Is the central Iowa cash corn market an efficient market?

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Is the central Iowa cash corn market an efficient market?

by

Kerry William Tudor

A Thesis Submitted to the Graduate Faculty in Partial Fulfillment of The Requirements for the Degree of

MASTER OF SCIENCE

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Signature have been redacted for privacy

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I. INTRODUCTION

A. The Problem

When a farmer makes the decision to store his grain and sell it at some later date or dates rather than sell it at harvest time, his objective is to maximize the difference between the price per bushel received and the per bushel cost of storing that grain. In the simplest case where all the grain is stored for the same length of time and sold at a single price, the farmer will want to maximize the net price received. Using symbols, this can be written

\[ P_n = P_s - W \]  

where \( P_n \) is the net price received by the farmer, \( P_s \) is the gross sale price or price quoted by the buyer, and \( W \) is the warehouse cost or cost of storing the grain from harvest to the date of sale. \( W \) includes, among other things, the costs of reducing the grain's moisture content to a level at which the grain is storable.

More realistically, since farmers typically liquidate their grain stocks through multiple sales, the objective is to maximize average net price. This can be expressed symbolically as

\[ \bar{P}_n = \frac{1}{B_u} \sum_{i=1}^{M} (P_{s_i} - W_i)B_{u_i} \]  

(1.2)
where \( \bar{P}_n \) is the average net price, \( M \) is the total number of market transactions or sales, \( P_{s_i} \) is the quoted price for the \( i^{th} \) sale, \( W_i \) is the cost of storing the quantity sold at the \( i^{th} \) sale from harvest to that sale date. \( B_{u_i} \) is the number of bushels sold at the \( i^{th} \) sale, and \( B_{u_t} \) is the total number of bushels sold.

This approach can be extended by incorporating the average net price into a rate of return, call it the return to storage, which allows the farmer to compare his return to storage with an appropriate opportunity cost - the rate of return he could have earned had he sold the grain at harvest and purchased a financial instrument or invested the proceeds in some capital project. The rate of return to storage can be written

\[
R = \frac{\bar{P}_n}{P_h} - 1
\]

(1.3)

where \( R \) is the return to storage, \( \bar{P}_n \) is the average net price from Equation (1.2) and \( P_h \) is the net price at harvest time. \( P_h \) is a net price because it is the price prevailing in the market less drying and shrinkage costs. If a farmer elects to sell his grain at harvest time, he must either pay directly for drying the grain or accept a reduced price for his product. Failure to account for such costs in both \( \bar{P}_n \) and \( P_h \) results in deflated values of \( R \). In addition, \( P_h \) is
treated as a single price for reasons of simplification. Realistically, it would be a composite of prices observed over several days or even weeks.

The farmer will realize a zero rate of return to storage if the average net price, $\bar{P}_n$, is exactly equal to $P_h$. If $\bar{P}_n$ is negative, in other words if storage costs exceed total revenue, the computed value of $R$ will be less than negative one. To make grain storage worthwhile, the farmer will want to realize a rate of return to storage which is greater than or equal to his appropriate opportunity cost. In other words, the farmer stores his grain in anticipation of a seasonal rise in prices for which $P_s - P_h$ exceeds the accrual of storage costs by a desirable amount.

In a world without uncertainty, farmers with perfect knowledge and perfect foresight would have no trouble predicting the maximum value $P_n$ would take on and the time of that value's occurrence during the marketing season. In the real world, however, uncertainty in ubiquitous, and farmers must rely on forecasts based on current knowledge when making marketing decisions. The volume of information available partially determines the effectiveness of forecasting. The other determinant is the ability of the forecaster to convert the information set into relevant decision-making tools. Since storage costs are either known a priori or can be
estimated fairly accurately, the key to maximizing $R$ is the ability to predict values of $P_s$.

If a farmer relies on private sources of information such as a market information service, the cost of his subscription must be taken into account when figuring the total cost of storage. On the other hand, publicly available information or information provided by government agencies is free. It may or may not include price forecasts. If a public agency does not provide price forecasts, the burden of transforming the available information into prices is left to the farmer. When price forecasts are provided, they are generally long range forecasts, or average prices expected over a given time period. By design, public agencies do not provide marketing recommendations as would a private market information service. A third option which is commonly used is to predict future price behavior on the basis of observations of past price behavior. This approach is supported by the ideas that certain patterns of price movements repeat themselves through time in a predictable manner, and that these patterns operate with a tendency toward persistence. In other words, rising prices tend to be followed by rising prices, and falling prices tend to be followed by falling prices.

Uncertainty, aside from creating a need for techniques
of prediction, has given rise to organized grain futures markets on which contracts for future delivery of grain are traded. The prediction of future prices, or more importantly, future price changes is important in futures markets also because successful prediction, aside from luck, is necessary for profitable trading. For this reason, traders spend a great deal of time and physical resources collecting and assimilating information which will determine the future price of grains.

Because the futures markets have replaced terminal cash markets as pricing reference points (11, 12) for local cash markets, the success of various prediction techniques utilized by farmers may depend on the characteristics of price changes in the futures markets. A large volume of literature has appeared in recent years which deals exclusively with measuring and analyzing price changes in competitive auction markets such as the stock market, commodity futures markets, the U.S. Treasury bill market, foreign exchange markets, and so on. The heart of this literature, the theory of efficient markets, implies that because information is used rationally and efficiently by traders, future price changes are not predictable from knowledge of past price changes. This has implications for the farmer who relies solely on observations of past prices.
when making marketing decisions. Furthermore, since farmers generally have neither the time nor the resources to collect and assimilate the volume of information used by traders in the futures market, they cannot expect to stay abreast of activity in the futures or cash markets.

B. The Purpose of this Study

The purpose of this study is to apply those statistical techniques used to analyze price changes in competitive auction markets to a single cash grain market, the central Iowa cash corn market, and determine the implications for the ways in which farmers make grain marketing decisions. If the corn futures market is an efficient market and daily price movements in cash bids by country elevators are closely related to price movements in the futures market, future price changes will not be predictable from knowledge of past price changes. Farmers might do better - either in terms of increased utility resulting from simplified decision-making processes or decreased costs - by not relying on procedures that use only past price behavior as information. Additionally, farmers would have to justify the costs of market information services on the basis of forecasting accuracy. The unpredictability of future price changes could nullify a promising forecast if unforeseen information
reaching the trading floor of the futures market resulted in a sharp decline in prices.

For reasons of clarity and consistency, the following definitions (12) will be adhered to throughout the analysis.

Cash price: a grain price determined by a transaction which transfers the ownership of actual grain from seller to buyer in either the immediate or deferred time period.

Futures price: a grain price determined by a transaction on a contract market which establishes a legally binding contract between buyer and seller to deliver or accept delivery of a fixed quantity of a certain quality or qualities of grain at a specific delivery point or points during a specific (deferred) calendar month.

Basis price: a grain price relating the measure of value represented by the nearby futures price to the specific, immediate conditions surrounding a transaction to transfer the ownership of actual grain in either the immediate or deferred time period. The basis price, in combination with the nearby futures price, establishes a specific cash price. (Basis price is commonly defined as the difference between the cash (or spot) price and the nearby futures price.)
II. RATIONAL EXPECTATIONS AND THE EFFICIENT MARKETS THEORY

An important paper in the literature dealing with expectations and price formation appeared in the early 1960's. The author of that paper, John Muth (20), was concerned with the treatment of expectations in dynamic economic theory, specifically with the role information played in the formation of expectations. Muth's contention was that past theories had not assumed enough rationality on behalf of individuals forming expectations. Since expectations were informed predictions of future events, they were called "rational" expectations, and the rational expectations hypothesis stated that these expectations were mathematically distributed about the prediction of the relevant or correct economic theory. In other words, the mathematical expectation of the aggregated informed predictions would be equal to the prediction of the complete set of relevant equations. The hypothesis also asserted that information was scarce and was generally not wasted.

The rational expectations hypothesis can be applied to the activities of traders in competitive auction markets. Since traders place bids on stocks or futures contracts which are based upon anticipations of the future, successful trading depends on how close those anticipations
are to the actual outcome. To maximize profits, traders will collect information up to the point where the cost of obtaining that information is equal to its productivity, and what information is collected is not wasted but used to form a rational expectation of the future. In general, these anticipations will be equal to the prediction of the relevant economic theory.

If traders anticipate that prices will be higher in the future, they will bid up the price of the stock or futures contract forcing profits toward a normal level. Abstracting commissions and risk, suppose that traders expect the price of a futures contract to rise to $P_{t+1}$ in the next time period from $P_t$, the current price. Let $r$ be a rate of return the trader could earn on his funds elsewhere. Then as long as

$$P_t < \frac{P_{t+1}}{1+r}$$

a trader would be willing to purchase the contract.\(^1\) In the aggregate, traders would bid up the price of the contract, $P_t$, until $P_t = \frac{P_{t+1}}{1+r}$ removing the possibility of selling the contract for a profit at time $t+1$.

\(^1\)A subscript to the left of $P$ indicates that the price is an anticipated price. The absence of a subscript to the left indicates an observed price. For example, $tP_{t+1}$ is the expectation, as of time $t$, of the price that will prevail at time $t+1$. $P_t$ is the price observed at time $t$. 
As long as the inequality existed, traders would force $P_t$ upward. Trading would cease when $P_t$ was brought into line with the discounted expected price. Of course, in the dynamic world of auction markets, equality would never be realized. There would only be a tendency toward zero profits.

Similarly, if the anticipated price was such that

$$P_t(1+r) > P_{t+1}^t,$$

traders would sell contracts until they were indifferent between selling the contract now and reinvesting the proceeds or selling the contract at $t+1$. Because trader's bids reflect their informed expectations, and because these expectations are mathematically distributed about the prediction of the correct theory, prices will reflect all available information. A market in which prices reflect all available information is, by definition, an "efficient market."

Persistence of direction of price changes would not be expected to exist in markets which use information efficiently. In active auction markets, competition for profits requires that information be bid into prices quickly because a large number of traders have access to the same information. Additionally, since traders search diligently for information,
any systematic movements in prices would be easily and cheaply discovered and used until the profitability of such knowledge was removed. Consequently, a series of price changes from an efficient market should exhibit little positive serial correlation.

If competition removes all serial dependence from price changes, profitable mechanical trading systems\(^2\) are ruled out. Mandlebrot (17) and Samuelson (21) have shown, using involved mathematical proofs, that nonprofitability would be consistent with price series which exhibit martingale properties. A martingale sequence is defined algebraically as

\[
E(P_{t+1} | B_t) = P_t
\]  

(2.1)

where \(E\) is the expectations operator and \(B_t\) is all information contained in the past history of the process. In words, the definition says that the expected value of price in the next period, given all currently available

\(^2\)A mechanical trading system is a rule or set of rules designed to help carry out speculative buying and selling independently of human decisions. The system determines on the basis of price movements when stocks or futures contracts should be traded. A simple example would be a rule which orders a trader to buy if the price moves up, say 5%, and orders him to sell if the price falls 5% from a subsequent high price.
information about the past, is the current price.\footnote{An alternative approach would have been to look at prices as they rose from a seasonal low to a seasonal high rather than looking at the entire time series. In that case, price movements would have been described by a submartingale sequence, $E(P_{t+1} | B_t) \geq P_t$. The drawback of such an approach is that fairly consistent seasonal patterns have not been observed in recent years, especially during the five years covered by this paper.}

In terms of predictability, the martingale property implies that the optimal, least squares predictor of $P_{t+1}$ is $P_t$. Subsequently, the best linear predictor of $P_{t+1}$ is $P_t$ which is consistent with what Granger and Morgenstern (10) have termed a "second-order martingale." The second-order martingale obeys the model

$$P_t = P_{t-1} + e_t$$

(2.2)

where $E(e_t) = 0$ and $\text{cov}(e_t, e_{t-s}) = 0, s \neq 0$.

If the corn futures market is an efficient market, it follows that the best predictor of tomorrow's price is today's price, given past prices. In addition, since the price $n$ days into the future is the current price plus the sum of $n$ price changes, the best predictor of any future price is today's price. Let $P_{t+n}$ be the price $n$ days into the future. Then

$$P_{t+n} = P_t + \sum_{i=1}^{n} e_{t+i}$$
and
\[ E(P_{t+n}) = E(P_t + \sum_{i=1}^{n} \tilde{e}_{t+i}) \]
\[ = p_t + \sum_{i=1}^{n} E(\tilde{e}_{t+i}). \]

But since \( E(\tilde{e}_{t+i}) = 0 \),
\[ E(P_{t+n}) = p_t. \] (2.3)

In other words, the series of daily price changes will approximate a random series.

The cash market, being tied closely to the futures market, should also exhibit the temporal characteristics of an efficient market, and cash prices should reflect all available information. Factors which determine the local basis price - local supply and demand conditions, storage and handling costs, transportation costs, and price risk - are taken into account when the futures price is adjusted to reflect local conditions. As long as changes in the basis price exhibit no serial persistence, in other words, if information relevant to the basis price is used quickly and adjustment is not drawn out over several days, the cash price should exhibit the same random behavior as that

\[ p_t \]

\[ \tilde{P}_{t+n} \]

\[ \tilde{e}_{t+i} \]
hypothesized for the futures prices. It follows that the best forecast one could make about the future in the cash market, given knowledge of past prices, is that prices will exhibit a seasonal pattern due to the seasonality of harvest and the existence of storage costs.
III. THE PROCEDURE

A. The Analytical Approach

The statistical analyses that will be used in this study are designed to test a time series of cash corn prices to see how well that time series conforms to the model associated with Equation (2.2). If that model is, in general, rejected by the battery of tests to be used, the efficient market hypothesis will be rejected. Initially, it is necessary to determine how closely the time series fits the model's single equation, \( P_t = P_{t-1} + e_t \). If prices satisfy this equation, then the vector of residuals will be price changes and statistical techniques can be applied directly to these first differences of prices.\(^5\) If the time series does not fit the equation, the series will exhibit a trend over time for which adjustments will have to be made in order to get an unbiased picture of the temporal relationship between price changes. The linear relationship between \( P_t \) and \( P_{t-1} \) will be estimated using ordinary least squares, and the parameter estimates will be tested to see if they conform to hypothesized values.

The assumptions usually made about the residuals of a

\(^5\)That \( e_t \) is the first difference can be shown simply by subtracting \( P_{t-1} \) from both sides of the equation, which gives \( e_t = P_t - P_{t-1} \).
regression equation are that the residuals are independent, identically distributed random variables with mean zero and variance $\sigma^2$, and the distribution is commonly assumed to be normal [i.e., $e_t \sim \text{NID}(0, \sigma^2)$]. If the time series fits the equation of the model and the residuals satisfy the above assumptions, the strict random walk model is satisfied. However, proving independence of successive price changes is not easily done. It is for this reason that the less restrictive second-order martingale model is used as a criterion.

The major portion of the analysis will consist of determining how closely the series of price changes conforms to the assumptions about regression equation residuals. This will be accomplished by testing for normality via a chi-square goodness-of-fit test, testing the hypothesis that the mean of the price changes is zero, and testing for systematic relationships such as seasonality and autocorrelation. Non-normality of the distribution does not preclude the model from holding, but it could have implications for the interpretation of statistical tests.

Both parametric and nonparametric tests will be used to test for systematic relationships among price changes. The nonparametric tests will be included so as to eliminate questions about populations from which price changes come.
The general categories into which the nonparametric tests fall are runs above and below the median, runs of the same sign, and runs up and down. The parametric test will test for significant autocorrelation of price differences lagged for various numbers of days.

The above tests are what Fama (7) calls weak form tests, in which the information set contains only the set of past prices. Semi-strong form tests, on the other hand, are concerned with how efficiently prices adjust to "obviously publicly available information." The semi-strong form test in this analysis will consist of observing price changes in the cash market between the day of release of the U.S.D.A. crop reports and the following trading day. If futures traders are continually collecting information on crops, the news should already have been bid into the price when the announcements were made, and aside from the effects of measurement errors on behalf of private information collectors, there should be no significant announcement effect.

B. The Data Set

The data for this study consist of daily cash prices - holidays and weekends excluded - from the central Iowa corn market, or more appropriately, cash bids on those days when corn futures contracts are traded on the Chicago Board of
Trade. The prices are collected and disseminated in the following manner: persons on the staff of The Des Moines Register contact four country elevators in the Des Moines area at 3:00 P.M. and ask for their cash bids as of 1:15 P.M., which is closing time for futures trading on the Chicago Board of Trade. On the following day, the newspaper publishes the highest and lowest bids under the subheading, Central Iowa Markets. The raw data used in this study is a five year series of the averages of those highest and lowest bids. The observations begin on the first trading day of 1973 and end on the final trading day of 1977 giving a total of 1247 observations. The prices used are bids for number two yellow corn but the first differences of these prices will serve as proxies for price changes of other grades.
IV. A REVIEW OF PAST STUDIES

This section will be concerned with findings that have come out of several studies of the corn futures market and one study that included cash corn prices. The efficient market theory has held up well in statistical analyses of the stock market but the results have been mixed when the theory has been applied to commodity markets. However, studies have tended to lump commodities together and accept or reject the efficient market (random walk) hypothesis based on the performances of the aggregated contracts. The focus here will be placed on the corn futures market so that a general picture of the efficiency of that market alone can be perceived. A survey of the literature will provide a standard against which the results of this study can be compared as well as a view of how statistical techniques have evolved in the literature.

Brinegar (1) studied the behavior of futures prices for preparation of a doctoral dissertation in the mid 1950's. He applied a test that was being developed by Holbrook Working to series of commodity futures prices for the purpose of determining whether systematic patterns were present. Working's test, called the index of continuity, was based on ranges of prices, and it was developed to overcome the shortcomings of test statistics which relied on computations
of covariances. The latter tests were criticized because they assumed rigid lags in recurrent patterns of prices over time and assumed that the observations were drawn from populations with constant standard deviations. Brinegar decided against the use of other nonparametric tests because they were time consuming and inefficient.

The data used by Brinegar consisted partly of daily closing prices for corn futures at Chicago over two five-year periods, 1937-41 and 1947-51. Because the test statistic required a continuous series of prices, Brinegar "spliced" prices from dominant contracts where a dominant future is one for which "open contracts exceed those of any of the other futures, and remain greater." On the basis of his tests, Brinegar found evidence of nonideal behavior of speculative prices; a tendency for continuity of prices in longer intervals and a slight reaction tendency in shorter time intervals.

Larson (16) also used Working's index of continuity as a testing device in an analysis of commodity futures prices. He included in his study closing prices of corn futures on the Chicago Board of Trade for two ten-year periods, 1922-31 and 1949-58. Larson concluded that his analysis had "demonstrated the existence of a high-order, low-weight moving average stochastic process generating price changes, as envisioned by Working's theory of anticipatory
Moreover, there was no indication of excessive fluctuations of prices as charged by critics of the futures markets. And finally, Larson stated that the results could be "given the economic interpretation that market price changes are closely tied to market news, which tends to be a true reflection of changing demand and supply conditions."

Houthakker (13) dealt solely with the profitability of "stop orders" as a test of nonrandomness of price changes. The stop order is a mechanical trading system in which a trader who is long sells a contract when the price drops x percent below the initial purchase price, and a trader who is short buys a contract when the price rises x percent above his initial selling price. Houthakker

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6 Working's article (26) is well-known to those who are familiar with the efficient markets-random walk literature and deserves recognition here even though it is not directly related to the rational expectations theme. The implications of Working's theory of anticipatory prices for futures markets are very similar to the implications of rational expectations, and his pioneering work in commodities markets has influenced much of the subsequent work.

7 A trader's position is termed "long" or "short" depending on whether he is a buyer or a seller in a contract agreement. A trader is said to be "long" of a commodity future if he is a buyer (agreed to take delivery). Conversely, a trader is said to be "short" if he is a seller (agreed to make delivery).
reasoned that a trader's average long term profits would not be affected if the price series was truly random. If the series was not random, the trader would recognize price patterns and adjust the percentage of his stop order accordingly, thus increasing profits over time. The x percent stop orders were applied to corn futures over the periods October 1, 1921 to October 1, 1939 and February 1, 1947 to October 1, 1956.

Fabricated traders went long or short on each contract for four months or until a stop order became effective. Commissions were ignored. Houthakker found that for every contract, some stop percentage between zero and 100 did better than no stop order at all and that stop orders appeared to be more effective at reducing losses than increasing profits. He concluded that the statistical significance of his results were difficult to assess because of the absence of more developed theories of random series, but nevertheless they indicated "the existence of patterns of price behavior that would not be present if price changes were random."

Stevenson and Bear (22), in reviewing past studies, questioned the validity of Larson's approach. They did not believe the measures of autocorrelation for decade-long time series would be representative of individual contracts; a
better approach would be to analyze each contract separately. Because past findings were mixed, Stevenson and Bear used a wider variety of tests and limited the range of the data set. A portion of the data analyzed was a set of price change series for July corn futures contracts covering a seventeen year period ending in 1968. This gave a total of approximately 4100 daily observations.

Price changes were plotted on probability graph paper and the distributions were found to be "definitely leptokurtic" - a leptokurtic distribution exhibits more observations in the center of the distribution and in the extreme tails than does a normal distribution - which was consistent with the findings of Fama (6) and Mandlebrot (18). The test of serial correlations revealed that six of thirty-six July contracts showed significant correlation for lags of one, two, and five days. An analysis of runs test to determine whether runs of price changes of the same sign were consistent with a random series gave results similar to the serial correlation tests. Greater than expected numbers of runs of one-days length and two-days length were observed and implied a tendency towards reversal. Stevenson and Bear also applied filter techniques or mechanical trading techniques which were similar to Houthakker's stop orders but were based on more sophisticated rules. In general, the application of filters indicated that tendencies for persistence of price
changes in the long run could result in profitable trading. The authors concluded that their tests suggested "that the random walk hypothesis does not offer a satisfactory explanation of the movement of those speculative prices" because of a short run tendency toward reversal and the profitability of filter techniques when compared to a buy-and-hold policy.

Cargill and Rausser (2, 3, 4) conducted three separate studies of commodity futures prices using a wide variety of techniques and data. Their 1969 study was based solely on spectral analysis as a test of randomness. The technique decomposes the variance of a time series and displays the series as a spectrum which represents the autocorrelation function. A flat spectrum indicates randomness.

Futures contract price changes for four commodities including corn were analyzed. The data for corn came from the five contracts which matured in 1967 - March, May, July, September, and December - and the number of observations per contract ranged from 226 to 232. Cargill and Rausser found that price changes were generally consistent with the random walk hypothesis and hence, with Working's theory of anticipatory prices.

Spectral analysis, the autocorrelation function, and the integrated periodogram were the statistical techniques
used in the 1972 Cargill-Rausser study. These techniques were applied to the five yearly corn futures contracts for the years 1962, 1966, 1967, and 1968 as well as to seven other commodities. The study revealed that a large number of contracts exhibited nonrandomness leading to the conclusion that the random walk model was not a satisfactory explanation of futures price behavior for commodities in general. Corn futures, however, were not shown to be inconsistent with the model.

For their 1975 study, Cargill and Rausser expanded the statistical base to six tests of serial correlation. These tests included three runs tests and examinations of the autocorrelation function, the integrated periodogram, and the spectral density function. The authors were critical of filter tests used in earlier studies and cautious about the results of spectral techniques. Filter tests were criticized because they offered no test of statistical significance. The profitability of filter rules when applied to truly random series is not known. Results based on spectral techniques may be suspect since the confidence intervals used are intended for point estimates, not the entire spectral function. Moreover, the decision as to whether or not a series is random is sometimes a subjective one.

The six statistical tests were applied to seven
commodities. For corn, this included five contracts per year for the years 1960 through 1972. The analysis showed that individual tests indicated varying degrees of non-randomness for the commodities, but in general, no commodity appeared consistent with the hypothesis of randomness. It was concluded that the "random walk model must be rejected as a realistic description of commodity markets. This, however, does not imply necessarily that the efficient market process is rejected . . . ."

Mann and Heifner (19) studied several commodities using two nonparametric tests of randomness. Initially, they determined the characteristics of distributions of price changes and found them to be leptokurtic or consistent with the stable Paretian hypothesis. Daily closing prices for 59 corn futures contracts, March 1960 to September 1971, were part of the price series analyzed. For one test, the hypothesis of randomness was rejected for all 59 contracts at the .01 level. The second test rejected the hypothesis of randomness for 56 of the contracts at the .05 level. The authors concluded that lack of statistical independence" suggests that prices on commodity futures markets do not adjust efficiently to new information about supply and demand."

Labys and Granger (15) conducted an extensive study of several commodities including both cash and futures prices.
The statistical tool was spectral analysis. Monthly, weekly, and daily price changes for corn covering roughly a fifteen year period ending in 1965 were tested for randomness. For futures prices, the monthly changes were described as a random walk with a slight suggestion of a seasonal component, and the weekly and daily changes were described as pure random walks. Monthly and weekly changes for Chicago cash prices were analyzed and in both cases the series were described as random walks with a barely significant seasonal component.

Gorham (9) conducted a "semi-strong" form test of the efficient market hypothesis for three agricultural commodities including corn. He was concerned with how well private information gatherers anticipated public-sector announcements, specifically U.S.D.A. announcements of the predicted size of the next harvest. If the private information gatherers collect information about the crop size and bid that information into prices, announcements by the U.S.D.A. should not have a significant effect on price changes. To test for an announcement effect, Gorham regressed the percentage change in price - the closing futures price of the post-harvest contract - between the day of the announcement and the trading day immediately following the announcement, on the percentage change in the
forecasted size of the crop since the previous announcement. The regression coefficient for corn was significant at the .01 level but the coefficients were not significant at the .05 level for the remaining commodities. Gorham explained these results by noting that corn was more strongly affected by changes in weather conditions than were the other commodities and, therefore, chances of discrepancies between public and private forecasts were greater. In addition, Gorham found that the improvement of forecasting accuracy over the growing season was similar for the private and public sectors.
V. THE EMPIRICAL RESULTS

Given a sequence of observations over time, \( Y_1, Y_2, \ldots \) and the autoregressive model

\[ Y_t = \rho Y_{t-1} + e_t \]  

(5.1)

where \( Y_0 = 0 \), \( \rho \) is a real number, and \( e_t \) is distributed independent normal with mean zero and variance \( \sigma^2 \), Dickey and Fuller (5) have constructed tables of significance points to test the hypothesis that \( \rho = 1 \); in other words to test the hypothesis that the time series is nonstationary with randomly generated first differences. The tables of significance were constructed from derived representations for the limiting distributions of the statistics \( \hat{\rho} \) and \( \hat{T} \), where \( \hat{\rho} \) is the maximum likelihood estimator of \( \rho \), and the likelihood ratio test of the hypothesis that \( \rho = 1 \) is a function of \( \hat{T} \). Tables were also constructed for the statistics \( \hat{\sigma}_\mu \) and \( \hat{T}_\mu \) for testing the more general model

\[ Y_t = \mu + \rho Y_{t-1} + e_t. \]  

(5.2)

The limiting distributions for the statistics were derived with the assumption that \( Y_0 = 0 \) and \( e_t \sim \text{NID}(0, \sigma^2) \), but the distributions hold for finite \( Y_0 \) and \( e_t \) which are independent, identically distributed random variables with mean zero and variance \( \sigma^2 \).
Three regression models were estimated to test the hypothesis that the time series of corn prices has a unit root.

Model 1 \[ P_t = \alpha + \beta_0 P_{t-1} + e_t \]
Model 2 \[ P_t = \beta_0 P_{t-1} + e_t \]
Model 3 \[ P_t = \alpha + \beta_0 P_{t-1} + \beta_1 (P_{t-2} - P_{t-1}) + e_t \]

Model 1 contained an intercept term to determine if the intercept was significantly different from zero. The coefficient was significant at the .05 level but not at the .01 level \((t = 2.5, n = 1246)\), therefore, it was not unreasonable to discard the intercept and estimate Model 2 without an intercept. The estimates of \(\beta_0\) and the standard deviations of the estimates are given in Table 1.

The calculated statistics for the three models are

Model 1 \[ n(\hat{\beta}_\mu - 1) = 1246(.9917412-1) = -10.2905 \]
\[ \hat{\beta}_\mu = (.00329895)^{-1}(.99174118-1) = -2.5035 \]

Model 2 \[ n(\hat{\beta} - 1) = 1246(.9998358-1) = .2046 \]
\[ \hat{\beta} = (.00069339)^{-1}(.9998358-1) = -.2368 \]

Model 3 \[ n(\hat{\beta}_\mu - 1) = 1244(.99196876-1) = -9.9909 \]
\[ \hat{\beta}_\mu = (.00331516)^{-1}(.99196876-1) = -2.4226 \]
Table 1. Estimates and standard deviations of estimates of roots of autoregressive models

<table>
<thead>
<tr>
<th>Model</th>
<th>Estimate of $\beta_0$</th>
<th>Standard deviation of estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.9998358$^a$</td>
<td>.0069339</td>
</tr>
<tr>
<td>2</td>
<td>.991742$^a$</td>
<td>.0039895</td>
</tr>
<tr>
<td>3</td>
<td>.99196976$^b$</td>
<td>.00331516</td>
</tr>
</tbody>
</table>

$^a_{n} = 1246.$

$^b_{n} = 1244.$

For each of the computed statistics, the tabulated probability of a smaller value (8, pp. 371, 373) fell between .10 and .90, therefore the hypothesis that $\rho = 1$ was not rejected at the .10 level. Because the roots of the models are not significantly different from one it can be concluded that $e_t = P_t - P_{t-1}$ and the analysis can continue with an examination of the residuals or price changes.

To determine the characteristics of the distribution of price changes, the first four moments about the mean were estimated and the mode and median were determined. These estimates are given in Table 2. The average price change is not significantly different from zero ($t = .29$).

$^8$For Model 3 the estimates of $\alpha$ and $\beta_1$ were not significant at the .01 level.
Table 2. Distributional characteristics of price changes

<table>
<thead>
<tr>
<th>Feature</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.0005</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>0.0588</td>
</tr>
<tr>
<td>Median</td>
<td>0.0000</td>
</tr>
<tr>
<td>Skewness</td>
<td>-0.7000</td>
</tr>
<tr>
<td>Mode</td>
<td>0.0000</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>4.6429</td>
</tr>
</tbody>
</table>

The distribution appears to be fairly symmetric since the estimate of the coefficient of skewness is a small negative number and the Pearsonian coefficient of skewness is +0.025. The most striking deviation from normality is the measure of kurtosis. For a normal distribution the value should be zero, but for the observed distribution the value is positive indicating the distribution is more peaked than a normal distribution.

A chi-square goodness-of-fit test was made to test the hypothesis of normality, and the results are consistent with the notion of a kurtosed distribution. Cells were established by partitioning the price changes at points $\pm x$ from the mean, zero. The expected and observed values for each cell are given in Table 3. The calculated statistic is almost nine times larger than the tabular value for the $\chi^2$ distribution so the hypothesis of normality was rejected. The number of observed values exceeded the number of expected values in the center of the distribution and in the extreme tails, but the opposite situation existed in the regions lying
between the peak and the tails. This phenomenon is consistent with the leptokurtic distributions found in several studies of auction market price changes.

Mandlebrot (18) did pioneering work with these long tailed distributions and concluded that they belonged to a family of nonnormal stable distributions characterized by infinite variance. Because a finite variance was nonexistent, it was assumed that standard statistical techniques which rely on decomposition of variance may give unreliable results. Another reasonable explanation for the shape of the observed distribution, especially for cash prices, is that the observations were drawn from different symmetric distributions with equal expected values but unequal variances. Because daily changes of cash prices are associated with a sequence of different futures
contracts over the course of a year, and because these contracts may have differing levels of price volatility, the resulting observed distribution could reasonably be leptokurtic. This, in fact, appears to be the case. The observations for all five years were placed into four groups representing calendar quarters and the means and variances were computed for each quarter. None of the means was significantly different from zero, but the variance for quarter three (.0053) was nearly twice as large as the variance for quarter two (.0027), and the difference was statistically significant.  

Although nonstationarity of the variance offers an alternative explanation for the leptokurtic distribution which does not assume infinite variance, the implications may be the same in either case. Large values in the tails of the composite distribution may give biased estimates of variance and result in spurious results for parametric tests of autocorrelation. In order to mitigate the effects of nonconstant variance on the results of this study, nonparametric tests supplement parametric tests.

9 The test statistic is \( \frac{\hat{\sigma}_i^2}{\hat{\sigma}_j^2} \) where \( \hat{\sigma}_i^2 > \hat{\sigma}_j^2 \), and the critical region is \( F > F_{.95, \frac{n_i-1}{n_j-1}} \). \( \frac{\hat{\sigma}_3^2}{\hat{\sigma}_2^2} = 1.963 \) which is greater than \( F_{.95, \frac{315}{311}} \) so the hypothesis that \( \sigma_3^2 < \sigma_2^2 \) is rejected.
The second major part of testing the efficient market hypothesis consisted of checking for systematic patterns in price changes. The test of runs above and below the median, the results of which are shown in Table 4, was designed to test the null hypothesis of randomness against the alternative of the existence of some systematic pattern. The median for each year was computed and all values above the median were assigned a letter a, while all observations below the median were assigned a letter b. A run is defined as a sequence— one or more— of identical letters which is followed and preceded by different letters or no letter at all. The expected number of runs, R, is calculated using the formula (23)

$$E(R) = \frac{2ab}{a+b} + 1,$$

(5.3)

and the variance is given by

$$\sigma^2(R) = \frac{2ab(2ab-a-b)}{(a+b)^2(a+b-1)}.$$  (5.4)

For large numbers of observations, the distribution of runs is approximately normal.

For three years, 1973-75, the null hypothesis of randomness could not be rejected at the .05 level, and for the remaining two years, 1976-77, the hypothesis was rejected at the .05 level but not at the .01 level. The
Table 4. Analysis of runs above and below the median

<table>
<thead>
<tr>
<th>Year</th>
<th>Median</th>
<th>Runs</th>
<th>Critical Regions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a=b</td>
<td></td>
<td>a</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>.05 .01</td>
</tr>
<tr>
<td>1973</td>
<td>.005</td>
<td>121</td>
<td>113 &lt;106</td>
</tr>
<tr>
<td>1974</td>
<td>.005</td>
<td>126</td>
<td>125 &lt;111</td>
</tr>
<tr>
<td>1975</td>
<td>- .005</td>
<td>125</td>
<td>124 &lt;110</td>
</tr>
<tr>
<td>1976</td>
<td>.000</td>
<td>125</td>
<td>108 &lt;110</td>
</tr>
<tr>
<td>1977</td>
<td>.000</td>
<td>125</td>
<td>107 &lt;110</td>
</tr>
</tbody>
</table>

\( a \) and \( b \) stand for observations above the median and observations below the median, respectively.

\( b \)Only the critical regions to the left of the expectations are given in the table since all the observed numbers of runs are less than the expected values.

Results of this test indicate that the differences between the behavior of the price series and the behavior of a truly random series are not highly significant. The fact that the numbers of observed runs all fall to the left of the expected values is indicative of an insignificant tendency towards persistence of price movements.

The results of the analysis of runs by sign test are given in Table 5. If it is assumed that the sample proportions are good approximations for the population proportions of positive, negative, or zero price changes, the formula for computing the expected number of runs of each
Table 5. Analysis of runs by signs of changes

<table>
<thead>
<tr>
<th>Direction of signs</th>
<th>Number of runs of one sign</th>
<th>Probability of a sign</th>
<th>Number of runs of one sign</th>
<th>Expected runs of one sign</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>597</td>
<td>.4799</td>
<td>309</td>
<td>310.50</td>
</tr>
<tr>
<td>-</td>
<td>556</td>
<td>.4469</td>
<td>306</td>
<td>307.49</td>
</tr>
<tr>
<td>0</td>
<td>91</td>
<td>.0732</td>
<td>77</td>
<td>84.40</td>
</tr>
<tr>
<td>TOTAL</td>
<td>1244</td>
<td>1.0000</td>
<td>692</td>
<td>702.39</td>
</tr>
</tbody>
</table>

The definition of a run is the same as that used for the runs about the median test with the exception that symbols replace letters. The standard error of the expected number of total runs of all signs, $m$, is computed by the formula

$$
\sigma_m = \left( \frac{\sum \frac{3}{2} n_i^2 \left[ \frac{2}{N} \left( \sum n_i^2 + N(N+1) \right) - 2N \right] - \sum 3n_i^3 - N^3}{N^2(N-1)} \right)^{1/2}
$$

(5.6)
where $n_i$ is the number of price changes of each sign. For large samples, the sampling distribution of $m$ is approximately normal (25). A test statistic to test whether the observed number of total runs is significantly different from the expected number is

$$K = \frac{(R+1/2) - m}{\sigma_m}.$$  \hspace{1cm} (5.7)

$R$ is the number of total observed runs, $1/2$ is a discontinuity adjustment, $m$ is the expected value, and $\sigma_m$ is the standard error.

Note in Table 5 that the sum of the expected runs of each sign sums to approximately 703. The observed number of runs is 692 and the calculated standard error is 16.71 which gives a $K$ statistic of -.63. For large samples, $K$ will be approximately normal with mean zero and variance one. Since the difference between the expected number of runs and the observed number is only .63 times the standard error, it cannot be concluded that the observed price series is not a random series; in other words a null hypothesis that the observations are independent cannot be rejected.

The results of the analysis of runs by length are shown in Table 6. Although this analysis is not a true statistical test since there is no proven test statistic, it is useful for comparing the observed numbers of runs of specific length with the corresponding expected numbers.
Table 6. Analysis of runs by length

<table>
<thead>
<tr>
<th>Length of run</th>
<th>Positive runs</th>
<th>Negative runs</th>
<th>Runs of zeroes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Observed</td>
<td>Expected</td>
<td>Observed</td>
</tr>
<tr>
<td>1</td>
<td>144</td>
<td>161.5</td>
<td>166</td>
</tr>
<tr>
<td>2</td>
<td>91</td>
<td>77.5</td>
<td>76</td>
</tr>
<tr>
<td>3</td>
<td>46</td>
<td>37.2</td>
<td>38</td>
</tr>
<tr>
<td>4</td>
<td>14</td>
<td>17.8</td>
<td>17</td>
</tr>
<tr>
<td>5</td>
<td>9</td>
<td>8.6</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>4.1</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>2.0</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>0</td>
<td>.9</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>0</td>
<td>.5</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>.2</td>
<td>1</td>
</tr>
<tr>
<td>TOTAL</td>
<td>309</td>
<td>310.3(^a)</td>
<td>306</td>
</tr>
</tbody>
</table>

\(^a\)Actual column sums and tabular sums may differ due to rounding.
The usual $\chi^2$ test for comparing observed values with expected values is not entirely appropriate here because the lengths of runs are not independent. Summing the observed values and expected values respectively for runs of length one, two, and three or more gives the total observed and expected runs of all signs. Those totals are as follows:

<table>
<thead>
<tr>
<th>Length of run</th>
<th>1</th>
<th>2</th>
<th>&gt;3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected no.</td>
<td>409.8</td>
<td>159.2</td>
<td>131.1</td>
</tr>
<tr>
<td>Observed no.</td>
<td>376</td>
<td>176</td>
<td>140</td>
</tr>
</tbody>
</table>

Inspection of these totals implies that run lengths are slightly longer than would be expected from a truly random series, although the differences cannot be shown to be significant or insignificant. There are fewer runs of length one than expected while the observed runs of length two and greater exceed the expected numbers. This is not inconsistent with the previous tests where a tendency towards persistence appeared but was not proved to be highly significant.

The analysis of runs up and down consisted of two separate tests, the first being a test of turning points. The total number of turning points in a series of observations is the sum of peaks and troughs where a peak is an
observation whose value is greater than the values preceding and following, and a trough is an observation whose value is less than the values of its immediate neighbors. The expected number of turning points and the variance for a truly random series are given by the following formulas (14):

\[
E(p) = \frac{2}{3}(N-2) \quad (5.8)
\]

\[
\text{var}(p) = \frac{16(N-29)}{90} \quad (5.9)
\]

In this approach, it is assumed that consecutive observations of equal value occur only rarely so tied values are treated as one observation. For the series of corn price changes this reduced the number of observations from 1246 to 1196, a reduction of approximately four percent. This reduced series yielded 786 turning points, and the expected number for a random series with 1196 observations was calculated to be 796. The standard deviation of the expected number of turning points is 14.57. Moreover, the distribution of the number of turning points tends quickly to normality as \( n \) increases. It is immediately obvious that the expected number of turning points falls within the .95 confidence interval, therefore the hypothesis of randomness cannot be rejected at the .05 level.

The second test of runs up and down was a test of
phase lengths. A phase is the interval between turning points, therefore the expected total number of phases is one less than the expected number of turning points. The expected number of phases of length d are given by the formula

\[ N_d = \frac{2(n-d-2)(d^2+3d+1)}{(d+3)!} \]  

where \( n \) is the total number of observations. The expected numbers of phases by length and the corresponding observed numbers are given in Table 7. Once again, the lengths of phases are not independent so Wallis and Moore (24) have suggested an alternative test to determine whether the observed numbers of phases are consistent with a random series. If the calculated \( \chi^2 \) statistic is less than 6.3, it is appropriate to use \( 6/7 \chi^2 \) with two degrees of freedom to test lengths 1, 2, and \( \geq 3 \).

The calculated \( \chi^2 \) statistic for the three celled test turned out to be 1.41 which is well below the tabular value for \( \chi^2_{.95,2} \). It is therefore appropriate to conclude, based on this test, that the time series is not significantly different from a random series. However, there is yet another weak indication of persistence of price changes since the observed number of phases of length one is less than the expected number.
Table 7. Expected and observed numbers of phases by lengths

<table>
<thead>
<tr>
<th>Length of phase</th>
<th>Expected number of phases</th>
<th>Observed number of phases</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>497.1</td>
<td>497</td>
</tr>
<tr>
<td>2</td>
<td>218.5</td>
<td>229</td>
</tr>
<tr>
<td>3</td>
<td>62.9</td>
<td>57</td>
</tr>
<tr>
<td>4</td>
<td>13.7</td>
<td>17</td>
</tr>
<tr>
<td>5</td>
<td>2.4</td>
<td>3</td>
</tr>
</tbody>
</table>

The parametric test for independence of price changes consisted of computing the simple correlation coefficient for various lags and determining whether that coefficient was significant statistically. The results are given in Table 8. The price changes were lagged for periods ranging from one to six days where a five day lag would represent approximately one calendar week. Two coefficients, for lags of two days and four days, were significant at the .01 level. Significant correlation of price changes should generally lead to rejection of the specific model being tested, however, the test assumes that the correlation structure is homogeneous over the entire five year period. If the long-term coefficient is significant because of strong relationships over a few subintervals and no pattern exists
Table 8. Correlation coefficients for lagged price changes

<table>
<thead>
<tr>
<th>Lag (days)</th>
<th>Coefficient (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-0.0447</td>
</tr>
<tr>
<td>2</td>
<td>-0.1738***</td>
</tr>
<tr>
<td>3</td>
<td>-0.0100</td>
</tr>
<tr>
<td>4</td>
<td>0.0557***</td>
</tr>
<tr>
<td>5</td>
<td>0.0100</td>
</tr>
<tr>
<td>6</td>
<td>-0.0529</td>
</tr>
</tbody>
</table>

*** Significant at .01 level.

otherwise, the long-term relationship may be spurious in terms of predictability. To determine if the lagged correlations for two days and four days are homogeneous over time, the time series was divided into twenty calendar quarters and correlation coefficients were calculated for each quarter. These coefficients are given in Table 9. Only four of twenty quarters had significant coefficients for the two day lag, but more importantly, there did not appear to be a systematic pattern to the size of the coefficients over time. For the four day lag only one coefficient was significant at the .05 level, and the coefficients did not exhibit dominance of one sign. Half
Table 9. Correlation coefficients for two and four day lags by quarters

<table>
<thead>
<tr>
<th>Year</th>
<th>Lag</th>
<th>Qtr. 1</th>
<th>Qtr. 2</th>
<th>Qtr. 3</th>
<th>Qtr. 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1973</td>
<td>2 day</td>
<td>.0618</td>
<td>-.1474</td>
<td>-.2214</td>
<td>-.2079</td>
</tr>
<tr>
<td></td>
<td>4 day</td>
<td>-.1447</td>
<td>-.0338</td>
<td>.1449</td>
<td>-.0042</td>
</tr>
<tr>
<td>1974</td>
<td>2 day</td>
<td>-.3386**</td>
<td>-.1070</td>
<td>-.2715**</td>
<td>-.0910</td>
</tr>
<tr>
<td></td>
<td>4 day</td>
<td>.3070**</td>
<td>.0477</td>
<td>.0857</td>
<td>.2478</td>
</tr>
<tr>
<td>1975</td>
<td>2 day</td>
<td>-.0274</td>
<td>.1194</td>
<td>-.3374**</td>
<td>.0580</td>
</tr>
<tr>
<td></td>
<td>4 day</td>
<td>-.0965</td>
<td>-.0132</td>
<td>-.0897</td>
<td>-.0493</td>
</tr>
<tr>
<td>1976</td>
<td>2 day</td>
<td>.0154</td>
<td>-.3256**</td>
<td>-.1559</td>
<td>-.0830</td>
</tr>
<tr>
<td></td>
<td>4 day</td>
<td>-.0168</td>
<td>.1101</td>
<td>.0688</td>
<td>.0762</td>
</tr>
<tr>
<td>1977</td>
<td>2 day</td>
<td>-.2261</td>
<td>-.1385</td>
<td>-.0709</td>
<td>-.0361</td>
</tr>
<tr>
<td></td>
<td>4 day</td>
<td>.0249</td>
<td>.0321</td>
<td>-.2416</td>
<td>-.0889</td>
</tr>
</tbody>
</table>

** Significant at .05 level.

*** Significant at .01 level.
of the signs were negative and the remaining half were positive.

The results of the serial correlations test indicate that care must be taken when drawing conclusions from such a test, especially when long time series are used. The results are difficult to assess because, first of all, significant autocorrelation is not continuously present throughout the five year period for any lag. Those intervals that do exhibit significant relationships may be indicative of a lack of efficiency or simply observations that were passed over before a significant statistical pattern emerged from the data. Secondly, the variance of the series is not constant over time which casts further doubts on the efficiency of the test. It is for these very reasons that Working was critical of serial correlation tests as tests of randomness (1, 16).

The final test employed was a semi-strong form test which checks for a price reaction to public announcements. All the tests previously employed were weak-form tests where the information set consisted solely of past prices. If the market is collecting and absorbing information efficiently, all information about the condition of the current crop should already be reflected in prices and U.S.D.A. crop reports should not result in an announcement
effect. On the other hand, if market participants are surprised by the announcement, the subsequent price change should be significantly different from zero as a result of adjustments to the new information.

To test for an announcement effect, price changes subsequent to U.S.D.A. crop reports were tested against distributions of price changes which were not affected by the crop reports. It was hypothesized that price changes immediately following the public announcements were indicative of an announcement effect if those prices were significantly different from the mean values of unaffected price changes. Means and standard deviations were calculated for daily price changes from the initial trading day in August through November for each of the five years. The five years were handled separately to compensate for likely differences in variance over time. The first five daily price changes following each announcement were excluded from the calculations to assure that reactions and secondary reactions to the reports would not contaminate the confidence intervals for unaffected price changes. In other words, if an announcement came on day t, the five price changes between day t and day t+5 were not part of the data used to calculate the mean and standard deviation. Assuming that a U.S.D.A. crop report provides the dominant piece of infor-
Formation that forms price changes between the closing price on the day of the announcement and the closing price on the trading day immediately following the announcement, a price change which is significantly different from the relevant mean unaffected price should indicate a surprise to market participants. It is more risky to make conclusions about price changes following the initial price change - the difference between the closing price on day \( t+1 \) and the closing price on day \( t \) - because new information might have reached the market in the interim. Therefore, only the initial price changes were tested.

The results of the semi-strong form test are given in Table 10. Four of nineteen price changes - one change was eliminated because of late planting in 1974 - were significant, one at the .10 level and three at the .05 level. It appears that participants in the market are sometimes surprised by U.S.D.A. crop reports because they have overestimated or underestimated the change in crop size since the previous announcement. This would indicate that publicly announced information is not always reflected in prices, a condition inconsistent with market efficiency.
Table 10. Price changes subsequent to U.S.D.A. crop reports

<table>
<thead>
<tr>
<th>Year</th>
<th>August</th>
<th>September</th>
<th>October</th>
<th>November</th>
</tr>
</thead>
<tbody>
<tr>
<td>1973</td>
<td>-.060</td>
<td>-.015</td>
<td>-.100</td>
<td>.090</td>
</tr>
<tr>
<td>1974</td>
<td>-</td>
<td>.035</td>
<td>-.040</td>
<td>-.005</td>
</tr>
<tr>
<td>1975</td>
<td>.105*</td>
<td>.070</td>
<td>-.045</td>
<td>-.040</td>
</tr>
<tr>
<td>1976</td>
<td>.055**</td>
<td>-.040</td>
<td>.075**</td>
<td>-.080**</td>
</tr>
<tr>
<td>1977</td>
<td>-.010</td>
<td>-.015</td>
<td>.030</td>
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* Significant at .10 level.
** Significant at .05 level.
VI. CONCLUSIONS

The central Iowa cash corn market does not appear to fully satisfy the definition of an efficient market, but the deviations from that definition are slight, indeed. Analyses of runs about the median, runs of the same sign, and runs up and down all indicated that the differences between the behavior of the series of observed price changes and a truly random series are not highly significant. However, these tests did consistently imply a slight tendency for the direction of price changes to persist. A parametric test used to detect autocorrelation within the price change series showed that there were statistically significant linear relationships between a given price change and the price changes two and four days later. This finding was not consistent with the model being tested, but questions about the interpretation of those results were raised after the five year long time series was broken down into quarters. It must be concluded that the second-order martingale model does not always hold, but it is questionable whether knowledge of the linear relationships between price changes would be helpful to futures traders or farmers. A third type of test which examined the time series for reactions to public announcements of U.S.D.A. crop reports led to the conclusion that private forecasters were sometimes surprised by such
announcements because they had formed inaccurate expectations. Gorham (9) reached a similar conclusion in his study of the corn futures market.

From the viewpoint of the farmer-producer, any differences between the central Iowa cash corn market and an efficient market may appear to be nonexistent. The evidence uncovered in this study implies that short-term price changes are largely unpredictable from past price changes. The fact that lengths of runs of price changes were not found to be markedly different from run lengths of purely random series indicates that prices adjust to new information quickly.

For the farmer-producer who must make marketing decisions in the face of uncertainty, the short-run situation can be analogized with a coin-tossing game. The farmer is faced with a dilemma in which he must determine an appropriate stopping time to end the game. As in a coin-tossing game, there is a tendency to continue when prices are "too low" in anticipation of higher prices in the future. At the other extreme, a farmer might not sell when prices are "high" because he would like to see them go still higher. Decisions to continue the game often lead to less than desirable outcomes because the marketing season between harvests has a limited life and storage costs
continue to accumulate. Farmers who postpone selling during a period of depressed prices face the risk of selling at a low price anyway because of the pressures on storage facilities created by the new crop. If prices are falling from a high point, selling is often delayed with hopes that prices will reverse themselves and return to the previous high point.

In the longer run, prices over the five year period did not appear to exhibit a significant seasonal pattern. $P_t$ was regressed on $P_{t-1}$ plus eleven dummy variables representing calendar months, and the only month that proved significant was July. The coefficients for the estimated equation were such that $P_t = P_{t-1} + .027 + e_t$ for the month of July. Yearly peak prices occurred during the months of January (twice), July (twice), and August; yearly lows occurred during the months of January-February, April, August, and December (twice). Although the lack of seasonality can be attributed partly to a general rise and subsequent decline of prices over the time period, it points out the difficulty of predicting the future from past observations.

In light of the above findings concerning cash price movements, marketing strategies which do not depend on prediction of short-term price movements will be superior
to those strategies that do. While such strategies cannot eliminate uncertainty about future price movements, they can make the decision-making process less burdensome for the farmer-producer. Some possible strategies might include forward contracting, selling portions of the grain stock at predetermined intervals, allowing the management of country elevators to make marketing decisions for the farmer, or using the recommendations of private forecasting agencies.

Obviously, each of these strategies has strong points and weak points. As mentioned earlier, the ability of private forecasters to hit peak prices determines their feasibility as a marketing tool; returns in excess of those resulting from less costly marketing tools must be large enough to justify the additional cost. In addition, new information will generally not reach private forecasters prior to reaching the trading floor of the futures market. A farmer cannot expect to outperform the market by simply buying information.

It is left to other researchers to study the above marketing strategies - as well as others which are appropriate but have been overlooked - in depth to determine their relative merits. A certain strategy may be appropriate in one case but not in the next. Factors that might determine which approach is best in a given situation include the storage location, the size and stability of
the farm marketing unit, and the debt-equity position of the unit. It is already apparent to those who are directly involved in the marketing process that short-term price instability makes decision-making difficult. Perhaps knowledge of the causes of that instability will be helpful in the search for new and better marketing strategies.

A final question concerns the importance of this study. A single market area, central Iowa, was focused upon partly because the statistical techniques used are time consuming and burdensome and partly because it was believed one market area should be fairly representative. Because very few cash markets do not use a futures market as a reference point for making cash bids, it seems reasonable to assume that the results are applicable elsewhere. As far as the future is concerned, it is impossible to say what will happen to the amount and type of information flowing into the market. It will be interesting to see if cash prices continue to behave as they did from 1973 through 1977 or if future conditions will be such that activities in the futures markets and, hence the cash markets will slacken resulting in less volatile prices. Possibly, it is the uncertainty about the future itself that makes further study in this area desirable.
VII. REFERENCES


5. Dickey, David A.; and Fuller, Wayne A. "Distribution of the Estimators for Autoregressive Time Series with a Unit Root." Unpublished research partially supported by the U.S. Bureau of the Census, Department of Statistics, Iowa State University, September 1977.


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