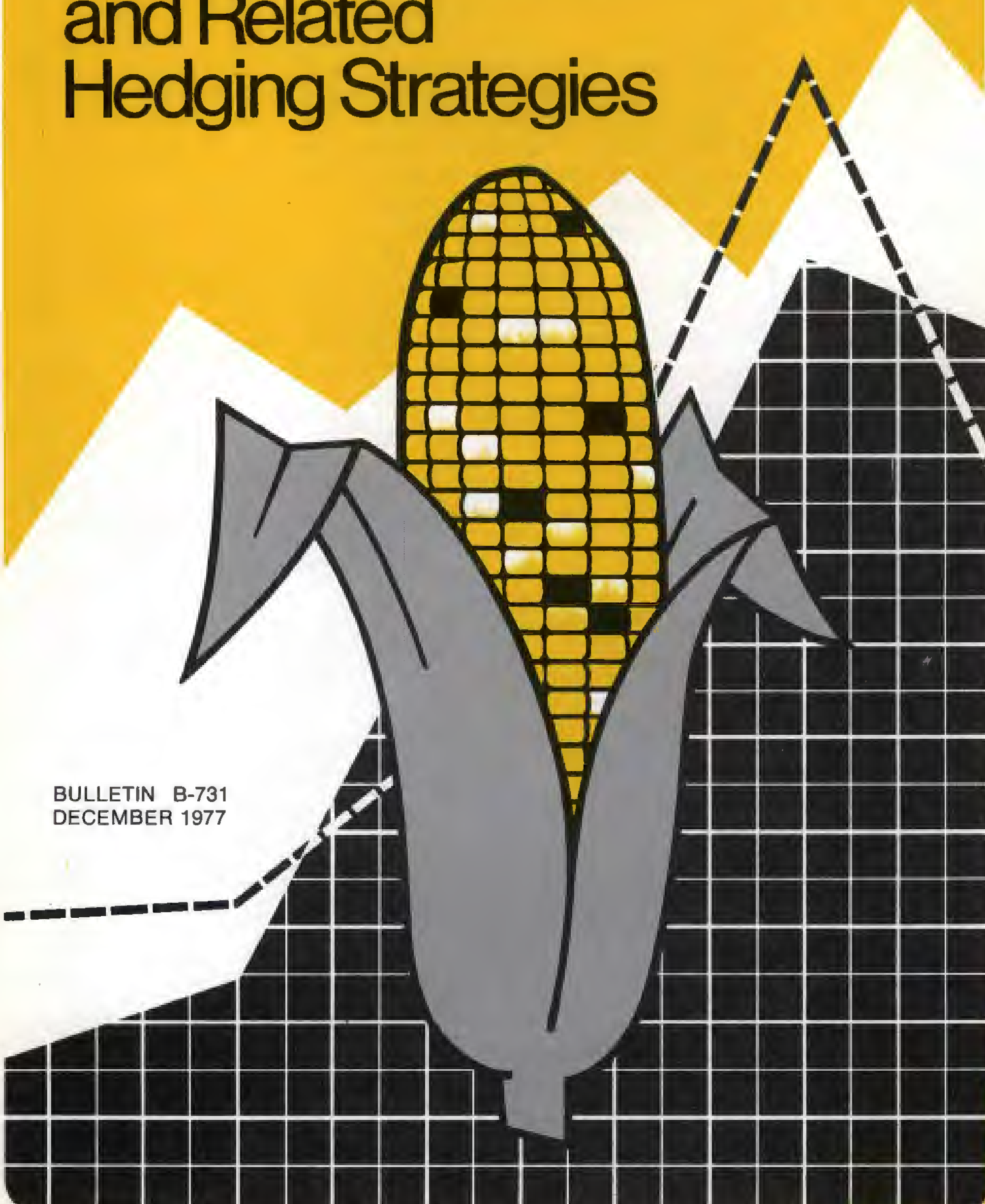
Quantitative Models to Predict Quarterly Average **Cash Corn Prices** and Related Hedging Strategies



BULLETIN B-731
DECEMBER 1977

Agriculture Experiment Station • Oklahoma State University

Contents

Introduction 4
- The Current Situation 4
- The Problem 5
- Literature Review 5
- Objectives 7
- Procedure 7

The Feed Usage Model 8
- The Model 8
  - Variables Influencing Number of Animals Fed 8
  - Variables Influencing Variation in Feeding Rates 10
  - Dummy Variables to Account for Seasonality 13
- Results of the Model 14
  - The October-December Feed Model 15

The Export Model 17
- The Dependent Variable 18
- The Model 19
  - Variables Influencing the Level of World Corn Exports 19
  - Variables Influencing the Level of U.S. Corn Exports 21
- Results of the Model 21
  - Dummy Variables to Account for Seasonality 23

The Price Model 23
- Values Indicating the Rate of Disappearance 24
- Variables Indicating the Level of Supply 24
- Expectations 25
- Dummy Variable 25
- Results of the Model 25
- Performance of the Model 28
  - Three-Month Predictive Model 28
  - Six-Month Predictive Model 28

Hedging Strategies for Corn 31
- Method of Analysis 31
  - Performance Criteria 32
- The Strategies 33
  - Strategy I: Unhedged Operation 33
  - Strategy II: Hedge and Hold 33
  - Strategy III: Hedge When Five-Day Moving Average>10-Day Moving Average 33
  - Strategy IV: Hedge When Five-Day Moving Average>10-Day Moving Average; Remove Hedge When Five-Day Moving Average<10-Day Moving Average 34
  - Strategy V: Hedge if Projected Cash Prices>Futures Price 34
  - Strategy VI: Hedge if projected Cash Price>Futures Price and Five-Day Moving Average>10-Day Moving Average 35

Strategy VII: Hedge if Projected Cash Price>Futures Price and Five-Day Moving Average>10-Day Moving Average; Remove Hedge When Five-Day Moving Average<10-Day Moving Average 35
Results 35

Summary 37

References 39

Quantitative Models to Predict Quarterly Average Cash Corn Prices and Related Hedging Strategies

Wayne D. Purcell and Thomas Wilson Richardson*

Introduction

The Current Situation

The livestock feeder encounters a series of obstacles in attempting to produce and market his product effectively. One of the most serious is uncertainty about the price of feed inputs. Since feed is a major variable cost in any feeding enterprise, effective planning without an adequate knowledge of probable feed price movements is very difficult.

During the 1970s, feed cost has ranged as high as 40-50 percent of the total cost of a fed steer. Because feed cost is such a large percentage of total cost, adverse fluctuations in the price of feed can have a disastrous effect on profit margins. Since 1970, such fluctuations have been quite common and often extreme.

Between 1965 and 1970 the largest movement in monthly average price for Chicago cash corn during any six-month period was $.30/bushel. Since 1970, price fluctuations for grain have become much more significant. For instance, in 1973 the monthly average cash price of corn rose from $2.52/bushel in July to $3.52/bushel in December.

Uncertainty about feed grain prices can affect the planning of livestock feeders in many ways. The farmer who operates a farming and feeding enterprise must decide whether to hold a large portion of his corn for sale in anticipation of high corn prices or to feed a large portion in anticipation of low corn prices.

The feedlot operator who has the option of buying large amounts of feed at different intervals may key his buying decision on anticipated prices. If feed grain prices are expected to rise he may purchase a large supply of feed in the current period. If the feedlot operator already holds some inventories but expects feed grain prices to decline at some later date, he may decide to reduce the feeding rate per animal unit so that additional inventories can be purchased at lower prices.

---

*Professor and former research assistant, respectively, Department of Agricultural Economics, Oklahoma State University.Research results reported in this bulletin are based on work conducted under project Hatch 1423, Oklahoma Agricultural Experiment Station.

The Problem

Currently there are very few feed grain price outlook or forecasting models which feeders can use in formulating marketing decisions. Such outlooks are badly needed as an aid to feeders who are always vulnerable to adverse price fluctuations. Not only does the lack of reliable feed grain price forecasts hinder knowledgeable expectations on the part of feeders but it also causes risk-reducing practices such as hedging to become less effective.

Literature Review

Weldon and Tweeten (1) present a model to predict seasonal average corn prices which focuses on total feed grain ending stocks as a predictor of price. In the model, the price of corn is expressed as a function of 1) the ratio of total feed grain utilization to total feed grain stocks, 2) the ratio of government-held ending stocks of feed grain to feed trade ending stocks of feed grain and 3) trend. The period analyzed was 1955-1970.

The feed grain price model is expanded by Anderson and Tweeten (2) in an attempt to show the relationship between wheat and feed grain prices. A wheat price equation is presented with seasonal average wheat price as a function of 1) the ratio of annual wheat utilization to wheat carryout, 2) the ratio of annual feed grain utilization in t-1 to feed grain stocks in t-1 and 3) a dummy variable used to reflect the change in wheat policy in 1964. The variables in the model explain 89 percent of the variation in seasonal average wheat prices.

Barr (3) developed a system of equations to measure factors affecting the annual demand for U.S. wheat. Relationships were developed for domestic and foreign demand. Domestic wheat demand, which is comprised mainly of food use and bears little resemblance to domestic feed grain demand, is not useful in an analysis of feed grain demand. Similar relationships exist, however, between wheat and feed grain export demand.

In the wheat export relation, quantity of wheat exported is specified as a function of 1) total wheat supplies of the major U.S. exporting competitors (Canada, Australia and Argentina), 2) total production of all grains in the rest of the world and 3) a time trend variable. The variables in the model explain 70 percent of the variation in wheat exports.

A study on the quarterly demand for corn for feed has been published by Butell and Womack (4). This analysis is very significant since feed demand represents a very large portion of the total demand for corn.

Four regression models are used to analyze the factors influencing feed demand for corn. There is a separate regression for each quarter of the corn marketing year beginning with the October-December quarter. The 1957-1974 marketing years are analyzed.

The October-December model specified feed usage as a function of 1) the average price received by farmers for corn, 2) the price of soybean meal, 3) production value of beef, pork and broilers and 4) prices received by farmers for livestock and livestock products. The explanatory variables account for 93 percent of the variation in October-December feed use. This model is very important since the correlation between the amount of corn fed during the October-December quarter and the amount of corn fed during the marketing year is .95. The author points out that an analysis of the October-December quarter can be useful in estimating the seasonal consumption pattern for a given supply of corn throughout the feeding year.

The predicted values produced from the model track fairly well historical prices using actual values for the explanatory variables. However, since the dependent variable feed use in the current time period is specified as a function of the independent variables in the current time period, it is necessary to predict the values of the dependent variables in future periods in order to forecast feed use. The authors give no indication of the method used to estimate the dependent variables.

The equations for the second and third quarters of the market year for corn are similar to the equation for the October-December quarter. In these models it was necessary to include additional explanatory variables to account for the lagged effect of certain economic variables on feed use later in the year. The authors suggest that there may be lagged economic influences when livestock and poultry producers adjust herd or flock size in response to changing economic signals. Current feed demand could be influenced by economic conditions that existed several quarters in the past.

An additional variable was included in the January-March and April-June models to account for lagging influences. The variable included was the average ratio of livestock prices received by farmers to average price received by farmers for corn for the three previous quarters. In the April-June model, the average price of soybean meal for the three previous quarters was also included.

A review of the literature in the area of commodity price analysis reveals the use of both single-equation models and simultaneous systems in price forecasting. Fox (5) presents a discussion on whether the single-equation or simultaneous system is better and offers the following observation:

> If the purpose of analysis is to estimate the expected price of a commodity with given values of other variables, the best answer can be given by a least squares regression with price dependent and other variables independent. If the purpose is to estimate elasticities of demand or other structural coefficients, this equation may not give an unbiased estimate. It will be unbiased only if current supply and other independent variables are not measurably affected by price during the marketing period. If these conditions are not met a system of simultaneous equations is needed if valid estimates of the coefficients of interest are to be obtained (p. 28).

However, if interest centers only on predicting the value of one variable from the value of others and if elasticities are not required, single equation least squares is useful even when the basic structure is simultaneous.

Objectives

The purposes of this study can be stated in three major objectives as follows:

1. To develop forecasting techniques that will allow projection of quarterly average cash corn prices (Chicago) two quarters into the future and to test the accuracy of the forecasting techniques.
2. To use the forecast as an input in hedging strategies for corn.
3. To test the relevancy of the forecasts and hedging strategies in decision situations.

Procedure

The development of a least-squares model to predict cash corn prices requires model specifications which encompasses the basic forces of supply and demand.

Domestic supply is comprised of carryin stocks plus production. On a yearly basis, supply is therefore essentially fixed or totally inelastic. Within the marketing year, however, the monthly or quarterly quantity moving through market channels can vary as corn is held or released from storage. Monthly and quarterly stocks of corn are analyzed as relevant indicators of supply. Also considered as a supply variable are the periodic USDA estimates of ending stocks.

The primary components of demand are domestic disappearance, with feed usage as the primary source of disappearance, and exports. With yearly supply of corn fixed, much of the variation in price will be due to shifts in the demand for corn. Separate models are developed to explain and predict feed usage and exports, respectively. The estimates of demand, supply indicators, variables designed to explain the variation in corn prices related to time and dummy variables to account for policy or other institutional changes are incorporated into a least-squares model specified to permit prediction of corn prices.

Once developed, the price predictions are employed along with other criteria in selected hedging strategies for corn. Consistent with the objectives of the study, emphasis is placed on the "long hedge" as used by the cattle feeder interested in protecting himself against increasing and/or variable corn prices. The strategies are tested by simulating feeding programs over time. Each strategy which involves hedging is compared to a control which involves no hedging to analyze 1) the impact on the mean cost of feeding cattle and 2) the impact on variability in costs of feeding cattle.

More detailed descriptions of procedure and the theoretical framework are available in the unpublished M.S. thesis by Thomas W. Richardson, *Quantitative Models to Predict Quarterly Average Cash Corn Prices and Related Hedging Strategies,* Department of Agricultural Economics, Oklahoma State University, December 1977.

The Feed Usage Model

One of the most important determinants of quarterly cash corn price is total corn disappearance during each quarter. This is the demand side of the price equation. In order to use disappearance as an explanatory variable in a predictive equation for corn price, a method of predicting disappearance must be developed.

Feed usage is the main component of corn disappearance. Between 1965 and 1975, feed usage averaged 76 percent of total corn disappearance (6).

Any estimate of total disappearance must begin with an analysis of feed usage.

The Model

The level of corn used for feed is determined by the number of animals to be fed and the feeding rate per animal. The feeding rate is an important short-run consideration. Feeding rates can be adjusted more rapidly to changing economic conditions than can livestock numbers. Livestock feeders tend to feed the group of animals on hand to some minimum weight. If the cost-price situation facing the feeder is favorable, he may increase the amount of corn fed per animal in order to increase slaughter weight. However, if economic conditions call for increased livestock output there is a biological constraint. Although there may be a lagged response in feeding rates, livestock production is expected to be less responsive to changing economic conditions. Figures 1 and 2 show quarterly variation in feed usage, feeding rates and animal units. The animal unit data is published by the USDA (6).

An animal unit is a common denominator for different types of animals based on the quantity of grain consumed. One cow equals one animal unit. A semilogarithmic scale is used so that equal distances along the vertical axis show equal percentage changes.

Variables Influencing Number of Animals Fed. Two categories of livestock which consume a large portion of the corn fed were chosen as a proxy for the number of animals being fed. The categories were cattle on feed and all hogs and pigs. The two groups account for over 50 percent of the corn fed to livestock annually (6). Poultry numbers were not considered because the variation in the amount of corn consumed by poultry was judged to be insignificant.

The 23-state cattle on feed report is issued quarterly (7). The figures for cattle on feed at the beginning of October, January, April and July were used as observations for the October-December, January-March, April-May and

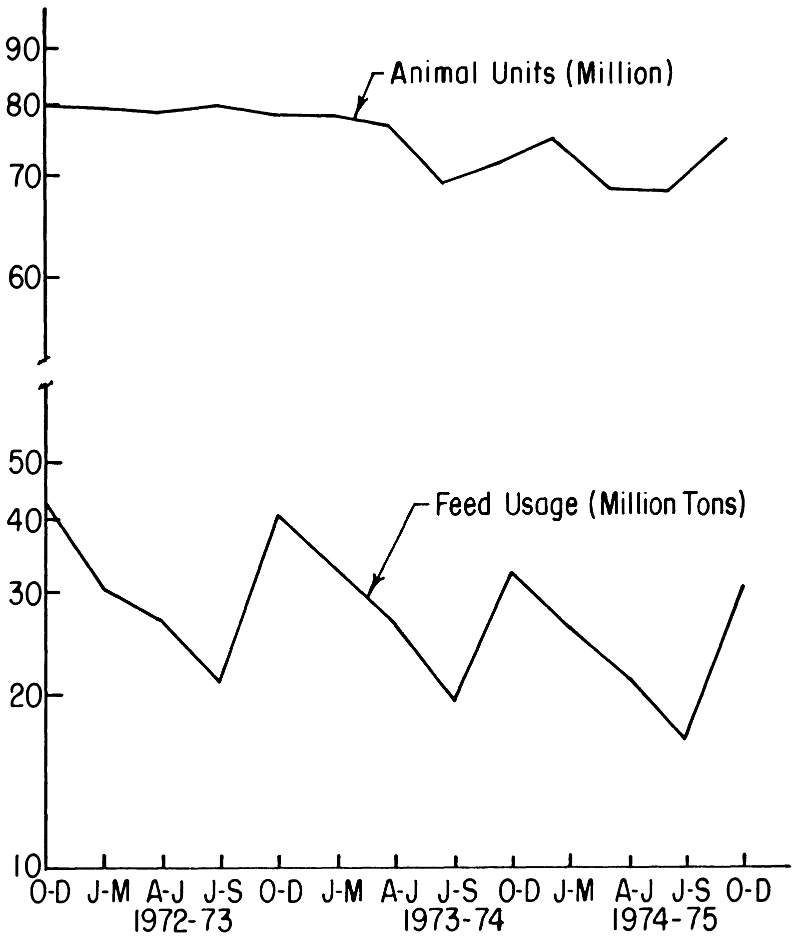


Figure 1. Corn used for feed and number of animal units fed.

June-September periods, respectively.

The number of hogs and pigs on farms is reported four times a year for 10 and 14 states (8). The 10-state series is the more consistent and reliable series and is used in this analysis. Numbers on December 1, March 1, June 1 and September 1 are used as observations for the October-December, January-March, April-May and June-September periods, respectively.

Hogs and pigs proved to be the most significant of the variables representing animal numbers. This variable was selected for the final model. It seems reasonable to expect that the number of hogs and pigs would prove the more valuable since this category accounts for approximately 35 percent of the total corn consumed by livestock (6). Also, changes in the number of hogs and pigs did not prove to be as highly correlated with other variables in the model as did cattle on feed. Cattle on feed did not significantly improve the R^2 when used in the model.

Variables Influencing Variation in Feeding Rates. The variables that are most often associated with corn feeding rates include those representing the variable costs of the feeding operation. In most feeding operations, corn is the major feed ingredient with soybean meal used as a protein supplement. In some cases grain sorghum is considered a substitute for corn. The prices of these inputs were considered to represent the major variable costs.

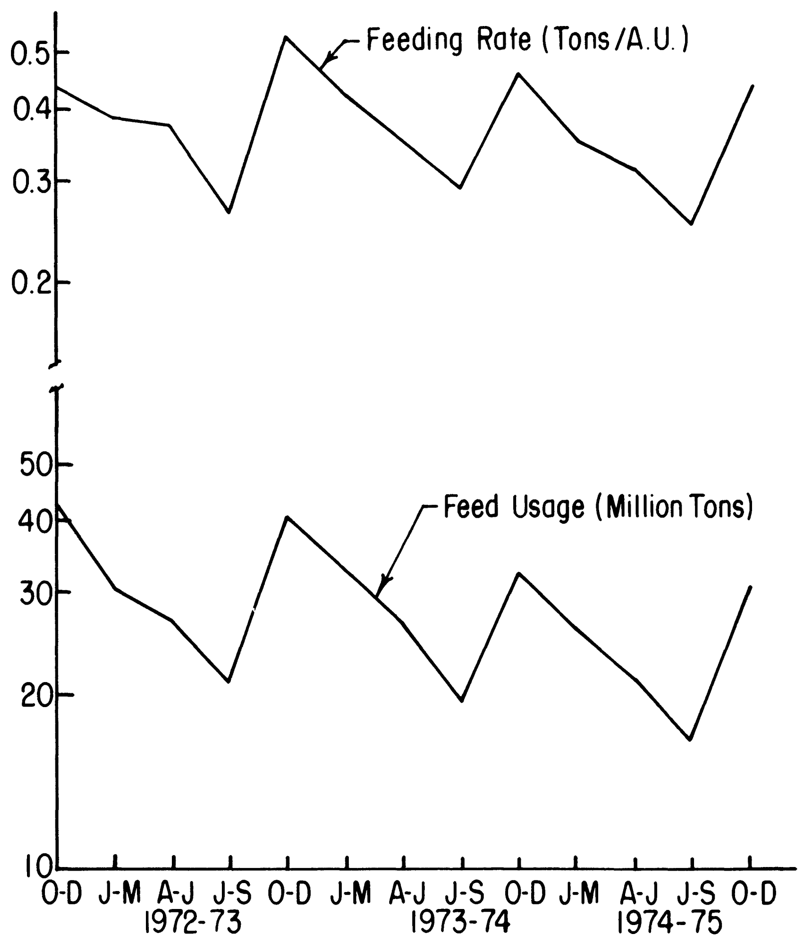


Figure 2. Corn used for feed and feeding rate per animal unit.

Feeding rates would be expected to vary inversely with the price of corn. As corn prices rise, corn feeding would be expected to fall. Corn prices used in the analysis were quarterly average cash corn prices for number 2 yellow corn at Chicago (9). The statistical analysis suggested that there is a lagged response of feeding rates to changing corn prices. The full effect of a change in corn prices on feeding is not seen until the quarter following the change.

Feeding rates would be expected to vary in the same direction as soybean meal prices. As soybean meal prices fall, less corn is fed relative to soybean meal. Soybean meal prices used were quarterly average prices for cash soybean meal at Decatur with 44 percent protein (9).

In some parts of the country grain sorghum is substituted for corn in the feed ration. As grain sorghum prices fall relative to corn prices, grain sorghum is fed in place of corn. Grain sorghum prices used in the analysis were quarterly average prices for number 2 yellow grain sorghum at Kansas City (9).

When corn, soybean meal and grain sorghum were used in the same regression equation, problems of multicollinearity developed. Since the trend in these feed input prices has been upward, particularly since 1971, they were correlated with each other. In an attempt to deal with the multicollinearity problem, ratios between corn and soybean meal and between corn and grain sorghum prices were calculated. The ratios reflect the price of corn relative to the price of feed inputs that could be substitutes for corn. The ratio of soybean meal to corn proved more valuable and was used in the final model.

Additional variables which influence the level of feed use are those reflecting the feeder's initial investment in the animal to be fed. Feeder pig prices and feeder steer prices were used to reflect this investment. The quarterly cost of feeder steers, all weights, for eight markets, was the feeder steer price series (10). Quarterly average prices paid for feeder pigs was the feeder pig series (11).

The variable which is likely most important in the decision process of the livestock feeder is the price of the finished animal. The feeding rate and the number of animals are affected. As the price per pound of the finished animal increases, the reaction of the feeder is first to feed to heavier weights, then to increase the number fed. Quarterly average slaughter hog prices at Omaha and quarterly average slaughter steer prices at Omaha were used in this analysis (10). Multicollinearity problems, similar to those encountered with grain prices, were encountered when livestock prices were used.

The commonly used livestock-corn ratios were used in an attempt to deal with multicollinearity problems. The hog-corn and steer-corn ratios are generated by dividing the price of the slaughter animal by the price of corn. The price of livestock relative to that of corn gives some indication of the profitability of feeding.

There are certain problems associated with the use of livestock-corn ratios to represent the relative profitability of a feeding operation when there is a great deal of variation in livestock and feed prices. Livestock-corn ratios do not account for the magnitudes of prices. Estimates of gross profit margins associated with hog and cattle feeding should be better indicators of profitability in feeding enterprises.

Estimated gross profit margins were calculated for hogs and steers. Costs such as transportation, management, shelter, fuel and marketing expenses were not considered. Only the cost of the feeder animal, the cost of feed and the price of the finished animal were considered. In calculating the margins it is assumed that the feeder purchased a feeder pig or feeder steer at the current price. The animal is fed a constant ration of corn and soybean meal purchased at the beginning of the feeding period at current prices. The animal is then sold at a given weight at the current price. All prices used were in the same time period. Margins might also be calculated using an expected price for the finished animal at the time the animal is to come off feed. The assumptions, data and methods of calculation used are shown in Tables 1 and 2.

Livestock margins are believed to be more realistic estimates of profitability than livestock-corn ratios. If the price of the animal and the price of corn double, the livestock-corn ratio will be unchanged. Holding other prices constant, the livestock margin will double in this situation. Suppose the price of corn is $1/bushel and the price of hogs is $25/cwt. Also, the hog is sold at 240 pounds and is fed 800 pounds of corn. If the prices of corn and hogs double the hog-corn ratio will remain at 16.7. The hog profit margin will increase from $39 to $78.

Steer margins proved to be more valuable in the model. This is due to some extent to the degree of correlation between hog and steer margins. Much of the variation in feed usage that might have been explained by hog margins was explained by other variables in the model such as the number of hogs and pigs. Hog producers can respond more rapidly to economic signals with increased output than can cattle producers. It seems likely that profit potential which would have been indicated by hog margins is reflected in hog numbers.

Table 1. Procedure for Estimating Gross Hog Margins.

Variable	Method of Calculation
Receipts	240-lb. hog × hog price[a]
Expenditures	15 bu. corn × corn price[b]
	.06 tons soybean meal × soybean meal price[b]
	40-lb. feeder pig × feeder pig price[c]
Gross Hog Margin	Receipts – Expenditures

[a]The price series for 220-240-pound barrows and gilts at Omaha taken from U.S. Department of Agriculture, *Livestock and Meat Situation*, Series LMS, 141-210. (Prices taken from selected issues of this monthly publication by the Economic Research Service.)

[b]Number 2 yellow corn prices at Chicago and 44%, bulk, soybean meal prices at Decatur taken from U.S. Department of Agriculture, *Grain Market News*. (Prices taken from selected issues of this weekly publication by the Agricultural Marketing Service.)

[c]Prices paid by farmers for feeder pigs taken from U.S. Department of Agriculture, *Agricultural Prices Annual Summary 1975*, Series Pr, 1-3 (1976). (Prices taken from this annual publication by the Statistical Reporting Service and Crop Reporting Board.)

Table 2. Procedure for Estimating Gross Steer Margins.

Variable	Method of Calculation
Receipts	1100-lb. steer × steer price[a]
Expenditures	56 bu. corn × corn price[b]
	.12 tons soybean meal × soybean meal price[b]
	500-lb. feeder steer × feeder steer price[c]
Gross Steer Margin	Receipts − Expenditures

[a]The price series for Choice Omaha steers taken from U.S. Department of Agriculture, *Livestock and Meat Situation*, Series LMS, 141-210. (Prices taken from selected issues of this monthly publication by the Economic Research Service.)

[b]Number 2 yellow corn prices at Chicago and 44% bulk, soybean meal prices at Decatur taken from U.S. Department of Agriculture, *Grain Market News*. (Prices taken from selected issues of this weekly publication by the Agricultural Marketing Service.)

[c]Average feeder steer prices for eight markets, all weights, taken from U.S. Department of Agriculture, *Livestock and Meat Situation*, Series LMS, 141-210. (Prices taken from selected issues of this monthly publication by the Economic Research Service.)

The size of the corn crop harvested and the carryin October 1 set the maximum level of feeding during the year. The availability of corn influences the level of feeding apart from its effect on price. The large supply during 1973 resulted in heavy corn feeding despite high corn prices during the same period. This is partly the result of the expense of storage and the lack of adequate storage in the corn belt in years of high supply. The variable, total corn supply on October 1 as a percentage of a 10-year average, makes a significant contribution to the model. Corn supply October 1 is reported by the USDA (6).

Dummy Variables to Account for Seasonality. The level of feed usage follows a distinct seasonal pattern during the year. If the crop year for corn were divided quarterly with three months in each quarter, the pattern would show the highest level of feed usage in the October-December quarter. The level of feed usage would then decrease through subsequent quarters with the lowest level in the July-September quarter. There would be a significant difference in the level of feed for each quarter.

The change in the reporting date for stocks in all positions has caused the seasonal pattern of feed usage to change for statistical purposes. In this analysis feed usage is observed in the October-December, January-March, April-May and June-September periods. The period beginning in October remains the period of highest feed usage. The April-May period is the period of lowest usage since it is comprised of only two months. The period previously beginning in July now begins in June. The addition of June results in a level of usage during June-September that is very close to that in January-March on the average.

A set of quarterly intercept dummy variables was used to account for the levels of feed usage in each quarter. Only the dummies for the October-December and April-May periods proved significant. The dummies were retained because no continuous variables were found that accounted for the variation in levels of quarterly usage. The October-December level of feed use is high simply because the corn crop is harvested in October and there is more corn available for feeding. The April-May period exhibits a low level of feeding because it is the shortest period.

Slope dummies tested were insignificant. Slope dummies were tested for each of the continuous variables in the model. The equation in its final form specifies intercept changes in the October-December and April-May periods with the slope of each of the continuous variables remaining the same.

Results of the Model

The feed usage model is presented in Tables 3 and 4. The variables in the equation explain 93 percent of the variation in feed usage. The standard deviation, 75.8, is 8.1 percent of the mean of the dependent variable. The regression is significant at the .0001 probability level. The first-order autoregressive coefficient, -.1166, is well within the acceptable range, indicating that autocorrelation is not a major problem. Some negative correlation does exist.

The regression coefficients for both dummy variables are significant at the .0001 probability level. These variables have the largest standardized beta coefficients indicating a substantial impact in the equation. The intercept which accounts for the seasonal variation in the January-March and June-September periods is insignificant indicating that the regression line is approximately a line through the origin during these periods. The slope of the regression is the same in all periods.

The regression coefficient for the stocks variable is significant at the .02 level. The theoretically correct positive sign on the coefficient indicates that the level of feed usage increases as a larger amount of corn is available at the beginning of the year.

The steer margins variable has the largest impact on the equation of any of the continuous variables. The regression coefficient is significant at the .001 level and has the expected positive sign. The value for steer margins is lagged three quarters. It was necessary to lag this value to account for the lagged

Table 3. Variables in the Feed Model.

Variable	Definition
FEED	Quarterly corn used for feed (million bu.).
DUMAM	Intercept dummy for the April-May period.
DUMOND	Intercept dummy for the October-December period.
STOCKS	Corn production and carryin as a percent of a 10-year average (million bu.).
STMARG3	Quarterly gross profit margins for a cattle feeder buying a 500-lb. feeder steer and feeding to 1100 lb. It is assumed that the steer is fed 56 bu. of corn and 240 lb. of soybean meal. Lagged three periods (dollars).
HOGPIG1	Quarterly hog and pig numbers. Lagged one period (000 head).
MCRATIO2	Quarterly average ratio of soybean meal prices and corn prices. Lagged two periods.

Table 4. Regression Estimates for Model with Feed Usage as the Dependent Variable.

Explanatory Variable	Regression Coefficient	t-statistic	Significance Level
DUMAM	−408.0534	−12.1668	.0001
DUMOND	222.4814	7.5442	.0001
STOCKS	3.9215	2.3860	.0227
STMARG3	2.0853	3.4704	.0014
HOGPIG1	0.0071	1.8795	.0700
MCRATIO2	0.8222	1.1344	.2646
INTERCEPT	22.3845	0.1057	.9164
R^2 = .933	Standard Deviation = 75.81		Durbin-Watson = 2.21

response of feeders to changing profit potential.

The coefficient for the variable hogs and pigs is significant at the .07 level. The positive sign indicates that the level of feed usage increases as the number of hogs and pigs increases. The value for hogs and pigs is lagged one quarter. The lag is due to the timing of the reports on hog and pig numbers. The number of hogs and pigs reported in the last month of each period is used as an observation in that period. The number of hogs in the last part of the last month of each period is probably a better indicator of the number of hogs in the subsequent period. For example, the number of hogs and pigs reported in December is probably a better indication of hog numbers in the January-March period than the October-December period.

The meal-corn ratio had the least impact of any variable in the model with a coefficient significant at the .30 level. This variable was retained since it contributed significantly to the R^2 and decreased the standard deviation. The theoretically correct sign is present indicating that as the price of soybean meal rises relative to the price of corn more corn is fed.

The actual values for feed usage are plotted with the predicted values in Figure 3. The predicted values track reasonably well, particularly in the more recent years. The dummy variables are responsible for capturing the seasonal turning points.

The October-December Feed Model. The lack of a historical data series prior to 1965 for the April-May and June-September periods prevented the development of quarterly feed usage models. Since there is only one observation per year for a quarterly model, only 10 observations would have been available for April-May and June-September. However, it became necessary to develop a separate model for the October-December period for which historical data were available.

Total corn supply or stocks was a key variable in the model discussed previously. Because the estimates of production prior to October 22 are somewhat imprecise, it is difficult to use the stocks variable until October 22.

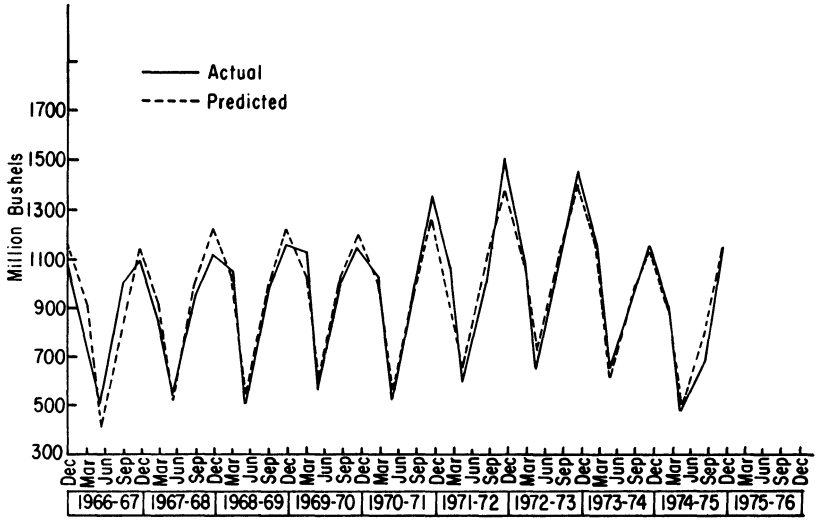


Figure 3. Quarterly feed usage of corn: actual and predicted.

This would make it necessary to wait until the end of October before predicting feed usage for the October-December period. For this reason a separate model was developed for October-December.

The variables used in the October-December model are different from those in the continuous model. This is partially due to the fact that values for some of the variables used in the continuous model were not available for the entire time period covered by the October-December model. Data for 1957-1975 are analyzed in the October-December model.

The October-December model is presented in Tables 5 and 6. The variables in the equation explain 95 percent of the variation in October-December feed usage. The standard deviation, 54.2, is 5.01 percent of the mean of the dependent variable. The regression is significant at the .0001 level.

Table 5. Variables in the October-December Feed Model.

Variable	Definition
FEED	Quarterly corn used for feed during the October-December quarter (million bu.).
DINT	Intercept dummy when the current estimate of production + carryin is greater than 110% of a 10-year average.
CATFEED1	Number of cattle on feed. Lagged one period (000 head).
HGPRICE1	Quarterly average slaughter hog price. Lagged one period (dollars/cwt.).
GSRATIO1	Quarterly average ratio of grain sorghum prices and corn prices. Lagged one period.

Table 6. Regression Estimates for Model with October-December Feed Usage as the Dependent Variable.

Explanatory Variable	Regression Coefficient	t-statistic	Significance Level
DINT	178.4993	3.6104	.0036
CATFEED1	0.0493	5.7607	.0001
HGPRICE1	3.0104	2.1001	.0575
GSRATIO1	174.4629	1.8207	.0937
INTERCEPT	261.0825	1.6025	.1350
R^2 = .950	Standard Deviation – 54.18	Durbin-Watson = 1.48	

The first-order autoregressive coefficient of .2422 is within the acceptable range but does indicate some positive autocorrelation.

The data reflecting the number of hogs and pigs were not available back to 1957. Instead, cattle on feed lagged one period was used. The regression coefficient for cattle on feed is significant at the .0001 level. The standardized beta coefficient indicates that cattle on feed had the largest impact of any variable in the model. The positive sign indicates that feed usage increases as the number of cattle on feed increases.

The coefficient for hog price is significant at the .06 level. The sign of the coefficient indicates that feed usage increases as the price of hogs increases. The coefficient for steer margins was not significant in the October-December model. It is likely that a portion of the variation that might have been explained by steer margins is explained by cattle on feed.

The grain sorghum-corn ratio is more significant in the October-December model than is the meal-corn ratio. Corn and grain sorghum are harvested during the same period. If the price of grain sorghum is low relative to corn, some grain sorghum can be substituted for corn. The regression coefficient is significant at the .09 level.

It was mentioned earlier that the most reliable estimate of production cannot be obtained until October 22. The intercept dummy, DINT, is used in the model if the September 22 estimate of production plus carryin is greater than 110 percent of normal. The dummy variable is significant at the .004 level. Actual values for October-December usage are plotted with the predicted values in Figure 4.

The Export Model

U.S. corn exports are the second major component of total corn disappearance. In recent years, exports have become a larger portion of total corn disappearance and have exerted a significant impact on corn prices. Between 1965 and 1972, exports averaged about nine percent of total disappearance annually. Since 1972, exports have averaged approximately 23 percent of disappearance annually. The unstable nature of the export market has contributed to the volatility of corn prices since 1972.

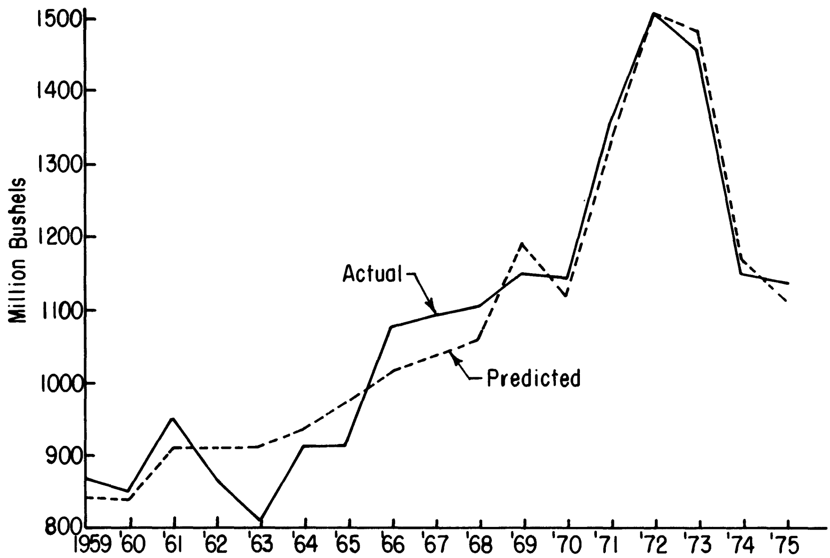


Figure 4. October-December feed usage of corn: actual and predicted.

The Dependent Variable

The export data which was used in this analysis excluded exports from the U.S. to the Soviet Union (USSR) and the People's Republic of China(PRC). Since these countries have been importers of U.S. corn during only four of the ten years under observation (1972-1976), the relationships developed in the regression were distorted by size of the Russian and Chinese purchases. Economic conditions thought to have prompted the Soviet purchases were present in other years in which the Soviet Union did not buy. It seems likely that political rather than economic considerations were the determining factor in the Soviet purchases.

Because of long-term trade agreements with the U.S., the Soviets can be expected to purchase significant quantities of corn in the future. A separate estimate of corn exports to the Soviet Union will be made. Annual estimates will be based on export commitment reports and USDA estimates. The timing of purchases within the year will be based on historical percentages and port capacity estimates. The Peoples' Republic of China is not expected to be a consistently large buyer in the near future. All data used in the model excludes the USSR and the PRC. Also, the observation for the January-March period in 1969 was excluded from the model. The dock workers' strike on the east and west coasts during the period impeded normal export movements.

The Model

The major importers of U.S. corn are the countries of Western Europe and Japan. Western European and Japanese imports of U.S. corn can be seen in Table 7. Since 1965, U.S. corn exports to Western Europe and Japan have averaged approximately 78 percent of annual corn exports from the U.S. For this reason, certain variables influencing Western European and Japanese demand for corn were used as proxies for world demand. World data were sometimes unobtainable. The data for Western Europe and Japan were found to be current, obtainable and consistent.

The majority of variables examined and chosen to represent demand for U.S. corn exports fit the traditional image of demand shifters rather than variables which determine the nature of that demand. This is due to the number of institutional barriers to trade that have existed during the 10-year period between 1965 and 1976. These barriers make foreign demand less responsive to price changes than to changes in production and domestic demand in the importing countries. Two important barriers are the European Economic Community (EEC) variable levy system and the Japanese quota system.

Variables Influencing the Level of World Corn Exports. Per-capita world corn production is an important determinant of export demand for corn. As world production falls below the level necessary to maintain desired consumption, demand for imported corn increases. Production in the Western Hemisphere (excluding the U.S.), Western Europe and Asia was used as an estimate of world production. Production in each of the three regions was divided by population to obtain per-capita production. The level of production relative to potential consumption was considered more important than the absolute level of production. Per-capita world corn production was chosen for the final model.

A large part of the corn imported by foreign countries is fed to livestock. It was thought that animal units might be a better deflator of production than population since changes in population are not expected to correspond to changes in animal numbers in the short run. An accurate series of world animal numbers was not found. Instead, Western European animals units were used to deflate Western European production. Western European production per animal unit was found to be very highly correlated with world production per capita and was not significant in the model. However, when EEC animal units were used alone, the model improved significantly. The addition of Japanese animal numbers did not help the model.

An additional production variable was tested in an attempt to account for the high degree of substitution between corn and other feed grains. This variable was world coarse grain production. Coarse grains include corn, barley, oats, grain sorghum and rye. If poor corn production coincided with adequate production of other feed grains, other feed grains might be substi-

Table 7. U.S. Corn Exports by Destination as a Percentage of Total U.S. Corn Exports, 1965-1975[a].

Destination	1965-66	1966-67	1967-68	1968-69	1969-70	1970-71	1971-72	1972-73	1973-74	1974-75
Western Hemisphere	4.3	4.9	7.9	8.3	8.7	5.8	4.3	7.9	10.1	10.2
Western Europe	74.2	67.8	69.9	62.7	54.6	55.9	54.7	46.1	43.5	54.2
EEC	59.3	57.7	60.6	58.3	45.4	51.5	47.7	35.5	31.2	37.5
Other Western Europe	14.9	19.1	9.3	4.4	9.2	4.3	7.0	10.6	12.2	16.7
Eastern Europe	2.5	3.3	3.2	4.6	3.4	5.7	5.1	3.8	2.3	5.9
USSR	--	--	--	--	--	--	11.7	12.8	12.9	4.4
Asia	15.9	22.3	18.2	23.9	31.9	3.1	22.1	28.2	29.0	22.2
Japan	13.8	15.5	15.7	21.0	28.3	25.6	15.3	19.3	19.9	18.0
PRC	--	--	--	--	--	--	--	3.1	5.2	0.1
Africa	2.9	1.7	0.7	0.5	1.3	1.4	2.0	1.0	2.2	2.9
Western Europe and Japan	88.0	83.3	85.6	83.7	82.9	81.5	70.0	65.4	63.4	72.2

[a]The percentages were calculated from data taken from U.S. Department of Agriculture, *Grain Market News (export data taken from selected issues of this weekly publication by the Agricultural Marketing Service).*

tuted for corn. Corn demand would not increase significantly in this case. However, coarse grain production did not improve the model. Because corn production is such a large portion of coarse grain production, coarse grain production was found to be highly correlated with corn production.

As a country achieves a certain amount of economic growth and affluence, there is a tendency for the portion of meat in the diet to increase. An index of Western European gross national product (GNP) was used to reflect the standard of living in Western Europe. This variable should indicate the potential for a high meat demand and the ability to import large quantities of corn. The index of Western Europe GNP proved to be insignificant in the model as the variable was highly correlated with world production and EEC animal units.

Variables Influencing the Level of U.S. Corn Exports. Total demand for U.S. corn exports was hypothesized to be highly price inelastic. However, price was tested as a variable in the export demand model. Quarterly average Chicago cash corn price was used to estimate the U.S. export price. The ocean freight rate from the U.S. gulf to the Amsterdam-Rotterdam-Antwerp range of Western Europe was added to the export price to reflect the import price for Western Europe. This price was lagged one and two periods to account for the lag between corn purchases and the arrival of the corn in Europe. The price variable was insignificant and had a sign considered to be incorrect on theoretical grounds.

Another variable thought to influence the demand for U.S. exports was coarse grain supplies of competing exporters. The major net exporters of coarse grains other than the U.S. are Argentina, Brazil, South Africa, Thailand and France. Coarse grain supplies of U.S. competitors did not improve the model as multicollinearity problems were encountered again.

Since the drastic increases in U.S. exports coincided very closely with the devaluations of the dollar in 1971 and 1973, many have speculated that changing rates have a significant impact on exports. As U.S. dollar depreciates relative to the currencies of other exporters, U.S. grain becomes cheaper even though prices do not change.

Results of the Model

The export equation is presented in Tables 8 and 9. The variables in the equation explain 88 percent of the variation in corn exports. The standard deviation, 32.3, is 16.8 percent of the mean of the dependent variable. The regression is significant at the .0001 level. The first-order autoregressive coefficient, -.4397, indicates that some negative autocorrelation exists but is within the acceptable range.

The regression coefficients for the dummy variables in the April-May and June-September periods are significant at the .0001 and .005 levels, respective-

Table 8. Variables in the Export Model.

Variable	Definition
EXPORTS	Quarterly U.S. corn exports excluding those to the USSR and PRC (million bu.).
DINT	Intercept dummy for the 1972 to date.
DUMAM	Seasonal intercept dummy for the April-May period.
DUMJJAS	Seasonal intercept dummy for the June-September period.
WCNPROD	World corn production per capita (bu./person).
EECAUS	EEC animal units at the beginning of the year (million units).
EXCHRTE2	Weighted composite index of U.S. currency values relative to the currencies of the major corn importers.

ly. The intercept which accounts for the level of exports during the October-March period is significant only at the .573 level. This indicates that between 1965 and 1972 the origin for the October-March period is not significantly different from zero. The dummy variable DINT is significant at the .073 level indicating a significant positive shift in the intercept after 1972.

The coefficient for the variable world corn production per capita is significant at the .005 level. The negative sign indicates that as world corn production per capita falls, U.S. exports of corn increase. This variable is the most significant of the continuous variables.

The variable, EEC animal units, has the largest impact on the model of any of the continuous variables as indicated by the large standardized beta coefficient. This variable is significant at the .027 level. The positive sign indicates that as the number of animal units in the European Economic Community increases, U.S. corn exports increase.

To determine the impact of changing exchange rates, a weighted composite exchange rate index was calculated for the currencies of the major corn importers. The index measures the value of foreign currencies vis-a-vis the dollar. The index for each country was weighted on the basis of the average amount of corn purchased from the U.S. over a six-year period. The variable was lagged two periods. The index did improve the model, but it proved to be the least significant of the variables chosen for the final model.

Table 9. Regression Estimates for Model with Exports as the Dependent Variable.

Explanatory Variable	Regression Coefficient	t-statistic	Significance Level
DINT	56.6931	1.8564	.0729
DUMAM	−77.3682	−5.9666	.0001
DUMJJAS	39.4464	3.0320	.0049
WCNPROD	−75.3934	−3.0590	.0046
EECAUS	8.1645	2.3205	.0271
EXCHRTE2	216.9144	1.6888	.1013
INTERCEPT	−79.0131	−0.5728	.5709
R^2 = .883	Standard Deviation = 32.35	Durbin-Watson = 2.81	

Dummy Variables to Account for Seasonality. The time periods used in this analysis result in a seasonal pattern from a statistical standpoint. The lowest level of exports is observed in the April-May period which contains only two months. The highest level of exports is observed in the June-September period which contains four months. Intercept dummies were used for these periods. An additional dummy was inserted to separate the period prior to 1972 from the period after 1972. This dummy was employed to reflect the increased corn production in the U.S. beginning in 1971-72.

The variable found to be least significant was the exchange rate index. This variable is significant at the .101 level. This variable remains in the model because it adds significantly to the R^2 and decreases the standard deviation. The theoretically correct sign is also present indicating that as the values of foreign currencies increase relative to the dollar, U.S. corn exports increase. The actual values for exports are plotted against the predicted values in Figure 5.

The Price Model

The price model is specified and tested by comparing actual and predicted prices 1) when observed values of the explanatory variables are used and 2) when predicted values of the explanatory variables are used. The latter comparison is the best indicator of the usefulness of the model since forecasts must be made using predicted values for the explanatory variables.

The relationship between corn price and the determinants of corn price is such that four quarterly models would be preferred to a continuous model as a

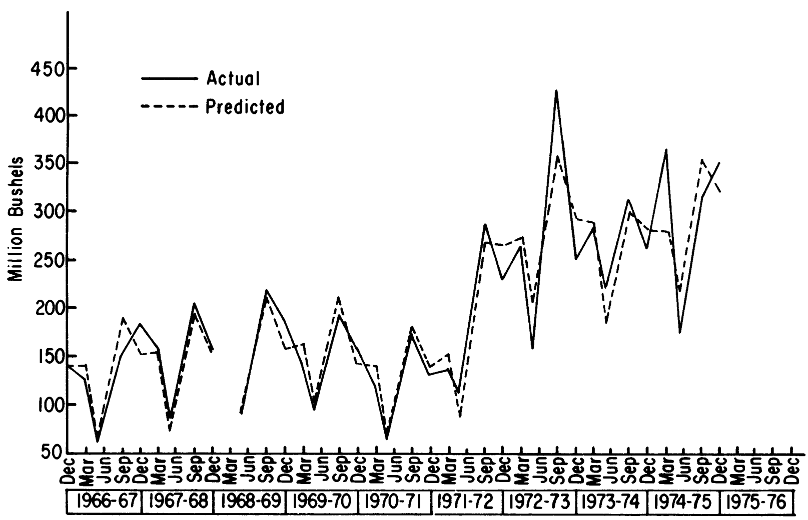


Figure 5. Quarterly corn exports: actual and predicted.

method of prediction. There is more seasonal variation in the explanatory variables than in the dependent variable. The rate of disappearance, or the level of stocks, exhibits a very distinct seasonal pattern. The rate of disappearance and the level of stocks decrease significantly during the marketing year. The pattern of corn price movement during the year is not so pronounced. Quarterly models would allow for the regression of price for a particular quarter on explanatory variables for the same quarter. This would eliminate the problem of seasonality. However, the data structure precluded the use of quarterly models.

Two methods were used to deal with seasonality in the explanatory variables. By the first method, the value of the explanatory variable was calculated as a percentage of "normal" for each quarter. "Normal" was defined as a 10-year average for each quarter. The second method involved the calculation of a four-quarter moving average for the value of the explanatory variable. Both methods proved satisfactory as a means of removing seasonality.

Values Indicating the Rate of Disappearance. Since feed usage and exports comprise the only significant portion of disappearance, these variables were first used separately in the model to indicate the rate of disappearance. A four-quarter moving average of feed usage was used to adjust for seasonality. Exports were not adjusted.

When exports and feed usage were used separately in the model, exports exerted too great an impact on the equation even though exports are small in comparison to feed usage. When exports were specified as a separate variable, the potential impact on the model was as great for exports as for feed usage. The high correlation between exports and price over the last half of the data set gave exports a significant regression coefficient. Variation in export values in the first half of the data set resulted in significant variation in predicted price. The influence exerted by exports in the model was not proportional to the actual influence of exports on price. Since feed usage was less variable, feed usage exerted less impact on the model than exports.

In order to obtain a more realistic estimate of disappearance, exports, feed, seed, food and industrial usage were combined to arrive at total disappearance. Disappearance as a percentage of "normal" was calculated for each quarter and tested. A moving average of disappearance was also tried.

The four-quarter moving average of disappearance proved to be more valuable in the final model. The moving average of disappearance was lagged one period. This lag was to reflect the delay in the publication of the figure for disappearance each period. For example, actual disappearance during the October-December period is not known until the second week in January. The information actually affects the market in the January-March period.

Variables Indicating the Level of Supply. Stocks in all positions were used to represent supply in each period. The stocks in all positions publication of the USDA reports total supply at the beginning of each period. This figure includes government and privately held stocks. In recent years, government-held stocks have been of little consequence. Stocks proved to be an important variable when used with disappearance in the model. The model containing these two continuous variables explained approximately 94 percent of the variation in corn price. There were, however, several periods within the data range in which the variation in price was not being adequately explained.

Expectations. The unexplained variation in price indicates that current stocks and disappearance do not determine price with precision. A portion of the unexplained variation in prices was thought to be due to the effect of expectations. Since market decisions are based on information available to buyers and sellers, it was necessary to incorporate into the model a variable which provided the information on which market expectations are based. One major source of information is the USDA outlook series.

The variable selected to account for expectations was the USDA estimate of corn carryout at the end of the marketing year. This estimate is the anticipated net supply-demand balance for the year. The USDA publishes this figure monthly and then quarterly in its outlook series. Estimated carryout proved to be very valuable in helping to explain the variation in corn price. The simple correlation between estimated carryout and price was -.83.

Dummy Variable. Corn price seems to be very sensitive to the expected carryout level, especially when the price level is above $2/bushel. In order to allow the slope of the regression with respect to estimated carryout to change, intercept and slope dummies were inserted in the model. An intercept dummy, DINT, was specified when corn price was greater than $2. An interaction dummy allowed the slope to change at this point. Figure 6 is a plot of price against estimated carryout. The slope dummy for disappearance was not significant.

Results of the Model

The price model is presented in Tables 10 and 11. The variables in the model explain 97 percent of the variation in corn price. The standard deviation, 12.6, is 7.2 percent of the mean of the dependent variable. The regression

Table 10. Variables in the Price Model.

Variable	Definition
CNPRICE	Quarterly average cash corn price, #2 yellow Chicago (cents/bu.).
DISAP1	Quarterly corn disappearance, moving average. Lagged one period (million bu.).
ESTCO	USDA estimate of carryout, September 30 (million bu.).
DINT	Intercept dummy, if price is greater than $2.
ESLOPE	Slope dummy, DINT × ESTCO.

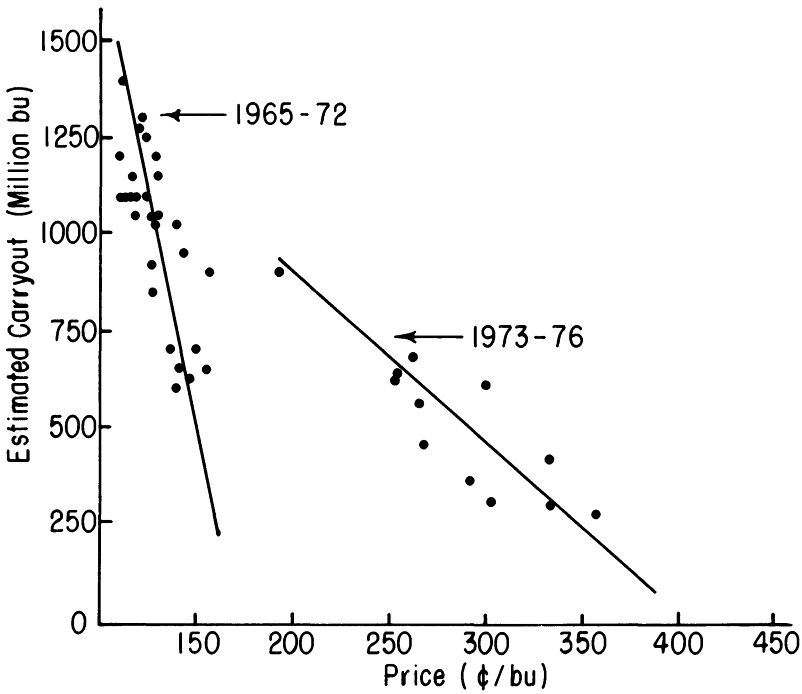


Figure 6. Corn price versus estimated carryout.

is significant at the .001 level. The first-order autoregressive coefficient, -.2348, is well within the acceptable range. A very slight degree of autocorrelation does exist.

The regression coefficient for the disappearance variable is significant at the .0001 level. The theoretically correct sign is present. This positive sign indicates that corn price increases as the level of disappearance increases. Disappearance has a slightly larger standardized beta coefficient than estimated carryout. The value for disappearance is lagged one quarter.

Table 11. Regression Estimates for Model with Corn Price as the Dependent Variable.

Explanatory Variable	Regression Coefficient	t-statistic	Significance Level
DISAP1	0.1014	4.8315	.0001
ESTCO	−0.4469	−4.1495	.0002
DINT	168.5534	9.6726	.0001
ESLOPE	−0.1226	−4.2570	.0002
INTERCEPT	59.4863	2.1592	.0376
R^2 = .974	Standard Deviation = 12.57	Durbin-Watson = 2.38	

The regression coefficient for estimated carryout is significant at the .0002 level. The negative sign on the coefficient indicates that as the expected carryout decreases, price increases. The increase in the responsiveness of price to changes in expected carryout since 1972 is evident in the model. The negative sign on the slope dummy indicates the higher responsiveness of price. After 1972, the change in price is twice as large for the same change in estimated carryout.

There is also a significant positive shift in the intercept after 1972. The standardized beta coefficient indicates that the intercept dummy has more impact on the model than any other variable. The intercept dummy is significant at the .0001 level. The intercept for the period prior to 1972 is also positive and significant at the .038 level.

The accuracy of the specified model is indicated by Figure 7. Actual corn prices are plotted with the predicted prices. The predicted values track well over the entire data range with the exception of the 1973-74 marketing year. In the October-December and April-May periods, the predicted price moves in the opposite direction from the actual price.

In October 1973 the second largest crop in history was harvested. This resulted in depressed prices during the October-December period. During the April-May period an even larger harvest was predicted by USDA for October 1974. A sharp price decrease resulted. In the following crop report, the USDA

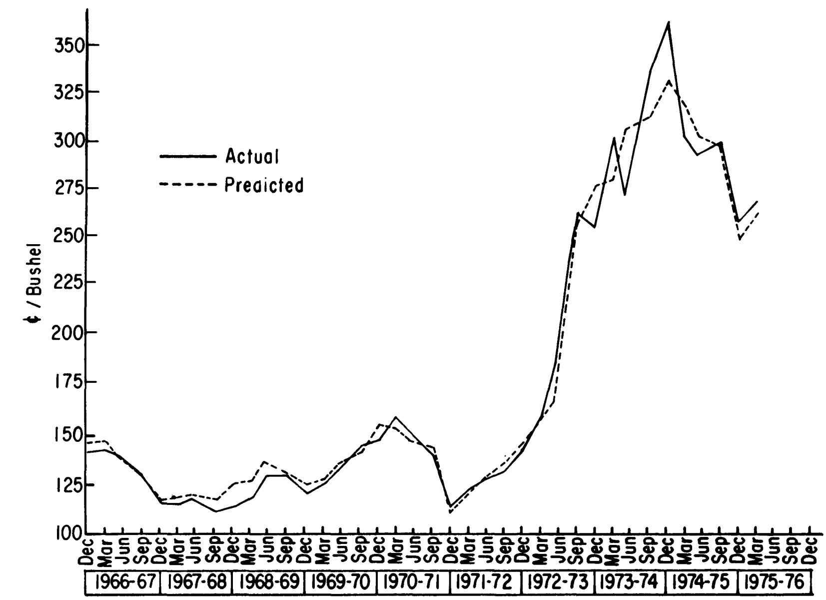


Figure 7. Quarterly average corn price: actual and predicted.

reduced the estimate of the October 1974 harvest significantly. A sharp increase in prices followed. This change in estimated production was not reflected in the prediction of the model.

In order to account for the impact of production and estimated production on price, USDA production forecasts would have to be used in the model. However, since it is the difference in production estimates that is important since these estimates can change each period, estimates of production would be of little value in a six-month predictive model. Also, drastic changes in production estimates, such as those in 1974, are not common.

Performance of the Model

The presentation of the model and the plot of the actual and predicted values gives an indication of the "goodness of fit" of the regression. However, since the objective is to predict price six months into the future, the usefulness of the model can only be established by its predictive performance when the predicted explanatory variables are used in the model. The model will be tested by using the predicted values of the explanatory variables to predict corn price three and six months into the future during the period 1967-1976. These predicted prices can then be compared with actual corn prices.

The variable DISAP1 is arrived at by adding feed usage, exports and seed, food and industrial usage. A four-quarter moving average is then calculated for this total and the average is lagged one period. The value for seed, food and industrial usage for a particular quarter is the value for the corresponding quarter during the previous year.

The error resulting from the use of predicted feed usage and exports to develop a variable to be used in another predictive equation is not as large as might be expected. The errors resulting from the prediction of feed usage and exports are reduced when DISAP is calculated. When feed usage and exports are added the errors from each estimate are offset in some cases. Also, the moving average smooths the predicted values and greatly reduces error. The deviation of the predicted values of DISAP from the actual values can be seen in Table 12 and Figure 8.

Three-Month Predictive Model. It is not necessary to use a predicted value for disappearance or estimated carryout in order to predict three months into the future. Since DISAP1 is lagged one period, the last observed value can be used in the three-month prediction. The value for estimated carryout is that published at the beginning of the period being predicted. The actual and predicted values for the three-month predictive model will be the same as in Figure 7.

Six-Month Predictive Model. In the six-month predictive model, the value for DISAP1 is predicted as shown in Table 12. The value of ESTCO is lagged. The actual and predicted values for the six-month predictive model can be seen in Figure 9.

Table 12. Calculation of Estimated DISAP and Deviation from Actual Values

Quarter and Year		Feed	Exports	Other	Disap- pearance	Estimated DISAP (4-qtr. moving avg.)	Actual DISAP (4-qtr. moving avg.)	% Error
J-M	1967	900	140	86	1126	1064	1078	1.3
A-M	1967	417	67	67	551	1046	1050	0.4
J-S	1967	856	188	120	1164	1040	1046	2.5
O-D	1967	1035	151	85	1271	1028	1062	3.3
J-M	1968	908	153	91	1152	1034	1088	5.2
A-M	1968	514	74	68	656	1061	1103	4.0
J-S	1968	985	193	120	1298	1094	1129	3.2
O-D	1968	1062	156	87	1305	1103	1125	2.0
J-M	1969	982	71	90	1143	1100	1158	5.3
A-M	1969	545	90	68	703	1112	1142	2.7
J-S	1969	987	213	117	1317	1117	1125	0.7
O-D	1969	1194	154	86	1434	1149	1143	0.5
J-M	1970	1018	161	90	1269	1181	1179	0.2
A-M	1970	586	91	66	743	1191	1206	1.2
J-S	1970	1004	213	117	1334	1195	1200	0.4
O-D	1970	1119	140	87	1346	1173	1191	1.5
J-M	1971	979	140	91	1210	1158	1159	0.1
A-M	1971	525	62	68	655	1136	1131	0.4
J-S	1971	908	179	119	1206	1104	1122	1.6
O-D	1971	1329	138	91	1558	1157	1177	1.7
J-M	1972	1056	153	94	1303	1180	1201	1.8
A-M	1972	640	87	71	798	1216	1260	3.6
J-S	1972	1107	269	129	1505	1291	1295	0.3
O-D	1972	1514	266	93	1873	1370	1360	0.7
J-M	1973	1124	274	97	1495	1418	1404	1.0
A-M	1973	713	206	73	992	1466	1452	1.0
J-S	1973	1115	357	217	1599	1490	1498	0.5
O-D	1973	1483	293	100	1876	1490	1501	0.7
J-M	1974	1141	290	107	1538	1501	1531	2.0
A-M	1974	603	184	81	868	1470	1535	4.4
J-S	1974	932	303	141	1376	1414	1468	3.8
O-D	1974	1168	280	106	1554	1334	1378	3.3
J-M	1975	887	279	112	1278	1269	1326	4.5
A-M	1975	463	220	84	767	1244	1237	0.6
J-S	1975	794	354	146	1294	1223	1228	0.4
O-D	1975	1112	319	106	1537	1219	1271	4.3

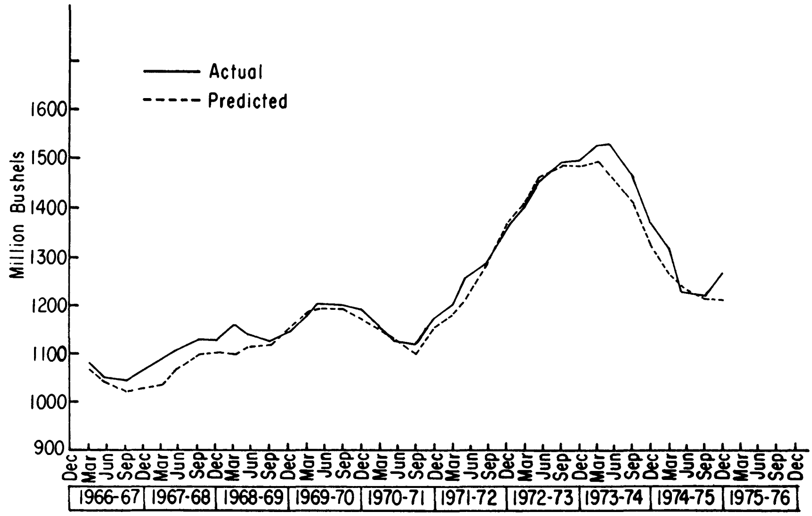


Figure 8. Quarterly DISAP: actual and predicted.

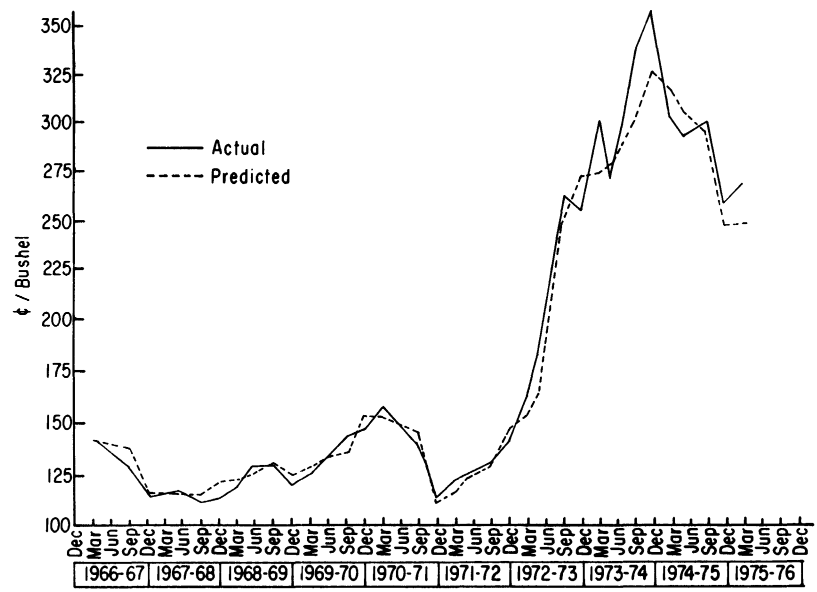


Figure 9. Quarterly average corn price: actual and predicted using predicted explanatory variables (six-month equation).

Hedging Strategies for Corn

For the purpose of this analysis, hedging is defined as the taking of opposite positions in the cash and futures market. The purpose of this section is to present and evaluate various hedging strategies which might be incorporated into a livestock feeder's decision model. The strategies relate only to the cost of feed. Since corn is the major feed input used by the majority of feeders, the strategies apply only to the cost of feeding corn. However, the conclusions resulting from the analysis of hedging strategies for corn should offer significant implications for decisions regarding other feed grains.

The strategies by design are not overly complicated so that direct application by the cattle feeder may be possible. Strategies of a speculative nature were not considered. The strategies are based on a feedlot operation in the 10,000-20,000-head range in the Oklahoma or Texas Panhandles. The cost structure of a smaller or very large operation may be different but the strategies would be applicable regardless of the absolute level of cost.

Method of Analysis

Observations on cost were for individual cattle feeding periods between September 1972 and June 1976. A feeding period was specified as 20 weeks. To insure that the analysis of typical cost would be applicable to both small and large operations, the cost of feeding corn was analyzed under two different buying situations.

In some cases feeders buy all corn needed for an entire feeding period at the beginning of the feeding period and pay storage costs. This situation was approximated by calculating the cost of the corn at the beginning of each feeding period and cumulating estimated storage cost through the period. Storage cost was estimated at 2 cents/bushel/month. The corn price used was the average price for number 2 yellow cash corn at Chicago during the week in which the feeding period began.

Since some feeders prefer to buy corn as it is needed, cost was also calculated on the basis of 20 weekly purchases. It was assumed that five percent of the corn needed during the period was purchased each week. Weekly average cash prices for number 2 yellow corn at Chicago were used (Table 13).

Table 13. Margin Requirements for One Corn Futures Contract.

Item	Definition or Calculating Procedure
Initial Margin	$1,500
Interest	9%
Feeding period	140 days
Feed per steer	56 bu.
Contract size	5000 bu.
Conversion factor	56/5000 = .0112
Initial margin cost per steer:	($15,000 × .09 × 140/360) × .0112 = $.52

The cost of hedging was also considered in the analysis. The initial margin for trading one corn contract was assumed to be $1,500. A nine-percent interest rate was applied to the $1,500 for the length of the feeding period as an estimate of opportunity cost or interest on a loan if the $1,500 was borrowed. Assuming that a steer consumed 56 bushels of corn during the feeding period, the initial margin per steer was $.52.

Margin calls were also considered in the calculation of profit or loss resulting from the hedging activities. Margin calls are requests for additional money to protect against the risk of an adverse price move in the interim between the establishment of a hedge position and its liquidation. In this analysis, margin deposits were assessed if the price of the futures contract moved against the original position by more than $.10/bushel. After price moved against the original position by $.10, $50 deposits were made for each subsequent $.01 move. The futures contract used in each strategy was the contract for the month during or just after the month closest to the time the cattle were to come off feed.

Total cost was calculated as the difference between the cost of the corn plus hedging cost and the profit from the hedge. The method of calculation of cost is presented in Table 13 and equations 1,2, 3 and 4.

(1) If PP − CFP > $.10 then

$$\text{MARGIN}_t = [(\text{PP} - \$.10) - \text{CFP}] \times 5000 \times .09$$

(2) If CFP − PP > $.10 then

$$\text{MARGIN}_t = [\text{PP} - (\text{CFP} - \$.10)] \times 5000$$

(3) $$\text{Net Cost} = \sum_{t=1}^{20} (\text{CCP}_t \cdot 250) - [(\text{SP} - \text{PP})\, 5000] + \sum_{t=1}^{140} \text{MARGIN}_t$$

(4) Net Cost Per Steer = Net Cost × .0112

where:

PP = price at which the futures contract was purchased
CFP = current price of the futures contract
CCP = current cash price
SP = price at which the futures contract was sold.

Performance Criteria. Two criteria can be used as the basis for comparison of the performance of the strategies. The first criterion is the mean cost of the corn purchased under each strategy. Since an objective of any feeding enterprise is to reduce cost, the feeder should be interested in incurring the lowest possible cost with respect to his corn purchases. The second criterion is the variability in cost for the alternative strategies. The feeder is interested in the lowest possible variation at a given level of cost since by reducing the variation in cost the feeder reduces risk.

On the basis of these criteria, the most successful strategy reduces both average cost and the variation in cost. To facilitate comparison, mean cost and the standard deviation of cost during the period analyzed were calculated for a situation in which corn purchases were completely unhedged. Any strategy is preferred to the unhedged situation if it accomplishes the following:

- decreases the mean cost of purchasing corn without adversely affecting the standard deviation.
- decreases the standard deviation without significantly increasing the mean cost of purchasing corn.
- decreases the mean cost of purchasing corn and decreases the standard deviation.

The Strategies

Strategy I: Unhedged Operation. The cost of unhedged purchasing of corn was estimated as a standard against which alternative hedging strategies might be compared. The cost of purchasing corn for an unhedged operation was calculated under two different buying situations as mentioned earlier. The first buying situation approximated the cost to the feeder who bought corn on an "as needed" basis. The second buying situation assumed the feeder purchased all corn for the entire feeding period at the beginning of the period. The results of the unhedged strategy with respect to mean cost and standard deviation per head were as follows:

Weekly purchases: Mean = \$159.10,
Standard Deviation = \$32.24.

One purchase: Mean = \$160.33,
Standard Deviation = \$39.07.

Strategy II: Hedge and Hold. When the feeder buys corn over time, he faces the risk of rising prices between purchases. One possible method of shifting this risk is by the purchase of corn in the futures market when corn is purchased in the cash market. Under this strategy a one-week supply of cash corn was purchased in week t at the same time cattle were put on feed. The simultaneous purchase of the amount of corn needed for the remaining 19 weeks of the feeding period was executed in the futures market. This long position was held throughout the feeding period. The hedge was lifted by the sale of corn in the futures market in week t + 19, the time when the cattle came off feed. The results were as follows:

Mean = \$150.60,
Standard Deviation = \$49.88.

Strategy III: Hedge When Five-Day Moving Average > 10-Day Moving Average. Though both Strategy II and Strategy III involve long hedges, the basis for placing the hedge is different for the two strategies. With Strategy II the long hedge is automatic and is placed whenever cash corn is purchased.

Strategy III is based on a five- and ten-day moving average of the closing prices of the futures contract that is being purchased. The two decision rules for hedging on the basis of the five- and ten-day moving averages are:

1. If the five-day moving average crosses the 10-day moving average from below in time period t, place the long hedge immediately and hold it throughout the feeding period.

2. If the five-day moving average is below the 10-day moving average in period t, wait until the five-day moving average crosses the 10-day moving average from below before placing the hedge. When the hedge is placed, hold this position throughout the remainder of the feeding period.

The 10-day moving average smooths daily changes in price indicating the underlying trend in prices. The five-day moving average is more sensitive to changing prices. Therefore, the five-day moving average leads the 10-day moving average and signals a new trend in the direction of price. The mean and standard deviation for this strategy were as follows:

Mean = \$150.38,
Standard Deviation = \$49.99.

Strategy IV: Hedge When Five-Day Moving Average > 10-Day Moving Average; Remove Hedge When Five-Day Moving Average < 10-Day Moving Average. Strategy IV differs from Strategy III in that the hedge, when placed, is not automatically held through the remainder of the feeding period. The first decision rule under Strategy IV is the same as under Strategy III. However, under Strategy IV, when the five-day moving average crosses the 10-day moving average from above, the long hedge was lifted by selling the equivalent of the purchase in the futures market. This process of trading in and out of the futures market on the basis of the five- and ten- day moving averages was continued during each feeding period. The mean and standard deviation resulting from this strategy were as follows:

Mean = \$149.72,
Standard Deviation = \$41.09.

Strategy V: Hedge if Projected Cash Prices > Futures Price. The hedging strategies discussed thus far have not been based on expectations of cash corn prices when the cattle are to be sold. Strategy V incorporates the outlook price projected by the corn price model. Under this strategy, the long hedge was placed and held if the cash corn price projection for the period nearest the time that the cattle were to be sold was greater than the price of the futures option nearest the time that the cattle were to be sold.

To allow for some margin of error in the cash price projection, the futures option was purchased only if the futures option price was below the lower limit of a confidence band around the cash price projection. The confidence band was specified as the projected price plus or minus the standard deviation of the price model. The mean and standard deviation resulting from this strategy were:

Mean = \$143.44,
Standard Deviation = \$40.47.

Strategy VI: Hedge if Projected Cash Price > Futures Price and Five-Day Moving Average > 10-Day Moving Average. Strategy VI combines Strategies IV and V. The long hedge was placed and held through the feeding period if the projected cash price was greater than the price of the futures option at the time the cattle were to be sold and if the five-day moving average of price was above the 10-day moving average. If the projected cash price was greater than the futures price and the five-day moving average was below the 10-day moving average, then the hedge was not placed until the five-day crossed the 10-day moving average from below. After the hedge was placed, it was held throughout the feeding period. The same confidence band mentioned in Strategy VI was used in Strategy VII. The mean and standard deviation resulting from Strategy VI were:

Mean = \$143.50,
Standard Deviation = \$40.44.

Strategy VII: Hedge if Projected Cash Price > Futures Price and Five-Day Moving Average > 10-Day Moving Average; Remove Hedge When Five-Day Moving Average < 10-Day Moving Average. Strategy VII combines Strategies IV and V. The long hedge was placed if the projected cash price was greater than the price of the futures option of the time the cattle were to be placed and if the five-day moving average was above the 10-day moving average. If the projected cash price remained above the futures price but the five-day moving average moved below the 10-day moving average, the hedge was lifted. The hedge was placed again when the five-day moving average crossed the 10-day moving average from below. The mean and standard deviation resulting from this strategy were as follows:

Mean = \$147.64,
Standard Deviation = \$38.23.

Results

The performance of the strategies with respect to mean cost and variance is summarized in Tables 14 and 15. In Table 14, strategies are compared to the unhedged operation in which corn is purchased weekly. In Table 15, strategies are compared to the unhedged operation in which corn is purchased only once during a feeding period. For each strategy, the change in the mean cost and the change in the standard deviation from the unhedged operation can be seen. High and low costs for each strategy are also presented.

When compared with weekly purchases, the strategies which involve cash price projections (V, VI, VII) result in the largest decreases in mean cost and the smallest increases in the standard deviation. This suggests that hedging can be a more effective tool for reducing costs when hedging decisions are based on reasonable expectations of future prices.

Table 14. Cost Comparison of Hedging Strategies and Weekly Corn Purchases (Unhedged).

Strategy	Mean	Change Compared To Strategy I	Standard Deviation	Change Compared To Strategy I	Range of Costs Low	High
			($/head)			
I	159.10		32.24		86.05	211.98
II	150.60	−8.50	49.88	+17.64	33.84	262.98
III	150.39	−8.71	49.99	+17.75	33.84	263.74
IV	149.72	−9.83	41.09	+8.85	50.84	239.60
V	143.44	−15.66	40.47	+8.34	33.84	211.98
VI	143.50	−15.60	40.44	+8.20	33.84	211.98
VII	147.64	−11.46	38.23	+5.99	50.84	211.98

Strategy IV is the only strategy not involving a price projection which results in a decrease in mean cost which is greater than the increase in the standard deviation. This strategy is the most selective of the strategies not involving a price projection. Strategies II and III are not as responsive to changing market conditions as Strategy IV. These strategies call for the hedge to be held once it is placed regardless of changing market conditions. All strategies result in a lower mean cost than the unhedged operation.

All strategies result in higher standard deviations than that of the unhedged operation. The amount of variability in cost indicated by the standard deviation is judged to be an important consideration. However, the level at which the variability occurs must also be considered. The level at which the variation in cost occurs is indicated by the high and low cost figures for each strategy. Although the unhedged operation results in a lower standard deviation than the strategies involving cash price projection, much of the variation resulting from the strategies involving projections is at a lower level. The high cost for both strategies is the same while the low cost for Strategies V and VI is $53/head lower than for the unhedged operation.

When the hedging strategies are compared with the unhedged operation in which all corn is purchased at the beginning of the feeding period, the results are similar to those for the unhedged operation purchasing weekly. The performance of the strategies appears slightly more favorable when compared to the unhedged operation which purchases once during the feeding period.

Table 15. Cost Comparison of Hedging Strategies and Corn Purchased Once Each Period (Unhedged).

Strategy	Mean	Change Compared To Strategy I	Standard Deviation	Change Compared To Strategy I	Range of Costs Low	High
			($/head)			
I	160.33		39.07		82.60	237.93
II	150.60	−9.73	49.88	+10.81	33.84	262.98
III	150.39	−9.94	49.99	+10.92	33.84	263.74
IV	149.72	−10.61	41.09	+2.02	50.84	239.60
V	143.44	−16.89	40.47	+1.40	33.84	211.98
VI	143.50	−16.83	40.44	+1.37	33.84	211.98
VII	147.64	−12.69	38.23	−0.84	50.84	211.98

Summary

Uncertainty about the price of feed inputs is a serious problem common to all livestock feeding enterprises. The volatile nature of current feed grain prices has an adverse effect on the livestock feeder's decision process. An adequate knowledge of probable feed grain price movements is necessary for effective long- or short-range planning. Reasonably accurate feed grain price outlook is needed as an aid to feeders in formulating marketing decisions.

The overall objective of this study was to develop forecasting techniques which would allow for the projection of future cash corn prices on a quarterly basis. These projections were then to be used as an input in hedging strategies for corn which might aid the livestock feeder in his efforts to realize protection against cash price variability. To achieve the objective it was necessary to develop a multiple regression model to predict cash corn prices. The projected prices from the regression model were then incorporated into the development of hedging strategies. Several strategies were developed in which the decision on whether to hedge or what type of hedge to execute was based on the price projected by the regression model.

The price model was comprised of two continuous explanatory variables and two dummy variables. The explanatory variables reflected the seasonalized level of corn disappearance quarterly and quarterly estimates of year-ending corn stocks made by the USDA. An intercept dummy and a slope dummy for ending stocks was specified. Ninety-seven percent of the variation in quarterly cash corn prices was explained by the model.

In order to project into the future, values for the explanatory variables were needed for future periods. Since USDA estimated carryout could not be predicted, it was necessary to lag the value of this variable to predict future prices. It was possible to predict the seasonalized value of disappearance, however. Separate models were developed to predict values for the two major components of disappearance, feed and exports. Residual corn disappearance was estimated from the residual disappearance for the previous year. The estimated values for feed usage, exports and residual disappearance were added and a moving average was calculated for this sum. It was necessary to seasonalize the value of disappearance because there was more seasonal variation in the independent variable, disappearance, than in the dependent variable, price.

Multiple regression was used to predict feed usage. In the model, feed usage was specified as a function of 1) stocks of corn as a percentage of normal, 2) steer margins lagged, 3) the number of hogs and pigs lagged, 4) the lagged ratio of soybean meal price to corn price and 5) seasonal dummy variables for the April-May and October-December quarters. Ninety-three percent of the variation in quarterly feed usage was explained by the model.

It was necessary to develop a separate model for October-December feed usage because the estimate for stocks as a percentage of normal is not always accurate prior to October 1. October-December feed usage was specified as a function of 1) the number of cattle on feed lagged, 2) the price of hogs lagged, 3) the lagged ratio of grain sorghum price to corn price and 4) an intercept dummy if the current estimate of production plus carryin stocks is greater than 110 percent of normal. Ninety-five percent of the variation in October-December feed usage was explained by the model.

Multiple regression was also used in developing the export model. In this model quarterly exports were specified as a function of 1) world corn production per capita, 2) the number of animals in the European Economic Community, 3) a weighted composite index of U.S. currency values relative to the currencies of the major corn importers, 4) seasonal dummy variables for the April-May and June-September quarter and 5) an intercept for the period after 1972. The variables in the model account for 88 percent of the variation in quarterly exports. The error present in the feed usage model and the exports models was reduced when the moving average of disappearance was calculated. The error in the predicted value of disappearance was less than the error present in the separate predictions for feed usage and exports. Between January-March of 1967 and October-December of 1975, the average percentage deviation of the estimated value of the moving average of disapperance from the actual value was less than two percent.

The projections from the price model were incorporated into various hedging strategies for what was judged to be a typical cattle feeding operation. In several strategies the decision of whether or not to hedge was based on the projections from the price model. The strategies using the price projections were superior to the other strategies on the basis of mean cost and standard deviation.

The forecasts and related hedging strategies discussed have the potential of reducing cost and thereby increasing net revenue to the cattle feeder. Although this analysis dealt specifically with a cattle feeding operation, the results should be applicable to other types of livestock feeding enterprises. Also, the forecasting techniques and hedging strategies applied to corn in this study are believed to be applicable to other feed grains.

References

(1) Weldon, Richard and Luther Tweeten. "Feed Grain Stocks and Prices." *Oklahoma Current Farm Economics*, Vol. 47 (September, 1974), pp. 3-6.

(2) Anderson, Kim B. and Luther Tweeten. "A Simplified Procedure to Predict Seasonal Average Wheat and Feed Grain Prices." *Oklahoma Current Farm Economics*, Vol. 48 (October, 1975), pp. 3-8.

(3) Barr, Terry N. *Demand and Price Relationships for the U.S. Wheat Economy*. Washington: Economic Research Service, November, 1973, pp. 15-25.

(4) Butell, Robert and Abner Womack. *April-June Feed Demand for Corn*. Washington: Economic Research Service, May, 1976, pp. 21-23.

(5) Fox, Karl A. *The Analysis of Demand for Farm Products*. Washington: Bureau of Agricultural Economics, Technical Bulletin 1801, 1953.

(6) U.S. Department of Agriculture. *Feed Situation*. Series fds, 248-263. Washington: Economic Research Service, published quarterly, selected issues.

(7) U.S. Department of Agriculture. *Cattle on Feed*. Washington: Statistical Reporting Service and Crop Reporting Board, published monthly, selected issues.

(8) U.S. Department of Agriculture. *Hogs and Pigs*. Washington: Statistical Reporting Service and Crop Reporting Board, published quarterly, selected issues.

(9) U.S. Department of Agriculture. *Grain Market News*. Washington: Agricultural Marketing Service, published weekly, selected issues.

(10) U.S. Department of Agriculture. *Livestock and Meat Situation*. Series LMS, 141-120. Washington: Economic Research Service, published monthly, selected issues.

(11) U.S. Department of Agriculture. *Agricultural Prices Annual Summary 1975*. Series Pr, 1-3 (76). Washington: Statistical Reporting Service and Crop Reporting Board, 1976.