. In this way, cattle feeders use their local basis in order to determine whether the marginal benefit of withholding cattle for future sale is greater than their marginal cost.

Critics of the cattle futures market contend that the futures market depresses cattle cash prices while increasing future cash price uncertainty (Taylor and Leuthold). The premise underlying this allegation is that the futures market "causes" prices in the cattle cash market.

Previous research concerning cattle price relationships have used within-sample fit analysis in order to detect Granger-type causality (Weaver and Banerjee; Oellerman and Farris). Other causality studies have used conditional mean prediction (i.e., point forecasts) to infer Granger-causality between different time series (Ashley, Granger, and Schmalensee; Bessler and Babula). This paper's contribution is to use prequential forecasting in order to test the presence of Granger-type causality between live cattle futures prices and slaughter cattle cash prices. This will extend Granger's definition from the mean to the entire forecast distribution, yielding a stronger test of *prima facie* causality (Granger).

This paper has three additional sections. The first discusses probabilistic causality. The second section will apply probabilistic causality to two cattle price series. The final section relates the research results to the possible existence of causality between cattle futures and cash prices and ends with suggestions for further research.

Probabilistic Causality

Granger's Definition of Full-causality (for this case) may be stated as follows:

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If $P(C_{n+1}|C_n, F_n) \neq P(C_{n+1}|C_n)$

where: C_{n+1} = the probability distribution of cattle cash prices for the following day.

C_n = present and past cattle cash prices.

F_n = present and past live cattle futures prices.

$P(C_{n+1}|\cdot)$ = the conditional probability distribution function of C_{n+1} given a particular information set available at time n .

then live cattle futures prices are said to be a linear prima facie cause of next period's cattle cash price, with respect to the given information set. Thus, for causation to occur, futures prices must have some unique information about the immediate future value of cash prices. This provides a more stringent test for causality than are causal inferences based on tests of within-sample fit or conditional prediction of the mean (Granger).

Probabilistic forecasting assigns probabilities of occurrence to future events, where these events are defined as intervals rather than as points. The measure of uncertainty with regard to these forecasted events is expressed by the concept of probability. Thus, probability forecasts are forecasts of probability distributions over future events. When these forecasts are made sequentially by observing this period's outcome of last period's forecast, and then making next period's forecast with this additional information, this is called prequential forecasting. Prequential forecasting combines probability forecasting with sequential prediction (Dawid).

A minimum property required of probabilities is that of being well-calibrated (Dawid). If all events (intervals) that a model forecasted a probability of $n\%$ and are observed $n\%$ of the time (i.e., with $n\%$ relative frequency), the model is defined as a well-calibrated forecaster. If events the model forecasted with an $n\%$ probability occur less (greater) than an $n\%$ relative frequency over time, then the model is defined as an over (under) confident forecaster. A calibration graph can be constructed by plotting the issued probability against the ex post relative frequency of that probability. A perfectly-calibrated model would appear as a 45-degree line on a calibration graph. Following Bessler and Kling's suggestion, if both models turn out well-calibrated distributions, then the model's relative forecast variances can be used to determine which is the better forecaster. This confines the use of prequential forecasting to the first two moments of the probability distribution.

Our version of probabilistic causality combines Granger's definition of full-causality with prequential forecasting. Given two well-calibrated models (a univariate and a bivariate model), if the bivariate model yields smaller forecast variances relative to the univariate model, then futures prices may be said to Granger-cause cattle cash prices. In other words, if the futures price series reduces the uncertainty associated with the next period's cash price, we infer futures causes cash. The implementation of the test will require explicit forecasts and realizations. In addition, a calibration test must be passed and variances compared. Failure to pass the calibration test would be equivalent to accepting an "anything goes" position on acceptable

probability distributions.

In applying prequential forecasting to tests of Granger-type causality, a realization is collected and bisected. The first half of the data set is used to identify and estimate univariate and bivariate models. In the second half, prequential forecasts are made by both models for the same random variable. A cumulative distribution of forecasted values is created for each data point in the forecast period by each model. Fractiles (the probability assigned to a particular interval's occurrence) for each period are determined by noting the point along the cumulative distribution function where the observed value is located. The process is repeated for each data point in the forecast period. Given the hypothesis of a well-calibrated model, chi-squared tests are made by contrasting the fractiles' expected to actual relative frequencies.

Empirical Results

Two price series were considered: the average daily direct sales price for 900-1300 lb. choice slaughter steers for the Texas-Oklahoma panhandle, and the daily settlement futures price for the nearby live cattle futures contract. The data set covered the time interval August 13, 1973 - January 27, 1978, and was divided into two subsets or periods (583 observations in the first period, 582 in the second period). These two periods were bisected in order to identify and estimate models over the first half of each of the two periods, and then testing those models by forecasting future cash prices in the second half of each period. Division of the original data set into two periods allowed testing whether the causal relationship remains constant over time.

Both cash and futures price series appeared to be covariance stationary. The hypothesis to be tested was whether live cattle futures prices Granger-caused slaughter cattle cash prices. Univariate and bivariate models were identified and estimated for each of the two time periods. Models were identified using the Final Prediction Error (FPE) and Hsiao's recursive fitting procedure. These models, identified over the first half of the two data sets, were then estimated using ordinary least squares (Table 1). All four models had acceptable Q-values, suggesting that their residuals were serially uncorrelated. Note that in both periods, lagged futures prices are in the cash price equation, suggesting that futures prices cause cash prices in a within-sample fit definition of Granger-type causality. Following the discussion given above, we require that a more rigorous test of "good forecasts" be passed for our probabilistic notion of causality to hold.

In the forecasting interval, 500 one-step-ahead forecasts are made for each consecutive data point (day), yielding 291 forecasted distributions for each of two periods. A stochastic simulation method suggested by Fair was used. Fair's procedure simulates different forecasts by taking into account forecast uncertainty due to the variance in a model's parameter estimates as well as in its residual term. After each forecast distribution is completed, the model is moved forward one data point and updated with the Kalman filter. This process is repeated 291 times for both periods, yielding 291 expected values, standard deviations, and observed fractiles. The observed fractiles for the models are then ordered and placed in 20 different classes. Chi-squared goodness-of-fit tests are conducted under the null hypothesis that the

fractiles are well-calibrated.

With respect to the hypothesis that futures prices Granger-cause cash prices, the χ^2 test statistic in period one was 220.43 (critical value of χ^2 with 20 degrees of freedom and a .05 level of significance is 31.4). Thus, the hypothesis that the univariate model for cash prices is well-calibrated is rejected at the 5% level of significance. The chi-squared statistic for the bivariate model is 25.8. We, therefore, do not reject the null hypothesis that the bivariate model is a well-calibrated (i.e., good) forecaster. Figure 1 graphs the calibration results for the first period (observations 1-583). Note the bivariate calibration line falls nearer to the 45-degree line over almost the entire probability line. This is a visual confirmation of the chi-squared test statistic. Standard deviations are contrasted for the poorly-calibrated univariate and well-calibrated bivariate models for the same period in Figure 3. Note that at virtually every data point (91%) the bivariate model results in lower forecast standard error — suggesting that the additional information represented by lagged futures prices in the cash price equation is important.

In period two, the chi-squared statistic was 201.6 for the univariate model and 136.97 for the bivariate. The hypothesis of well calibration is rejected for both, thus both models fail to act as good forecasters of cash price probability distributions. Calibration results for the second period (observations 584-1165) are graphed in Figure 2. Note here that both calibration curves lie quite far from the 45-degree line.

Standard deviations are contrasted for both the univariate and bivariate models for the forecast intervals in period two (Figure 4). In this period, 74% of the bivariate model's standards deviations were less than those produced by the univariate model. Thus, again the bivariate model was able to reduce the uncertainty in the forecast of next period's cash price. However, since it was not well-calibrated (as the univariate model, too, was poorly-calibrated) it is probability best not to conclude that futures prices Granger-cause cash prices over this second period.

Conclusions

For the first period the univariate model was poorly-calibrated while the bivariate model was well-calibrated. In the second period neither model was well-calibrated (a good forecaster). Thus, applying our requirement that both models be first made well-calibrated, no causal inferences can be yet made for either of the two periods.

Models which are poorly-calibrated are evidence that the model identified and estimated in the earlier stages may have failed to adequately describe the stochastic process which generated the realization. If so, then previous procedures, which had been successful in selecting models which produced optimal point forecasts, fail when held to the higher standard of forecasting well-calibrated distributions. Perhaps, alternative methods of model identification and estimation may produce well-calibrated linear models. Or, the poor calibration may result because the actual time series model is non-linear. Since the theory of non-linear time series models is still in an embryonic state, a possible alternative would be to attempt to recalibrate the

poorly-calibrated model in order to find a well-calibrated one (Bessler and Kling). Another possible reason for poorly-calibrated models may be due to significant structural change occurring between the identification/estimation and forecast periods.

Should well-calibrated univariate and bivariate models be found, then suggestions for further research would include extending this analysis to a larger data set in order to test the robustness of the causal relations over time. Increasing the forecast horizon would allow testing the length of duration in periods where a causal relation is shown to exist.

Table 1* -- Cattle Cash Price Models

Period One:

Univariate

$$(1) C(0) = 1.009 + 1.191C(1) - 0.215C(2)$$

Bivariate

$$(2) C(0) = 0.231 + 0.892C(1) + 0.290F(1) - 0.088F(2) - 0.101F(3)$$

Period Two:

Univariate

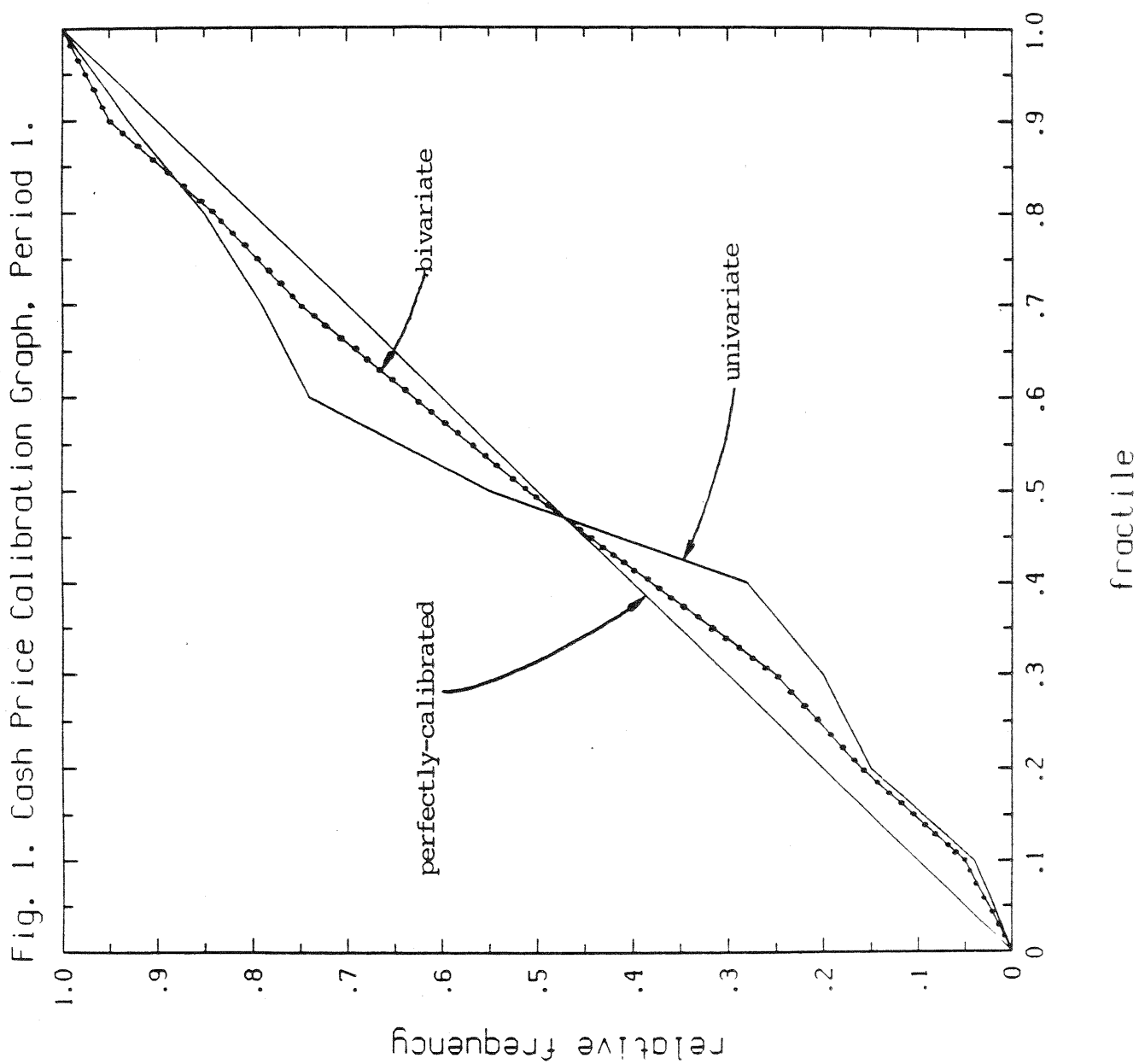
$$(3) C(0) = 0.920 + 1.190C(1) - 0.239C(2) + 0.141C(3) - 0.123C(4) + \\ 0.278C(5) - 0.270C(6)$$

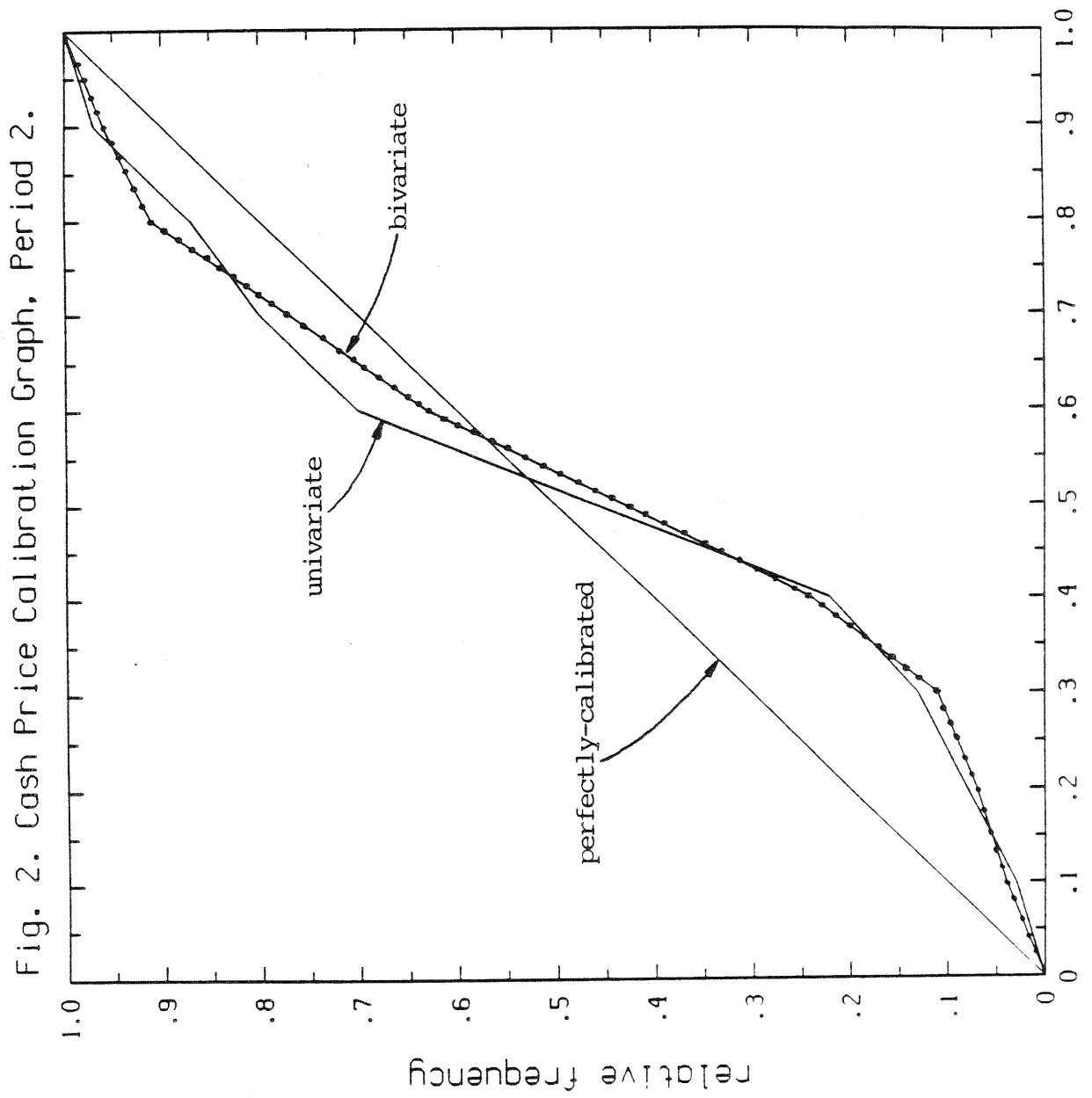
Bivariate

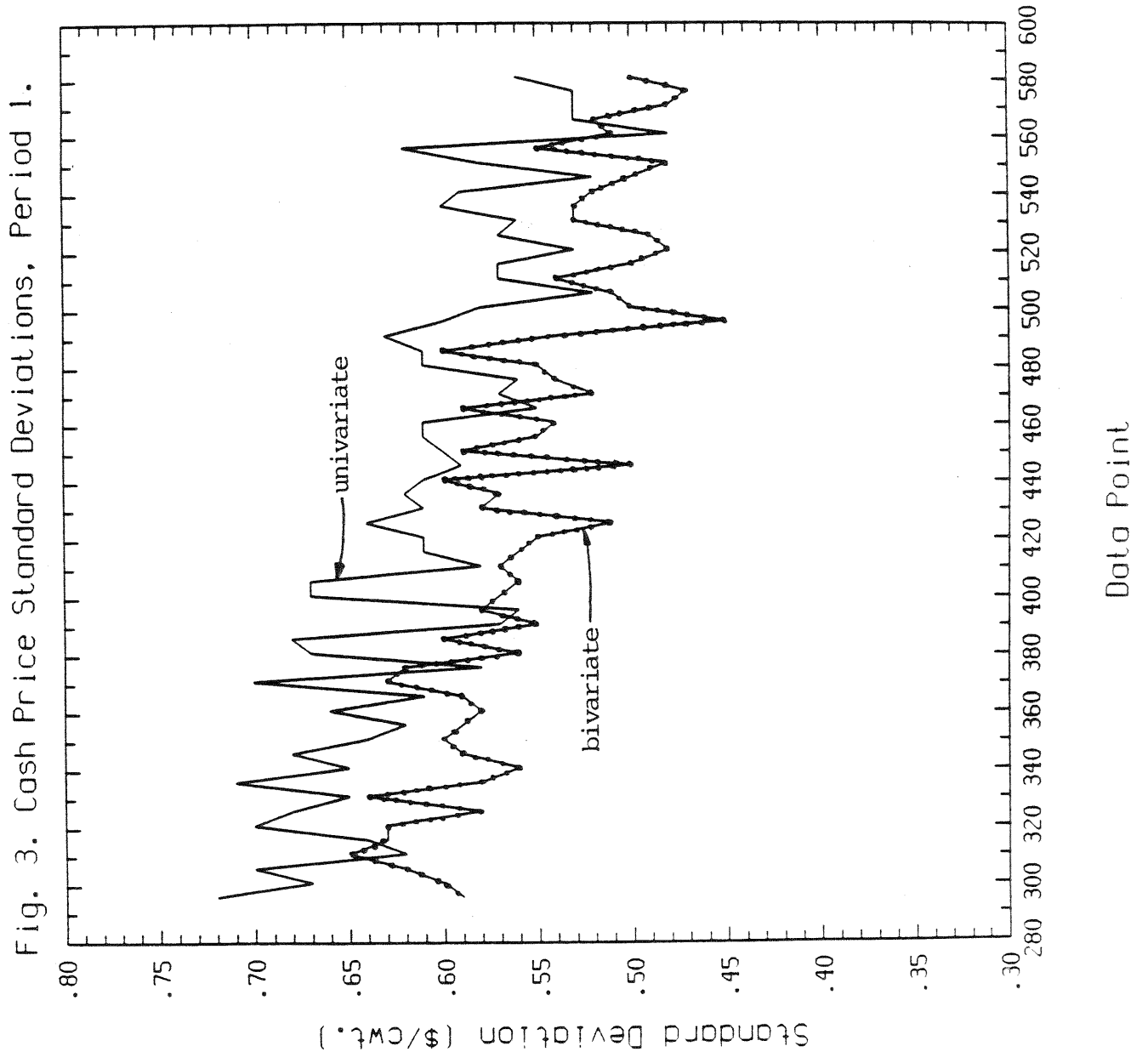
$$(4) C(0) = 0.308 + 1.010C(1) - 0.176C(2) + 0.112C(3) - 0.104C(4) + \\ 0.232C(5) - 0.224C(6) + 0.191F(1) - 0.141F(2)$$

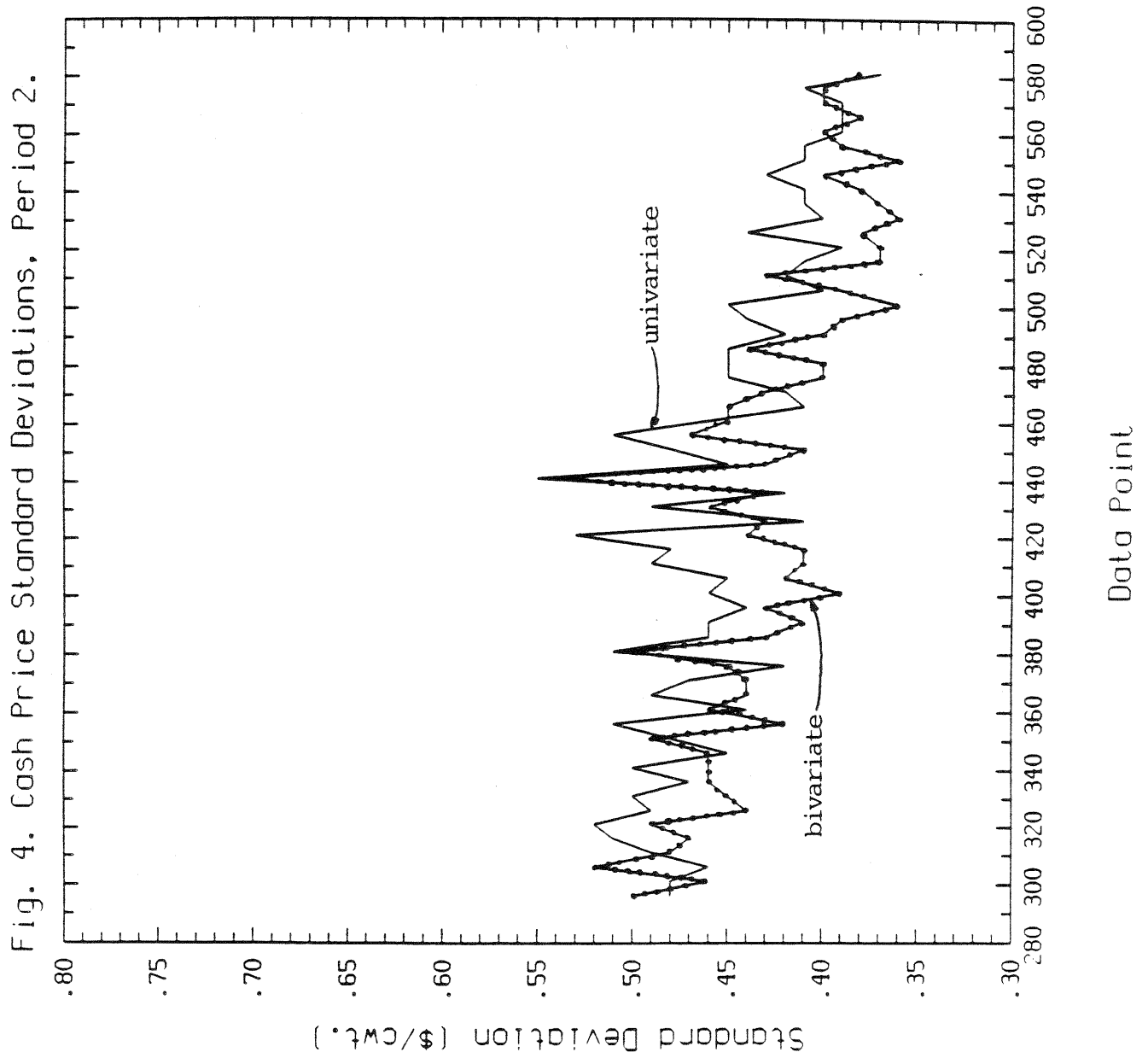
* C(i) are slaughter cattle cash prices for lag i.

F(j) are live cattle futures prices for lag j.









REFERENCES

- Ashley, Richard, C.W.J. Granger, and R. Schmalensee. "Advertising and Aggregate Consumption: An Analysis of Causality." Econometrica. 48(1980):1149-67.
- Bessler, David A., and R. Babula. "Forecasting Wheat Exports: Do Exchange Rates Matter?" Journal of Business and Economic Statistics. 5(1987):397-406.
- Bessler, David A., and J.L. Kling. "Prequential Analysis of Cash and Futures Cattle Prices." Work. Pap., Texas A&M Univ., 1987.
- Dawid, A.P. "Statistical Theory: A Prequential Approach." J. Royal Statist. Soc. A(1984):278-92.
- Fair, R.C. "Evaluating the Predictive Accuracy of Models" in Handbook of Econometrics, Vol. 3, ed. Z. Griliches and M. Intriligator, Amsterdam, The Netherlands: North Holland Publishing Co., 1983.
- Granger, C.W.J., "Testing for Causality: A Personal Viewpoint." Journal of Economic Dynamics and Control. 2(1980):329-52.
- Hoffman, George. "The Effects of Futures Prices on the Short-Run Supply of Fed Cattle and Hogs." Livestock Futures Research Symposium, ed. R.M. Leuthold and P. Dixon. pp. 163-85. Chicago: Chicago Mercantile Exchange, 1979.
- Hsiao, Cheng. "Autoregressive Modeling of Canadian Money and Income Data." J. Amer. Statis. Assoc. 74(1979):553-60.
- Leuthold Raymond M. "The Price Performance on the Futures Market of a Non-storable Commodity: Live Beef Cattle." Amer. J. Agr. Econ. 56(1974):271-79.
- McCarty, J. (1987): Personal Communication, Agricultural Marketing Services, U.S.D.A.
- Oellerman, Charles M., and P.L. Farris. "Futures or Cash: Which Market Leads Live Beef Cattle Futures Prices?" J. Futures Markets. 5(1985):529-38.
- Taylor, Gregory S., and R.M. Leuthold. "The Influence of Futures Trading on Cash Cattle Price Variations." Selected Writings on Futures Markets: Basic Research in Commodity Markets. ed. Ann Peck, The Board of Trade of the City of Chicago, 2(1977):323-29.
- Weaver, Robert D., and Aniruddha Banerjee. "Cash Price Variation in the Live Beef Cattle Market: The Causal Role of Futures Trade." J. Futures Markets. 2(1982):367-90.