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Title: Temporal Price Relationships in Cash Forward and Futures Markets for White Wheat

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Forward pricing is a marketing tool available to Pacific Northwest white wheat growers for reducing price risk. The cash forward contract is the traditional pricing mechanism used for this purpose. In September 1984, another option for forward pricing was made available through the introduction of a new futures market for white wheat traded at the Minneapolis Grain Exchange.

This research analyzes price behavior in these two forward pricing markets in 1985 from two perspectives. Using the efficient market hypothesis, this study first evaluates the temporal price relationships in each market. Second, the research measures the relationships between the two markets in light of the concept of causality.

Prices in an efficient market should reflect all available information. In this research, the weak form test for the efficient market hypothesis, known as the random walk

model, assessed pricing efficiency in both markets. The random walk hypothesis holds when successive price changes are independent. Based on the evidence of statistically insignificant autocorrelation coefficients, the futures market was efficient under the random walk hypothesis. There were no systematic patterns in the price movements. In contrast, in all delivery time periods except December, the cash forward market exhibited nonrandomness in price changes.

The analysis on the relationship between the two markets was made using Granger's definition of causality. Using ordinary least squares regression, this research evaluated the causal link between the two price series with two parallel tests, the direct Granger's and the Sims'. Strong causality ran from futures prices (FT) to cash forward prices (CF) in the September harvest time delivery period. Some causality from FT to CF lingered into the December and March storage month delivery periods. There were no causal relationships in other delivery periods except a feedback from CF to FT in the March period.

Despite low trading activity, futures prices were found to represent an efficient market. Thus, they accurately reflected market signals concerning the supply of, and demand for, white wheat. On the contrary, nonrandomness found in cash forward prices suggests inefficiency in this market. The causality found from FT to CF is consistent with the expectation. Farm level forward pricing activity is greatest for harvest (August/September) and immediate post-harvest delivery months. This causes buyers of cash forward contracts to pursue price risk management. Thus, futures prices were used as references, or hedges, in setting cash forward prices in these delivery time periods.

The irregular causality pattern between the two markets implies a changing market environment, possibly caused by differing price determination processes over time. Serial dependence in cash forward prices may be providing misleading signals about the white wheat market. However, the weak form test used here could not estimate the magnitude of the inefficiency.

Temporal Price Relationships in Cash Forward and Futures Markets for White Wheat

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I. INTRODUCTION

White wheat is one of five major classes of wheat produced in the United States. Production is concentrated in the three-state Pacific Northwest (PNW) region comprised of Idaho, Oregon, and Washington. During the past five years, the PNW has accounted for roughly 80 percent of all white wheat produced in the United States. In recent years, 60 to 70 percent of this production has been exported, primarily to Asian and Middle Eastern countries.

The export orientation of PNW white wheat has focused major market activities in Portland, Oregon, the general location of the terminal export elevators on the Columbia River. Prices at farm or country elevator locations throughout the PNW are routinely calculated as the Portland price less related transportation and handling costs. Thus, the price for white wheat in the Portland market is commonly quoted for all locations in the region.

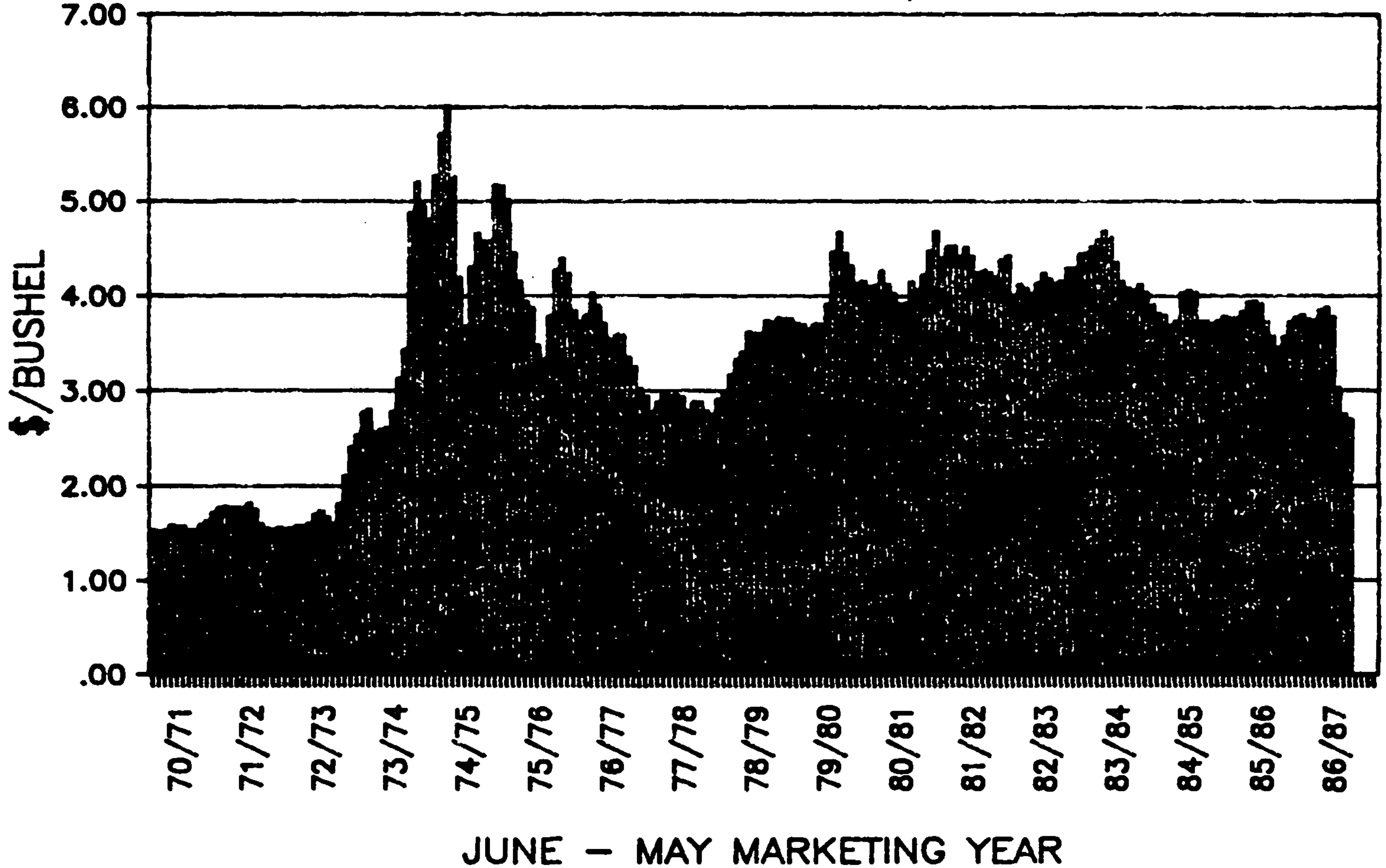
Estimates indicate that about 40 percent of the wheat produced in the PNW is marketed by producers in the immediate post-harvest period from August through October (USDA). The remainder is frequently stored for later sale either on-farm or in various country elevator locations throughout the producing area. This portion of the crop may be sold in the current or succeeding marketing years, or placed under loan in the government wheat program.

Wheat farmers in the PNW have experienced periodic financial losses and gains due to the volatility of wheat prices over time (see Figure 1). During the period between 1972 and 1978, wheat prices fluctuated widely relative to earlier years. However, this instability has moderated since 1979. Within the June-May wheat marketing year, the standard deviation of monthly price has averaged $.30 per bushel between 1979 and 1985 compared to nearly $.90 per bushel in the 1972-1978 period. Although the volatility of white wheat prices has declined, the variability in cash price over the marketing year is still significant, potentially accounting for five to ten percent of gross farm sales value.

Four interrelated factors have been identified that influence PNW white wheat prices: 1) world wheat production and utilization; 2) Australian wheat production and stocks; 3) PNW production and stocks; and 4) international or domestic political/macroeconomic variables such as embargoes or the exchange rate (Sargent, 1982). Recent research (Dickens, 1981) demonstrates that different marketing plans are needed for different farm management objectives, given price uncertainty. Dickens' study also showed that average farm income can be increased, and marketing risk decreased, through the careful selection of a marketing strategy consistent with farm management goals.

FIGURE 1. PORTLAND WHITE WHEAT PRICE

MONTHLY AVERAGE CASH PRICE; 1972 – 1986



Forward Selling as a Marketing Alternative

There are several marketing alternatives available to PNW wheat growers. These alternatives can be grouped into four categories: 1) sell at harvest; 2) hold or store wheat for later sale in anticipation of a speculative gain; 3) forward sell prior to harvest or delivery; and 4) participate in the farm program provided by the government. Producers choose an alternative or combination of the options in their marketing decisions. This research focuses on alternatives in group 3, which provide a means of reducing the risk of unstable wheat prices over time.

Forward selling, or contracting for sale prior to harvest or delivery, is used primarily to establish a price in advance of delivery. The two main types of forward selling are cash forward contracts and futures contracts. These two mechanisms are similar in that price is established when the contract is made, rather than at the time of payment and delivery of the physical commodity. The differences between the two contracts will be discussed in Chapter II.

A New Futures Market for White Wheat

Cash forward contracting has been the traditional forward pricing alternative for PNW white wheat growers. The Portland white wheat market, comprised of major grain export companies and merchandisers, facilitates forward pricing through cash bids for future delivery periods, typically one to four months in the future.

Prior to September 1984, no specific white wheat futures contract was available for forward pricing. Thus, speculators and hedgers[1/] were limited to the four non-white wheat futures contracts available at the Chicago Board of Trade, the Kansas City Board of Trade, the Minneapolis Grain Exchange, and the Mid-America Exchange. Each of these four contracts contain awkward delivery terms for hedging white wheat, resulting in irregular basis patterns over time (Dewbre, 1977). As a result, attempts to hedge white wheat using traditional short positions against mid-western deliverable wheat contracts prove unattractive to white wheat growers and country elevators (Wirak, 1979).

A specific white wheat futures contract was developed by the Minneapolis Grain Exchange (MGE) in consultation with wheat growers and merchandisers in the PNW. The white wheat contract was expected to offer producers and merchandisers an additional risk management alternative in developing marketing strategies. Trading began in September 1984, with the December 1984 contract. The MGE white wheat futures contract closely resembles the other wheat futures contracts with some slight differences. The contract calls for delivery of the white wheat at one of the Portland (lower Columbia River) terminal grain elevators, although trading takes place in Minneapolis. Delivery is made in terms of a ship-

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1/ As considered here, hedging refers to the initiation of a position in a futures market that is intended as a temporary substitute for the sale or purchase of the actual commodity.

ping certificate, in order to facilitate existing merchandising and transportation operations in the Portland market.

Reported trading volume during 1985 for the five contract months of MGE white wheat futures was: (MGE)

March	May	July	September	December
(in thousand bushels)				
5,628	5,079	250	2,380	6,742

The average five-year production of white wheat for the period 1981-1985 is 304 million bushels. Thus, the reported trading volume in this futures market during its first year represents a small fraction (6.6 percent) of average annual production.

Recent analysis (Cornelius, 1986) has pointed out that the activity in this new market for the first year did not meet expectations. Some reasons suggested for this lower than expected activity level are as follows: 1) The government farm program has replaced the free market as the dominant pricing mechanism. This has reduced price variability, and wheat producers have found little need for hedging in the futures market. 2) There have been some marketing obstacles, e.g., unfamiliarity with the new contract, geographical distance between Minneapolis (where the contracts are traded) and Portland (where the physical product is marketed), and possibly under-capitalized traders.

Specific Problem Statement and Objectives

Given the fact that use of this new marketing alternative has not lived up to expectations, pricing performance in this new market as well as in the traditional cash forward market is of particular interest. Using forward selling to reduce price risk, in effect, implies allocating resources by this price mechanism. Farmers weigh their production and storage plans in accordance with forward price expectations. Intuitively, the new futures contract for white wheat should be related to the cash forward market, but low liquidity in the first year of trading raises questions concerning the appropriateness of the futures contract in the white wheat market. In order to evaluate the performance of forward pricing in allocating resources, there is a need for research to explore the nature of price movements in cash forward and futures markets.

The overall objective of this research is to examine the temporal price relationships within the cash forward market and the futures market, and the relationships between the two markets. In so doing, the research addresses the following specific objectives:

a) Evaluate the randomness in price movements in order to determine pricing efficiency in each market. An efficient market hypothesis asserts that prices reflect all available information. If cash forward or futures markets are efficient, they accurately represent current and expected future supply and demand for white wheat.

b) Determine the lead-lag or causal link between the two markets. Measuring this interrelationship will help determine whether the new white wheat futures market plays an active, passive, or no role in establishing cash forward price.

Knowledge of the relationships in a) and b) should provide insight into the effectiveness of these forward pricing mechanisms, and may help farmers, exporters, and elevator managers formulate efficient marketing plans.

Procedures

There are several methods available for testing market efficiency. This research will employ the weak form test where the information set is a time series of historical prices. The weak form test examines the randomness of prices and determines whether or not the market is a random walk or conforms to the martingale hypothesis. A naive autocorrelation function is used to identify the pricing efficiency.

The lead-lag relationship between cash forward and futures is examined by causality testing. Bivariate time series of cash forward and futures prices are tested using Granger's definition of causality. The possible causal orderings are unidirectional, bidirectional, and no causal relationship. Two parallel models, the direct Granger's and the Sims', are used to test the relationships. Ordinary least squares estimates of the proposed models are used to investigate the causal link between the two prices.

This study analyzes pricing performance in the two markets using daily reported price quotes of five different delivery periods corresponding to futures market contract months: March, May, July, September, and December of 1985. The research thereby encompasses roughly one year's experience with the new white wheat futures contracts. The comparison can be regarded as an investigation into the initial stages of a thinly-traded futures market.

Thesis Organization

Chapter II presents theoretical background on forward trading, the efficient market hypothesis, and the causality concept. Some previous empirical works are also explored. Models and data used in this research are discussed in Chapter III. Chapter IV presents the research results. Chapter V summarizes and concludes the thesis. Daily price quotes used in the models are shown in Appendix A. Detailed results on causality testing are presented in Appendix B.

II. THEORY AND LITERATURE REVIEW

This chapter will review the economic theory pertaining to forward pricing in agricultural commodity markets. Similarities and differences between the two alternatives in forward pricing, cash forward and futures contracts, are examined with specific reference to farm marketing decisions. Literature concerning the efficient market hypothesis and the causality concept will be reviewed as groundwork for examining price relationships in the two markets.

Economic Rationale of Forward Pricing

Forward trading is an old practice of commerce, but organized markets conducting commodity futures trading have become prominent only during the past century (Gray, 1971). Cash forward and futures contracts have long played an important role in economic affairs. They have a common ability to facilitate advanced sale. The economic justification for trade in both types of contracts are 1) for hedging in order to reduce exposure to the risk of cash price fluctuation, and 2) as factors in the price discovery processes (Purcell, 1979).

To hedge is to transfer price risk by taking opposite positions in the current "spot" and forward trading markets. The wheat grower who harvests and stores wheat is said to be "long" in the cash market. He can choose between cash forward and futures markets in order to hedge his position. For example, he may either sell a forward contract or a futures contract, resulting in a "short" position in the forward trading market. The opposite or off-setting positions establish a set price, although the settlement process is different between cash forward and futures markets. The hedged position protects the grower against a subsequent fall in cash price, while denying the opportunity to capitalize on rising cash prices. Thus, from the hedger's perspective, forward pricing is a price risk management tool.

Cash forward and futures pricing mechanisms provide the opportunity to hedge in pre-, as well as in post-harvest periods. Growers can enter into forward pricing during the planning, production, as well as the storage phase.

Forward pricing also serves as a force in the price discovery process. At a given point in time, the price quotation for a distant forward or futures contract is assumed to represent the consensus of all parties' expectations about the level of cash price in that future period. Hence, the level of forward trading becomes a factor which influences production, storage, and sales decisions. This can be a direct input into the discovery of wheat prices during the marketing year.

The similar characteristics between the two types of forward pricing contracts can be deceptive. Sometimes people overemphasize the similarity and give little consideration to the differences. There are, however, significant differences between the two types of contracts. Wheat producers engage in private cash forward contract with grain elevators or merchandisers, whereas the futures contract transactions occur in an open auction on the exchange floor. Terms under cash forward contracts can be tailored closely to the needs of individual farmers. In contrast, futures contracts offer standardized terms which generally do not match exactly the farmers' products. Thus, while the cash forward contract is fulfilled by physical delivery of the commodity, futures contract are mostly liquidated by opposite transactions before maturity. An individual who hedges by selling a futures contract normally chooses to liquidate the hedge not by delivery but by buying the futures back, and subsequently selling cash grain.

There are advantages and disadvantages in both cash forward selling and hedging in the futures market. Each type of contract is a means of fixing returns and hence eliminates or reduces prices risks. Cash forward contracts assure an outlet for the growers' output. No broker's fee or margin requirements are involved. The disadvantage is that the seller of a cash forward contract bears the risk of default by the opposite party. The integrity of the contract depends on the soundness of the buyer's financial position. On the other hand, effective arrangements in the organized exchange prevent such default in the futures trading. However, the following discussion about the "lumpiness" of the contracts, the margin requirements, and the possible adverse basis changes shows that, in general, farmers prefer cash forward selling to the futures contracts (Paul et al., 1985).

Trade in grain futures contracts is only in standard quantities, such as 5,000 bushels. Thus, "lumpiness" arises because of a mismatch between the standardized quantities and the desired sale. Margin requirements can cause financial hardship to the hedger. For example, after the farmer had sold a futures contract and put up some amount of margin, the broker demands more margin when prices rose afterward. If the farmer is unable to cover this margin call, he is forced to lift the hedge prematurely, and left in a speculative position.

Another matter that influences farmer's preference for cash forward over futures markets is basis risk. Basis is the difference between cash and futures prices. At the time the farmer hedges, he would like to lift the hedge when the basis is favorable; e.g. cash price is high relative to futures price. However, there is an uncertain relationship between futures and cash price movements. Hence, the hedger is at a disadvantage if the futures price is high relative to the cash price.

The differences in contract characteristics imply imperfect substitutability between cash forward and futures. Although growers may prefer cash forward contract, there are occasions when futures provide a better alternative. Liquidity of futures contracts is an important consideration in this context. A recent study by Nelson (1985) suggests that using both types of contracts as complements may lead to an optimal strategy.

In summary, cash forward and futures contracts differ primarily in merchandising terms. The differences described above also imply that forward contract and futures contract prices may be quite different (Cox et al., (1981); Jarrow and Oldfield (1981)). Nelson (1985) emphasizes the difference of these two prices by defining it as a basis. He argues that the conventional term "basis", (cash price minus futures), is irrelevant for pre-harvest decisions on marketing strategy. This is because pre-harvest sale for immediate delivery of an immature crop cannot be treated as a marketing alternative.

In attempting to predict price movements for forward trading, traders rely on both fundamental and technical analysis. Fundamental analysis involves the basic economic concepts of supply and demand. Traders identify factors that have the potential to affect supply, demand, or both. Assessing their effect, traders then take a position in the relevant markets. Technical analysis primarily involves the examination of past patterns in price movements (Paul et al. 1985). Recognition of such patterns help traders in making their decisions. These two analyses can be used together. If fundamental analysis is used as the determinant of whether to hedge, the technical analysis can be used as a signal of when to hedge (Purcell, 1979).

The thrust of this research is on the evaluation of price movements of white wheat in forward trading markets. The attempt is thus regarded as a supplement to technical analysis in formulating a marketing plan. Theoretical and empirical works pertaining to temporal price relationships with respect to pricing efficiency are presented first. Causality literature follows as a groundwork for examining the relationship of prices between the two markets.

Efficient Market Hypothesis

Theoretical Framework of the Efficient Market Hypothesis

It is widely accepted that supply and demand relationships determine long run price behavior. However, supply and demand do not always provide insight into the daily or weekly price movements, and short run price behavior is of primary interest to commodity traders. Stochastic models of short run price behavior were first studied in the context of economics in 1900 by Louis Bachelier (Mandelbrot, 1966). Bachelier's model demonstrates that for a price series $Z(t)$, the increment $Z(t+T) - Z(t)$ is independent of the values of Z up to and including time t, where $T = 1, \ldots, n$. Bachelier also asserted that $Z(t+T) - Z(t)$ is a Gaussian random variable with zero mean and a variance proportional to T. This assumption is referred to as the "random walk", meaning that successive price changes are random.

There have been variations in the random walk hypothesis since the empirical work of Bachelier. Some researchers assert the random walk model in the form: $P_t = P_{t-1} + \varepsilon_t$ or $\varepsilon_t = P_t - P_{t-1}$, where ε_t is a sequence of independent identically distributed random variables. The pioneering work designed to explain the random walk nature of commodity prices is "A Theory of Anticipatory Prices" by Holbrook Working (Gray, 1971). Working (1958) hypothesized an idealized market in which decisions on cash and futures prices incorporate all available and relevant information. Hence, today's futures market price should equal the current expectation of the subsequent cash price of the commodity to be delivered at the same point in the future. With slight modification, this concept can be interpreted as the efficient market hypothesis; or equivalent to what is called "rational expectations" (Dewbre, 1981).

An efficient market should follow a martingale[2/] process. Elton (1984) explains a martingale or fair game process in the following way. Let I_t be the information set available at a time t. With I_t, the trader can make an estimate of his return[3/] between time t and time t+1. He then can compare the estimated return with the equilibrium return. Whether the estimated return is above or below equilibrium should be unrelated or contain no information about actual return. Hence, a fair game asserts that there is no

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2/ A martingale is a stochastic sequence of variables with the major characteristic that the conditional expected value of the random variable for time t+1 equals the value for time t.

3/ A return is defined as the first difference between prices at time t and time t-1.

way to use I_t to make above normal profit. The fair game model does not require identical return distributions and does not imply that returns are independent through time.

An efficient market is the one in which prices at any time fully reflect available information (Fama, 1970). The efficient market theory is classified into three categories; weak form tests, semi-strong form tests, and strong form tests. In the weak form test, the information set I_t (referred to in the fair game process explained above) is just historical prices. For semi-strong form tests, I_t also includes other publicly available information. Finally, for strong form tests, the focus is whether specific groups of people have monopolistic access to any information, public or private, relevant to price formation. In short, all efficient market tests are concerned with the speed with which information is translated into prices (Elton, 1984).

Thus, the random walk model is a restrictive version of the weak form of the efficient market theory and can be considered a special case of a martingale or fair game process. Elton concludes that if the random walk model holds, the weak form efficiency must hold, but not vice versa. Evidence supporting the random walk model is evidence supporting weak form efficiency.

Samuelson (1965) proved the randomness of futures price movements using the fundamental property of conditional expectation. Sheffrin (1983) elaborates and explains this proof under the rational expectations view. With the information set I_t at time t, today's forecast of the price at time T in the future is $E(P_T | I_t)$. Tomorrow's forecast of the price at T is then $E(P_T | I_{t+1})$. Now, focusing at time t or today, the new information that will be available between today and tomorrow to improve tomorrow's forecast is a random variable. However, the best guess of that information is already embodied in today's forecast. Thus, today's forecast represents the best guess of tomorrow's forecast or

$$E\{E[P_T | I_{t+1}] I_t\} \quad = \quad E[P_T | I_t].$$

Relating this idea to the futures market, the assumption is that the market sets futures prices, F(t,T), equal to the conditional expectation of the spot price at the closing date of the contract or $F(t,T) = E[P_T | I_t]$. Similarly, for tomorrow's price, $F(t+1,T) = E[P_T | I_{t+1}]$. Hence,

$$E[F(t+1,T) - F(t,T) | I_t] \quad = \quad 0.$$

This is equivalent to saying that expected gain (above normal) from holding a futures contract from period t to period t+1 is zero. This does not imply that expected return is zero. The implication is that expected profits cannot be made on the change in prices. In other words, in efficient market past price series contain no information about the change from today's price to tomorrow's price.

<u>Empirical Work on the Efficient Market Hypothesis</u>

There are more tests of the random walk hypothesis for the stock market than on the commodity market. Fama (1970) made reference to empirical works on capital market. He concluded that the capital market is efficient under the weak form tests. In another study by Fama (1975), the short term government securities market between 1953 to 1971 was used to test this hypothesis. The data confirm that movements in nominal interest rate on Treasury bills reflected fully the information about the inflation rate.

Using the random walk hypothesis, Cargill and Rausser (1975) tested seven commodities: corn, oats, soybeans, wheat, copper, live beef cattle, and pork bellies. There are 464 futures contracts involved, covering the period from 1960 through 1972. The commodity contracts are from three major markets: Chicago Board of Trade, Chicago Mercantile Exchange, and the New York Market. The results do not confirm the random walk hypothesis. There were clear and strong nonrandom elements in futures price series. In contrast, a study on corn futures by Carter (1984) found that Winnipeg barley futures as well as corn futures between 1977 to 1981 were efficient under the weak form test. Stevenson and Bear (1970) studied the July contract for Chicago corn and soybeans between 1957 to 1968, and concluded that there were systematic patterns in price movements.

Veeman and Moreau (1985) examined pricing efficiency in the Winnipeg rapeseed market between 1979 to 1983, and found that serial correlation existed in November contracts of 1981 and 1983, and also in March contracts of 1980, 1981, and 1983. A recent study on market efficiency of the cash forward contract for PNW white wheat for the period 1981 to 1982 was conducted by Reynolds (1984). The results suggest that the efficient market hypothesis under the random walk model holds. Since the data are on a weekly basis and the test was done for only one contract month, the finding is inconclusive.

There are many estimation procedures involved in the above and other empirical studies. One study may use several methods on the same data to ensure that the results are not sensitive to any particular test or method of estimation. These methods, including the one used in this thesis, are discussed further in Chapter III.

The inconsistencies in research results cited above may be due to the application of the different estimation techniques and the different time periods studied for a particular commodity. The studies that found nonrandomness in prices imply that the random walk hypothesis does not offer a satisfactory explanation of commodity markets.

Causality

Theoretical Framework of Causality

The definition of causality as used in this research was introduced by Granger (1969). Based on earlier work by Wiener (1956), Granger gives the following definition: "If $\sigma^2(X/U) < \sigma^2(X/U-Y)$, we say that Y is causing X, denoted by $Y_t \Longrightarrow X_t$. We say that Y_t is causing X_t if we are better able to predict X_t using all available information (U) than if the information apart from Y_t (U-Y) had been used." Granger defines U as all the information in the universe accumulated since time t-1. In simple terms, the variable Y is said to cause X with respect to a given universe (U) including at least X and Y, if the current value of X is predicted better by using past values of X and Y than by using only past value of X (U-Y) (Bishop, 1979; Geweke, 1984).

The above definition is quite controversial and differs from those offered by philosophers of science. Granger's definition is defined in terms of predictability with the following assumptions: a) the variables being tested result from stochastic processes; b) the series are stationary; and c) the future cannot cause the past. Although there are numerous criticisms, researchers use Granger's definition of causality on the ground that its usefulness is in the construction, estimation, and application of econometric models. A recent analysis suggests researchers use caution in interpretation of causality tests. Critics of causality testing cite problems with model specification, assumptions, and data transformations. The stationarity-inducing transformations are specified as not causality preserving (Conway et al., 1984; Zellner, 1979).

However, Granger's definition is the only one that offers testable models. Thus, in general, economists refer to this concept as Wiener-Granger causality. Based on the above definition, the unidirectional causality orderings are Y_t ====> X_t, and X_t ====> Y_t. Bidirectional causality or feedback (Y_t <====> X_t) occurs when Y_t is causing X_t and X_t

is causing Y_t. Finally, Y_t ==/=> X_t means no causal relationship.

A useful elaboration and development of the testable implications of Wiener-Granger causality is found in Geweke (1984). Geweke asserts that in applying this causality concept, the relevant universe of information must be specified, and the class of predictors must be limited. The relevant information to be determined depends mainly on a priori considerations from economic theory. In some instances, the information is suggested by earlier work on similar issues that do not focus on question of causality. The class of predictors considered is linear either in levels or logarithms. This is because of the analytical convenience of the linearity assumption. Due to the assumption of stationarity underlying Granger's definition, linearity specification is especially attractive because only linear predictors are necessarily time invariant.

Geweke (1984) presents the Wiener-Granger causality concept using a canonical form. From the definition, X and Y, each possesses autoregressive representations:

$$X_t = \sum_{r=1}^{\infty} a_{1r} X_{t-r} + u_{1t}, \quad var(u_{1t}) = E_1 \qquad (2.1)$$

$$Y_t = \sum_{r=1}^{\infty} d_{1r} Y_{t-r} + v_{1t}, \quad var(v_{1t}) = T_1 \qquad (2.2)$$

The disturbance vectors u_{1t} and v_{1t} are each serially uncorrelated. Since u_{1t} is uncorrelated with all X_{t-1}, (2.1) represents the linear projection of X_t on its own past. In the same manner, (2.2) denotes the linear projection of Y_t on past Y. The linear projections of X_t on past X and past Y, and of Y_t on past Y and past X are:

$$X_t = \sum_{r=1}^{\infty} a_{2r}X_{t-r} + \sum_{r=1}^{\infty} b_{2r}Y_{t-r} + u_{2t}, \quad var(u_{2t}) = E_2 \qquad (2.3)$$

$$Y_t = \sum_{r=1}^{\infty} d_{2r}Y_{t-r} + \sum_{r=1}^{\infty} e_{2r}X_{t-r} + v_{2t}, \quad var(v_{2t}) = T_2 \qquad (2.4)$$

The linear projections of X_t on past X and current and past Y and likewise of Y_t can, thus, be denoted by:

$$X_t = \sum_{r=1}^{\infty} a_{3r}X_{t-r} + \sum_{r=0}^{\infty} b_{3r}Y_{t-r} + u_{3t}, \quad var(u_{3t}) = E_3 \qquad (2.5)$$

$$Y_t = \sum_{r=1}^{\infty} d_{3r}Y_{t-r} + \sum_{r=0}^{\infty} e_{3r}X_{t-r} + v_{3t}, \quad var(v_{3t}) = T_3 \qquad (2.6)$$

Finally, the linear projections of X_t on past X and all Y, and Y_t on past Y and all X can be represented by:

$$X_t = \sum_{r=1}^{\infty} a_{4r}X_{t-r} + \sum_{r=-\infty}^{\infty} b_{4r}Y_{t-r} + u_{4t}, \quad var(u_{4t}) = E_4 \qquad (2.7)$$

$$Y_t = \sum_{r=1}^{\infty} d_{4r}Y_{t-r} + \sum_{r=-\infty}^{\infty} e_{4r}X_{t-r} + v_{4t}, \quad var(v_{4t}) = T_4 \qquad (2.8)$$

Geweke proves that each u_t and v_t in each of the above equations is uncorrelated with all X and Y in the relevant equation.

From (2.1) and (2.3), the implication is that Y causes X if $E_2 < E_1$, or equivalently when $b_{2r} \neq 0$. Since $E_2 \leq E_1$ in any case, Y does not cause X if and only if $E_1 = E_2$. Hence,

$$Y \Longrightarrow X \quad \text{if} \quad \ln(E_1/E_2) \neq 0 \quad \text{or}$$

$$Y \Longrightarrow\!\!\!\!\!\!\not\ \ X \quad \text{if} \quad \ln(E_1/E_2) = 0. \text{ Similarly,}$$
$$X \Longrightarrow Y \quad \text{if} \quad \ln(T_1/T_2) \neq 0 \quad \text{or}$$
$$X \Longrightarrow\!\!\!\!\!\!\not\ \ Y \quad \text{if} \quad \ln(T_1/T_2) = 0.$$

Geweke proved that $\ln(E_1/E_2) = \ln(T_3/T_4)$ and $\ln(T_1/T_2) = \ln(E_3/E_4)$.

Sims (1972) and Sargent (1979) proved a similar proposition from which Sims develops a model for causality testing which will be discussed further in Chapter III. Briefly, Sims asserts that the prediction of Y on the entire X process equals the prediction of Y on current and past X's if and only if Y fails to cause X.

Empirical Work on the Causality Concept

The causality concept proposed by Granger has been used to some extent in both macro and micro economics models. Sims (1972) tested the causal orderings between money and income for the period 1947 to 1969. The results show that the unidirectional causality existed from money to income while the hypothesis that income caused money was rejected. Another study on the relationship between money and consumer price index found that there existed unidirectional causality from money to CPI in 1951 to 1976 (Bishop, 1979).

In agricultural markets, there are numerous applications of causality tests. Bessler and Brandt (1982) found that there were strong lead and lag relationships between sow farrowings and hog prices, and between cattle prices and cattle on feed in the data for period 1963 to 1979. The rapeseed futures price was found to cause soybean futures price for the November 1979 contracts (Carter and Rausser, 1983). This study established such a relationship between the thinly traded (rapeseed) market and the heavily traded (soybean) market.

Using the Chicago soft red wheat futures price as a proxy for the white wheat market, Reynolds (1984) concluded that there was no causal link between the cash forward market and the futures market for September contract during the period from 1980 to 1982. Apart from the appropriateness of futures price data, Reynolds used weekly price series which might prevent discovery of causal relationship that occurs on a daily basis.

A recent study by Barkley and Helander (1985) attempted to determine the role of commercial bank loans in local economic development in Arizona. The data for period 1975 to 1981 shows no indication that bank loans caused economic development in Granger's sense. On the contrary, economic activity is said to lead bank lending.

Summary

This chapter reviewed the economic implications of forward pricing. The efficient market hypothesis was explored as a basis for testing whether pricing in cash forward and futures markets for white wheat are efficient. The hypothesis will help determine what types of temporal price patterns exist in each market. The causality test was reviewed because of its potential power in determining the role of the futures market in influencing the cash forward market, and vice versa. This lead-lag relationship between the two markets may be identified by the Granger's causality concept.

III. METHODOLOGY AND DATA

The purpose of this chapter is to develop appropriate methodology for determining price relationships in the two forward pricing markets for white wheat. The efficient market model for testing randomness of prices in each market will be proposed first. Two parallel models, the direct Granger's and the Sims', will be developed for causal link testing. The nature of the data used for both analyses will also be discussed.

Efficient Market Model

As discussed in Chapter II, the random walk hypothesis may be represented as:

$$P_t = P_{t-1} + \varepsilon_t$$

$$[t = 1, 2, \ldots, n;\ E(\varepsilon_t) = 0;\ r(\varepsilon_t, \varepsilon_{t+k}) = 0 \text{ for } k \neq 0]$$

where P_t = the price on day t and ε_t = a random variable. There are several methods used in testing the weak form market efficiency. Analysis of runs, filter techniques, and serial correlation are among the most common practices in empirical works.

Fama (1965) and Cargill and Rausser (1975) use the "runs" test in studying the capital market and the commodity market, respectively. A sequence of price changes of the same sign is called a run. Denote a price increase by +, a price decrease by -, and no change by 0. Then, there are three different possible types of runs, e.g. ++---0+++ has four runs; a run of two +'s, a run of three -'s, a run of one no change, and a run of three +'s. Price changes are said to be positively related if a + is followed by + and a - by -, and there are longer sequences of +'s and -'s than could be attributed to chance. Hence, fewer runs than expected is evidence of nonrandomness in price.

There are a variety of filters that can be used to test for pricing efficiency. Representative filtering techniques can be found in Stevenson and Bear (1970), Cargill and Rausser (1975), Fama (1965), and Elton (1984). One type of filtering technique that is commonly applied to futures price data is the following. If the closing price rises at least X percent from a previous low, buy and hold (that contract) until the price declines at least X percent from a subsequent high, at which time sell the contract. If the market is efficient under the random walk hypothesis, such a mechanical rule will not consistently yield returns above normal.

The third widely used method for random walk hypothesis testing is through an examination of serial correlation. The empirical works of Fama (1965), Cargill and Rausser, and Stevenson and Bear also include this method. Additional applications of the technique can be found in Carter (1984), Fama (1975), and Veeman and Moreau (1985).

This thesis will use the serial correlation method, a detailed discussion of which is given below. It must be pointed out, however, that each of the three methods has its own limitations and it is difficult to compare their effectiveness. Serial correlation is selected here because of its simplicity in application and sound statistical basis.

Serial Correlation Model

Within the serial correlation method, there are several approaches to examine price relationships. Elton (1984) and Reynolds (1984) use a similar methodology by fitting the relationship:

$$P_t - P_{t-1} = \alpha + \beta(P_{t-1} - P_{t-2}).$$

An ordinary least squares regression is used to estimate the coefficients α and β. If β is statistically significant, the implication is that there is some relation between price changes in period t and period t-1. Recent studies by Carter and Veeman and Moreau use an autocorrelation function instead of a regression equation. This research also uses an autocorrelation function, as discussed below.

The difference in prices or price changes between today and yesterday ($P_t - P_{t-1}$) is a return. Taking logs of the price change produces $\ln P_t - \ln P_{t-1}$. Gordon (1984) advocates working with the change in logarithm of price because it is independent of the units of measurement, allowing direct comparison. Elton specifies that log of the price ratio (P_t/P_{t-1}) is equivalent to the continuously compounded rate of return (R_t). Hence, given a time series of returns (R_t, R_{t+1},....., R_N), the Box-Jenkins (1976) autocorrelation function is of the form:

$$\hat{P}_k = \frac{\sum_{t=1}^{N-k} (R_t - \bar{R})(R_{t+k} - \bar{R})}{\sum_{t=1}^{N} (R_t - \bar{R})^2}$$

where $\hat{P}$ = autocorrelation coefficient;

R_t = $\ln P_t - \ln P_{t-1}$;

$\bar{R}$ = $(1/N) \sum_{t=1}^{N} R_t$;

N = number of observations;

k = the lag between observations.

For the random walk assertion to hold, the null hypothesis is stated that there should be no pattern to the size of the autocorrelation coefficients. The value of each $\hat{P}_k$ should not be significantly different from zero. This is equivalent to saying that there is no autocorrelation in successive price changes.

To identify autocorrelation, the approximate standard error of $\hat{P}$ is used. For this purpose, $\sigma(\hat{P}) = 1/(N)^{1/2}$, under the null hypothesis that the true autocorrelation is zero. Under the assumption of a normal distribution, $\hat{P}$ is statistically significant at the 5 percent level if it is larger than twice its standard error.

Ljung-Box's (1978) Q-statistic is also used to test whether the autocorrelation coefficients as a group are significant. The test statistic is of the form:

$$Q = N(N+2) \sum_{k=1}^{m} [(P_k)^2/(N-k)]$$

where m = number of intervals of lags. The chi-squared distribution is used to test the significance of the Q-statistic.

The above proposed autocorrelation function will be used to test the randomness of prices in both the cash forward and the futures markets for white wheat. Temporal price relationships tested in such a manner would help determine market efficiency in each market. Causality models will be developed in the following section.

Causality Models

This section will present models used to test the relationship between the two markets. The cash forward price and futures price at day t are denoted CF_t and FT_t, respectively. Two separate measures, the direct Granger's test and the Sims' test are employed as explained below. Both tests directly utilize ordinary least squares regression as suggested by Geweke (1984).

The Direct Granger's Test

The direct Granger's test is a statistical test to assess whether futures prices cause cash forward prices by regressing current values of CF on past values of CF and FT. The regression equations are of the following forms:

$$CF_t = \alpha_o + \sum_{i=1}^{p} \alpha_{1i} CF_{t-i} + \varepsilon_{1t} \quad (3.1)$$

$$CF_t = \alpha_o + \sum_{i=1}^{p} \alpha_{1i} CF_{t-i} + \sum_{j=1}^{q} \alpha_{2j} FT_{t-j} + \varepsilon_{2t} \quad (3.2)$$

where ε_{1t} and ε_{2t} are each serially uncorrelated series.

Similarly, regression equations to test whether cash forward price causes futures price are:

$$FT_t = \beta_o + \sum_{i=1}^{p} \beta_{1i} FT_{t-i} + \delta_{1t} \quad (3.3)$$

$$FT_t = \beta_o + \sum_{i=1}^{p} \beta_{1i} FT_{t-i} + \sum_{j=1}^{q} \beta_{2j} CF_{t-j} + \delta_{2t} \quad (3.4)$$

where δ_{1t} and δ_{2t} are each serially uncorrelated series.

To test FT ====> CF is equivalent to testing the hypothesis that the coefficients of the lagged independent variables (α_2's in (3.2)) are jointly significantly different from zero. To perform this test, the F-statistic is used;

$$F^* = \frac{SSE_1 - SSE_2}{q} \Big/ \frac{SSE_2}{N-p-q-1} .$$

SSE_1 and SSE_2 are the sum of squared errors from the ordinary least squares regression from (3.1) and (3.2), respectively, and N is the number of observations. The test statistic has an F distribution with q degrees of freedom in the numerator and N-p-q-1 in the denominator. If the error sum of squares in (3.1) is not significantly higher than that in (3.2), the omission of the lagged independent variables (FT's) has no effect on the explanatory power of the equation. In such a case, the F^* value will be small. Accordingly, the null hypothesis that the α_2's are jointly not different from zero is accepted, which infers that FT $=\!\not=\!\Rightarrow$ CF. To test whether CF ====> FT, the same procedure will be applied to equations (3.3) and (3.4).

Since the above regression equations are autoregressive processes, the usual Durbin-Watson statistic cannot be relied on in testing for autocorrelation of the residuals. Box and Pierce (1970) suggest the Q-statistic instead;

$$Q = N \left[\sum_{k=1}^{M} (r_k)^2 \right]$$

where r = k^{th} lag autocorrelation of the residuals;

M = number of autocorrelations used in calculation [$M = \min(N/2, 3N^{1/2})$].

The statistic is tested against the chi-square distribution at M degrees of freedom. This is not the true asymptotic distribution. Hence, it can be considered only as an approximate measure of the general autocorrelation of the residuals (Doan and Litterman, 1983).

It is generally recognized that autocorrelation is quite common in economic time-series data. Although autocorrelation can be positive as well as negative, most economic time series generally exhibit positive autocorrelation because they either move upward or downward over a period of time rather than exhibit negative autocorrelation by an up-and-down (see-saw) movement over time (Gujarati, 1978). The presence of substantial autocorrelation of the residuals implies that the calculated values of the usual t and F statistics will be higher than they should be (Granger and Newbold, 1974). With this in mind, the simple first difference method is employed to filter the original series. The generated bivariate time series ΔCF_t and ΔFT_t, where $\Delta CF_t = CF_t - CF_{t-1}$ and $\Delta FT_t = FT_t - FT_{t-1}$ are then used to form regression models. However, the regression equations are of slightly different forms as follows.

Test for FT ====> CF

$$\Delta CF_t = \sum_{i=1}^{p} \alpha_{1i} \Delta CF_{t-i} + \varepsilon_{1t} \qquad (3.1a)$$

$$\Delta CF_t = \sum_{i=1}^{p} \alpha_{1i} \Delta CF_{t-i} + \sum_{j=1}^{q} \alpha_{2j} \Delta FT_{t-j} + \varepsilon_{2t} \qquad (3.2a)$$

Test for CF ====> FT

$$\Delta FT_t = \sum_{i=1}^{p} \beta_{1i} \Delta FT_{t-i} + \delta_{1t} \qquad (3.3a)$$

$$\Delta FT_t = \sum_{i=1}^{p} \beta_{1i} \Delta FT_{t-i} + \sum_{j=1}^{q} \beta_{2j} \Delta CF_{t-j} + \delta_{2t} \qquad (3.4a)$$

The procedure to test FT ====> CF and CF ====> FT is the same as in the case of original series.

In this research, causal orderings are conducted with both the original data series and the filtered series. The autocorrelation problem, if it exists, is expected to be lessened when using the filtered series.

<u>Inference from the Direct Granger's Test</u>

The possible causal relationships between cash forward and futures prices resulting from the F-test analyses are summarized in Table 1.

Table 1
Causal Relations Indicated by Joint F-test
from the Direct Granger's Model

Causal Direction	On α_2's in Eq. 3.2 or 3.2a as a group		On β_2's in Eq. 3.4 or 3.4a as a group
FT ====> CF (unidirectional)	> 0	and	= 0
CF ====> FT (unidirectional)	= 0	and	> 0
FT <====> CF (bidirectional)	> 0	and	> 0
FT <==/=> CF (no causality)	= 0	and	= 0

The number of lags (p and q values) used ranges from 1 to 7 days. In general, the values of p and q must be large enough to remove substantial autocorrelation in the residuals and the selection of p and q can be based on a priori knowledge (Bessler and Brandt, 1982). In this research, 1 to 7 day lags are used based on Reynolds' (1984) finding that weekly price data revealed no causal link between cash forward and Chicago red wheat futures. Thus, daily series with lags of up to one week will provide a test of intervals not examined previously.

The Sims' Test

Based on Granger's definition of causality, Sims developed an alternative testing procedure. With the information set containing X and Y, the Sims' test can be conducted as follows:

> Regress Y on past, (current), and future values of X, taking account by generalized least squares or prefiltering of the serial correlation in w(t). Then if causality runs from X to Y only, future values of X in the regression should have coefficients insignificantly different from zero, as a group (Sims, 1972).

Thus, the lead-lag or causal relation between cash forward and futures prices may be represented by the following regression equations.

Test for FT ====> CF

$$FT_t = \alpha_o + \sum_{i=0}^{p} \alpha_{1i} CF_{t-i} + \varepsilon_{1t} \qquad (3.5)$$

$$FT_t = \alpha_o + \sum_{i=-q}^{p} \alpha_{2i} CF_{t-i} + \varepsilon_{2t} \qquad (3.6)$$

where ε_{1t} and ε_{2t} are each serially uncorrelated series.

The statistic for testing the significance is also an F-test;

$$F^* = \frac{SSE_1 - SSE_2}{q} \Big/ \frac{SSE_2}{N-p-q-2} .$$

SSE_1 and SSE_2 are the sum of squared errors of the ordinary least squares regressions from (3.5) and (3.6), respectively. Under the null hypothesis that coefficients of future values, α_{2i} (where i = -1 to -q), are not significantly different from zero as a group, F^* is compared with the table F value for q, N-p-q-2 degrees of freedom. If the null hypothesis is rejected, future values of CF are significant in explaining current value of FT. Hence, causality in Granger's sense is established from FT to CF.

<u>Test for CF ====> FT</u>

$$CF_t = \beta_o + \sum_{i=0}^{p} \beta_{1i} FT_{t-i} + \delta_{1t} \quad (3.7)$$

$$CF_t = \beta_o + \sum_{i=-q}^{p} \beta_{2i} FT_{t-i} + \delta_{2t} \quad (3.8)$$

where δ_{1t} and δ_{2t} are each serially uncorrelated series.

The same testing procedure used for (3.5) and (3.6) is applied here. If F^* is small, the future coefficients β_{2i} (where i = -1 to -q), are not significantly different from zero; the inference is that CF ==/=> FT.

Using the same rationale as in the case of the direct Granger's test, original data series can be transformed and filtered by the first difference method. The same procedure discussed above can be conducted on the following regression equations.

<u>Test for FT ====> CF</u>

$$\triangle FT_t = \sum_{i=0}^{p} \alpha_{1i} \triangle CF_{t-i} + \varepsilon_{1t} \quad (3.5a)$$

$$\triangle FT_t = \sum_{i=-q}^{p} \alpha_{2i} \triangle CF_{t-i} + \varepsilon_{2t} \quad (3.6a)$$

<u>Test for CF ====> FT</u>

$$\triangle CF_t = \sum_{i=0}^{p} \beta_{1i} \triangle FT_{t-i} + \delta_{1t} \quad (3.7a)$$

$$\triangle CF_t = \sum_{i=-q}^{p} \beta_{2i} \triangle FT_{t-i} + \delta_{2t} \qquad (3.8a)$$

Inference from the Sims' Test

The causal directions from F-test analysis are summarized in Table 2.

Table 2
Causal Relations Indicated by Joint F-test from the Sims' Model

Causal Direction	On α_{2i} in Eq. 3.6 or 3.6a as a group (i=-1 to -q)		On β_{2i} in Eq. 3.8 or 3.8a as a group (i=-1 to -q)
FT ====> CF (unidirectional)	> 0	and	= 0
CF ====> FT (unidirectional)	= 0	and	> 0
FT <====> CF (bidirectional)	> 0	and	> 0
FT <==+==> CF (no causality)	= 0	and	= 0

The number of lags (p) is from 1 to 7, and the number of leads (q) is also from 1 to 7. Hence, all regressions are symmetric in lead and lags (p = q).

The Data

There are two forward price series used in this research, cash forward delivery contract price and futures contract price. The cash forward price represents the Portland, Oregon cash white wheat market. Futures prices are for the white wheat futures contract traded at the Minneapolis Grain Exchange (MGE), which is also based on the Portland market.

Futures price information was obtained directly from the MGE. The price series used was the daily closing price. Five different time periods are examined, corresponding to the delivery months specified in the futures contract: March, May, July, September, and December of 1985. Thus, the study covers approximately the first full calendar year's experience with white wheat futures contract.

Open interest and volume data reported by the MGE reveal a sharp contrast in trading volume among these futures contracts. As pointed out in Chapter I, the March, May, and December contract were the most heavily traded, with trading volume in excess of five millions bushels. By comparison, trading volume for the July contract was only 250,000 bushels, and the September contract two million bushels. These statistics indicate a relatively thinly traded futures contract, considering total exports during the twelve months period reached nearly 200 million bushels (USDA).

While futures prices can be obtained conveniently from the MGE, cash forward prices pose some problems. Increasingly, cash forward prices are made under private treaties between grain exporters and various wheat sellers. These cash forward bids are thought to reflect future export business negotiations and expectations by a particular export elevator.

In recent years, the use of the open-outcry Portland grain exchange by merchandisers has declined, to the extent that this exchange ceased operations in 1985. Cash forward contract prices are thus outside conventional USDA price gathering instruments, with reported prices evidently based on "best judgment" of experienced market news reporters in Portland. On any given day, a range of prices is possible from alternative terminal elevators based on individual merchandising needs. Interfirm competition keeps prices comparable within a range of a few cents per bushel, but this range varies depending upon logistical needs and merchandising activity.

In order to standardize the price series for cash forward bids, a consistent set of prices reporting bids for forward month delivery was obtained from Van Dykes Elevator in North Plains, Oregon, showing bids offered by Columbia Grain Company, a major export terminal elevator in Portland. Mid-morning bids made for delivery in the months corresponding to the MGE futures market delivery period were tabulated. Hence, a set of cash forward prices comparable to the futures prices on the corresponding day was obtained.

The availability of forward prices, either futures or cash delivery, varied over time. For example, forward delivery bids for "new crop" delivery (August/September) may be offered as early as January by elevators in order to facilitate forward pricing decisions by producers. For other lightly traded months, such as May, most forward pricing activity is grouped into the two or three months prior. Observations range from a low of 67 days prior to delivery for the May cash forward contract to 218 days for the December futures contract. No documentation currently exists to reliably assess sales volume on cash forward contracts due to the proprietary nature of this market.

Appendix A shows daily price quotes of both types of contracts for the five contract months of interest. For efficient market testing, all entries in each contract month were used. For causality testing, cash forward prices were paired with futures price day by day. Thus, only paired observations were used in the latter test.

Summary

This chapter developed models to examine price relationships in the cash forward and futures markets. An autocorrelation function was proposed for testing temporal price patterns in each market. The direct Granger's and the Sims' tests were designated to determine causal relationships between the two markets. The nature of data used was also explained.

IV. THE RESULTS

This chapter will discuss and interpret the results of the methodologies outlined in Chapter III. All calculations were performed using RATS (Regression Analysis of Time Series), a computer software package. Entries used in all cases are the daily price quotes for the cash forward and futures markets. The results and implications from the efficient market models for each market will be discussed first. Discussion of the findings of the causal relationship between the two markets will follow.

The Market Efficiency Results

The Cash Forward Market

Table 3 gives the values of autocorrelation coefficients:

$$\hat{P}_k = \frac{\sum_{t=1}^{N-k} (R_t - \bar{R})(R_{t+k} - \bar{R})}{\sum_{t=1}^{N} (R_t - \bar{R})^2}$$

where k is the lag between observations. The value of k is from 1 to 24 (days) or in some cases from 1 to N/4, where N is the number of observations.

Statistically significant autocorrelation in cash forward price between current and one-day lag was found in all contract months except December. Some autocorrelation in later lags was also indicated. The price series exhibited some correlation in the 16 and 18-day lags of March, and in

Table 3
Autocorrelation Coefficients for First Differences of the Natural Logs of Daily Cash Forward Prices; 1985

Lags	March	May	July	September	December
1	0.312*	-0.494*	-0.445*	-0.481*	0.107
2	0.133	0.100	-0.001	-0.008	-0.021
3	-0.067	-0.136	0.064	0.009	0.064
4	-0.074	0.088	-0.062	0.003	-0.020
5	-0.082	-0.004	0.011	-0.007	-0.068
6	-0.128	0.021	-0.024	0.008	-0.141
7	-0.108	-0.021	-0.089	-0.006	-0.060
8	-0.076	0.005	0.281*	0.040	-0.124
9	-0.038	-0.026	-0.118	-0.065	0.046
10	-0.100	-0.017	-0.056	0.045	0.112
11	0.004	0.053	-0.126	-0.030	-0.129
12	-0.007	-0.027	0.317*	0.008	-0.032
13	0.032	-0.011	-0.243*	0.015	0.123
14	0.030	0.024	0.080	-0.007	0.114
15	0.076	-0.024	-0.016	-0.001	0.031
16	0.243*	-0.034	-0.013	-0.006	-0.010
17	0.150		0.003	0.008	-0.016
18	0.235*		-0.058	-0.014	-0.170
19	0.101			0.016	0.089
20	0.059			0.002	-0.054
21	-0.057			-0.002	-0.041
22	-0.139			0.006	-0.064

Table 3 (continued)

Lags	March	May	July	September	December
23	-0.123			-0.006	0.078
24	-0.032			-0.001	0.073
# of observations	105	66	79	126	92
$\sigma(\hat{P})$	.098	.123	.113	.089	.104

* Significant at 5%

Q-statistic for Autocorrelation

Lags Interval	Mar	May	Jul	Sept	Dec	df[a]	Critical Value[b]
1-6	16.12	19.45	17.00	29.86	4.02	5	11.07
1-12	19.48	19.86	37.48	31.08	9.43	11	19.68
1-18	37.92	20.08[c]	44.23	31.16	16.06	17	27.60
1-24	44.96	-	-	31.22	19.51	23	35.20

[a]Degrees of freedom.

[b]Chi-squared Distribution, at 5% significance level.

[c]1-16 lags for May contract, with critical value at 15 df at 5% = 25.00.

the 8, 12, and 13-day lags of July. When judged as a group, the Q-statistics in most intervals of March, May, July and September contracts also reveal autocorrelation in the price series. This analysis finds that the random walk hypothesis held only for the December cash forward contract. Thus, the price changes, in most cases, were nonrandom.

As noted by Cargill and Rausser (1975), rejection of a random walk process does not routinely imply that the efficient market hypothesis is also rejected. In other words, evidence of serial correlation may be consistent with the efficient market process. The above statistical test of serial correlation only indicates that in most cases increments in prices over the life of the cash forward contract were not uncorrelated. These deviations from the random walk process consist mainly of small, nonzero, autocorrelation coefficients in the series of daily price changes. The serial correlation coefficients may not be large enough to form the basis of a profitable trading rule. Unfortunately, the available statistical tests do not have sufficient power to determine whether profits[4/] can be generated from the presence of systematic price behavior.

December is the only contract month that exhibits randomness in prices. Thus, the cash forward market for December contract was considered to be efficient without further qualification. Given serial dependence in prices, the mar-

4/ In this case, profits refer to expected gain above normal transaction by any market participants who can detect and exploit the nonrandomness in price movements by inventing a trading scheme.

ket for the other four contract months would be regarded as inefficient only if mechanical trading rules or filters could be established to increase expected profits. Such filtering techniques are beyond the scope of this research and are not explored here.

The existence of nonrandomness in prices has some implications. Deviation from the random walk process in the cash forward market is anticipated. This kind of market is not classified as a highly organized commodity market in comparison to a futures market. In the cash forward market, all existing knowledge of market conditions may not be incorporated into current price; new information may not cause a price change. The traders in this market may react with varying skill to varying sources of information. This phenomenon causes delays in the response to price-making forces.

The Futures Market

Table 4 shows autocorrelation coefficients of futures prices for the same five contract months of interest. The values of $\hat{P}_k$ are given from k = 1 to 24-day lags. Only three indications of significant autocorrelation at the 5 percent level were noted; the 1-day lag for the September contract and the 4-day lags for the March and December contracts. However, in all cases, they are not significant at the 1 percent level. Moreover, the Q-statistic indicates that the white wheat futures prices exhibited no serial

Table 4
Autocorrelation Coefficients for First Differences of the Natural Logs of Daily Futures Prices; 1985

Lags	March	May	July	September	December
1	0.109	-0.026	0.058	0.173*	-0.001
2	0.005	-0.021	-0.039	-0.059	-0.135
3	-0.029	0.115	0.024	-0.014	0.027
4	-0.186*	-0.014	0.071	0.038	0.164*
5	-0.143	-0.109	-0.002	.000	0.004
6	0.033	0.118	0.010	-0.002	0.001
7	0.008	-0.039	0.028	0.046	0.081
8	0.011	-0.037	-0.040	0.006	-0.010
9	-0.009	-0.019	-0.035	0.018	0.066
10	0.089	-0.007	0.003	-0.114	0.013
11	0.043	-0.006	-0.012	-0.013	-0.013
12	-0.045	-0.001	0.050	0.039	-0.029
13	-0.017	0.032	-0.053	0.011	0.061
14	-0.003	-0.001	-0.091	0.006	-0.041
15	0.001	0.038	0.030	0.022	0.075
16	-0.007	-0.071	0.070	-0.040	0.015
17	0.110	0.068	-0.064	-0.075	0.020
18	-0.001	-0.085	-0.093	-0.044	-0.122
19	0.046	0.022	-0.114	-0.035	0.049
20	0.011	-0.015	0.047	.000	0.014
21	-0.032	-0.141	0.008	0.028	0.051
22	-0.041	-0.047	-0.041	0.016	-0.075

Table 4 (continued)

Lags	March	May	July	September	December
23	0.014	0.078	0.041	-0.040	0.042
24	-0.012	-0.060	0.087	0.066	0.081
# of observations	132	175	131	164	217
$\sigma(\hat{P})$	.087	.076	.087	.078	.068

* Significant at 5%

Q-statistic for Autocorrelation

Lags Interval	Mar	May	Jul	Sept	Dec	df[a]	Critical Value[b]
1-6	9.50	7.33	1.45	5.85	10.16	5	11.07
1-12	11.25	7.94	2.34	8.89	12.95	11	19.68
1-18	13.18	11.71	6.83	10.70	19.28	17	27.60
1-24	14.02	18.29	10.98	12.30	23.95	23	35.20

[a]Degrees of freedom.

[b]Chi-squared Distribution, at 5% significance level.

dependence in any time period. Thus, the random walk hypothesis is accepted. The implication is that the futures market was efficient, and that no trading program could be established to increase expected profit.

The initial year of activity in the white wheat futures market has resulted in a relatively low volume of trading. An important point relating to price behavior on thin or illiquid futures markets is noted by Carter and Rausser (1983) and Thompson (1984). According to these researchers, price behavior in a thinly traded market should be analyzed differently from a liquid market. Moreover, Carter and Rausser specify that noncompetitive price behavior in thin markets often has resulted in their being classified as inefficient. Thus, their argument is inconsistent with the finding of the efficient market for white wheat futures in this research.

Causality Test Results

Tables 5 through 8 show the test results for causality between futures prices and cash forward prices. The results from the direct Granger's model appear in Table 5 and Table 7. Table 6 and Table 8 give the results for the Sims' model. Reported results are obtained from the regressions run on the price series that have no problem of autocorrelation in the residuals. In all cases save one, the original series is used in the direct Granger's model. Because of the autocorrelation problem, however, filtered series are used in most parts in the Sims' model. The complete test results

Table 5
One-Way Causality Test from Futures to Cash Forward;
Direct Granger's Model[a]

Lags		Mar	May	Jul	Sept	Dec
7	F-test[b]	3.73*	1.01	2.01	5.50*	2.69*
		(7,76)	(7,37)	(7,52)	(7,98)	(7,64)
	Q-test[c]	13.58	5.50	15.63	5.73	20.45
		(27)	(21)	(24)	(30)	(24)
6	F-test	4.39*	1.25	2.25	6.28*	2.87*
		(6,79)	(6,40)	(6,55)	(6,101)	(6,67)
	Q-test	12.38	6.10	18.20	6.06	19.36
		(27)	(21)	(24)	(30)	(24)
5	F-test	4.79*	1.34	2.50*	4.61*	2.62*
		(5,82)	(5,43)	(5,58)	(5,104)	(5,70)
	Q-test	14.50	6.40	16.40	5.33	28.35
		(27)	(21)	(24)	(30)	(27)
4	F-test	5.63*	1.50	2.75*	6.05*	2.99*
		(4,85)	(4,46)	(4,61)	(4,107)	(4,73)
	Q-test	15.86	6.46	22.88	5.27	26.95
		(27)	(21)	(24)	(30)	(27)
3	F-test	7.88*	1.91	3.44*	8.53*	2.36
		(3,88)	(3,49)	(3,64)	(3,110)	(3,76)
	Q-test	16.76	4.92	22.50	4.26	24.90
		(27)	(21)	(24)	(30)	(27)
2	F-test	12.34*	2.93	4.95*	14.40*	2.01
		(2,91)	(2,52)	(2,67)	(2,113)	(2,79)
	Q-test	17.74	4.76	17.87	3.21	25.69
		(27)	(21)	(24)	(30)	(27)
1	t-test[d]	3.79*[e]	3.18*	3.45*	6.16*	1.66
		(94)	(55)	(70)	(116)	(82)
	Q-test	15.09	5.66	17.40	2.67	26.80
		(27)	(21)	(24)	(30)	(27)

[a]Uses original series; i.e., regression is run on Eq.(3.2) unless indicated by [e].
[b]H_o: Coefficients of causal variables (futures prices) are equal to zero as a group. Degrees of freedom appear in parentheses below the F-statistic.
[c]H_o: Residuals of the regression have no autocorrelation. Degrees of freedom are in brackets.
[d]t-test is used in place of F-test for lag 1. Degrees of freedom are in brackets.
[e]Uses filtered series i.e., regression is run on Eq.(3.2a).
* Significant at 5% level.

Table 6
One-Way Causality Test from Futures to Cash Forward; Sims' Model[a]

Leads		Mar	May	Jul	Sept	Dec
7	F-test[b]	3.45*	1.43	.90	5.32*	5.72*[e]
		(7,68)	(7,29)	(7,44)	(7,90)	(7,56)
	Q-test[c]	18.77	7.84	9.79	20.01	18.88
		(27)	(18)	(21)	(30)	(24)
6	F-test	2.56*	1.48	.74	6.40*	6.14*[e]
		(6,72)	(6,33)	(6,48)	(6,94)	(6,60)
	Q-test	16.29	10.49	12.86	19.77	21.79
		(27)	(18)	(21)	(30)	(24)
5	F-test	2.97*	1.44	.58	6.89*	6.34*[e]
		(5,76)	(5,37)	(5,52)	(5,98)	(5,64)
	Q-test	14.40	5.36	10.74	19.85	21.64
		(27)	(21)	(21)	(30)	(24)
4	F-test	3.48*	1.73	.47	3.06*	6.84*[e]
		(4,80)	(4,41)	(4,56)	(4,102)	(4,68)
	Q-test	14.08	7.55	15.30	17.30	27.22
		(27)	(21)	(24)	(30)	(24)
3	F-test	4.27*	1.54	.56	3.03*	4.91*[e]
		(3,84)	(3,45)	(3,60)	(3,106)	(3,72)
	Q-test	17.30	8.77	16.16	17.78	28.49
		(27)	(21)	(24)	(30)	(24)
2	F-test	6.45*	2.28	1.31	4.20*	1.19
		(2,88)	(2,49)	(2,64)	(2,110)	(2,76)
	Q-test	19.24	8.73	14.31	19.44	22.87
		(27)	(21)	(24)	(30)	(27)
1	t-test[d]	3.85*	1.11	1.40	2.82*	1.23
		(92)	(53)	(68)	(114)	(80)
	Q-test	22.92	7.60	16.09	19.26	25.27
		(27)	(21)	(24)	(30)	(27)

[a]Uses filtered series; i.e., regression is run on Eq.(3.6a) unless indicated by [e].
[b]H_o: Coefficients of the future values of the cash forward prices are equal to zero as a group. Degrees of freedom appear in parentheses below the F-statistic.
[c]H_o: Residuals of the regression have no autocorrelation. Degrees of freedom are in brackets.
[d]t-test is used in place of F-test for lag 1. Degrees of freedom are in brackets.
[e]Uses original series; i.e., regression is run on Eq.(3.6).
* Significant at 5% level.

Table 7
One-Way Causality Test from Cash Forward to Futures; Direct Granger's Model[a]

Lags		Mar	May	Jul	Sept	Dec
7	F-test[b]	2.40*	.86	1.27	.91	.89
		(7,76)	(7,37)	(7,52)	(7,98)	(7,64)
	Q-test[c]	9.23	9.48	12.23	11.80	14.59
		(27)	(21)	(24)	(30)	(24)
6	F-test	2.70*	.43	1.25	.97	.93
		(6,79)	(6,40)	(6,55)	(6,101)	(6,67)
	Q-test	8.45	7.12	13.30	10.89	14.79
		(27)	(21)	(24)	(30)	(24)
5	F-test	2.57*	.77	1.03	1.16	1.10
		(5,82)	(5,43)	(5,58)	(5,104)	(5,70)
	Q-test	7.09	4.84	14.82	11.34	18.85
		(27)	(21)	(24)	(30)	(27)
4	F-test	4.16*	1.08	1.33	.33	2.26
		(4,85)	(4,46)	(4,61)	(4,107)	(4,73)
	Q-test	8.39	4.46	15.81	11.91	14.89
		(27)	(21)	(24)	(30)	(27)
3	F-test	3.72*	.79	1.65	.26	1.46
		(3,88)	(3,49)	(3,64)	(3,110)	(3,76)
	Q-test	12.51	4.54	15.26	11.51	17.85
		(27)	(21)	(24)	(30)	(27)
2	F-test	3.75*	.62	2.49	.24	2.51
		(2,91)	(2,52)	(2,67)	(2,113)	(2,79)
	Q-test	16.55	4.18	16.36	13.16	29.24
		(27)	(21)	(24)	(30)	(27)
1	t-test[d]	.43	-1.04	1.68	.00	2.57*
		(94)	(55)	(70)	(116)	(82)
	Q-test	17.30	3.99	16.62	16.35	28.41
		(27)	(21)	(24)	(30)	(27)

[a]Uses original series; i.e., regression is run on Eq.(3.4).
[b]H_o: Coefficients of causal variables (cash forward prices) are equal to zero as a group. Degrees of freedom appear in parentheses below the F-statistic.
[c]H_o: Residuals of the regression have no autocorrelation. Degrees of freedom are in brackets.
[d]t-test is used in place of F-test for lag 1. Degrees of freedom are in brackets.
* Significant at 5% level.

Table 8
One-Way Causality Test from Cash Forward to Futures; Sims' Model[a]

Leads		Mar	May	Jul	Sept	Dec
7	F-test[b]	4.04*	1.03[e]	1.54[e]	.87[e]	.87
		(7,68)	(7,29)	(7,44)	(7,90)	(7,56)
	Q-test[c]	25.76	7.06	19.77	5.53	19.55
		(27)	(18)	(21)	(30)	(24)
6	F-test	3.42*	.46[e]	1.44[e]	.89[e]	1.44
		(6,72)	(6,33)	(6,48)	(6,94)	(6,60)
	Q-test	25.68	6.08	16.03	5.97	20.14
		(27)	(18)	(21)	(30)	(24)
5	F-test	4.34*	.37[e]	1.28[e]	1.14[e]	1.90
		(5,76)	(5,37)	(5,52)	(5,98)	(5,64)
	Q-test	25.13	6.58	17.83	5.37	18.77
		(27)	(21)	(24)	(30)	(24)
4	F-test	4.54*	.42[e]	1.29[e]	.24[e]	2.44
		(4,80)	(4,41)	(4,56)	(4,102)	(4,68)
	Q-test	24.70	6.13	17.73	5.42	18.59
		(27)	(21)	(24)	(30)	(24)
3	F-test	4.32*	.38[e]	1.57[e]	.24[e]	2.83*
		(3,84)	(3,45)	(3,60)	(3,106)	(3,72)
	Q-test	22.25	5.52	18.02	3.97	15.78
		(27)	(21)	(24)	(30)	(24)
2	F-test	5.56*	.44[e]	2.24[e]	.41[e]	2.07
		(2,88)	(2,49)	(2,64)	(2,110)	(2,76)
	Q-test	20.61	5.60	13.85	4.17	16.43
		(27)	(21)	(24)	(30)	(27)
1	t-test[d]	3.00*	-1.08[e]	1.64[e]	.24[e]	1.88
		(92)	(53)	(68)	(114)	(80)
	Q-test	18.68	6.11	13.70	2.99	15.86
		(27)	(21)	(24)	(30)	(27)

[a]Uses filtered series; i.e., regression is run on Eq.(3.8a) unless indicated by [e].
[b]H_o: Coefficients of the future values of the futures prices are equal to zero as a group. Degrees of freedom appear in parentheses below the F-statistic.
[c]H_o: Residuals of the regression have no autocorrelation. Degrees of freedom are in brackets.
[d]t-test is used in place of F-test for lag 1. Degrees of freedom are in brackets.
[e]Uses original series; i.e., regression is run on Eq.(3.8).
* Significant at 5% level.

on both price series for both models, including the coefficient's values of interest, are given in Appendix B.

One-Way Causality Test from FT to CF

The significance of the F-statistics in Tables 5 and 6 for both the Granger's and Sims' tests confirm strong causality running from FT to CF at all leads and lags in the March and September delivery periods. In Table 5, insignificant F-statistics indicate that FT did not cause CF in May, except the 1-day lag. This is confirmed by the Sims' model in Table 6.

In the July delivery period, there seems to be contradiction between the two models. The Sims' model suggests FT did not cause CF in any of the lead-lag intervals, while the direct Granger's model shows that FT caused CF in lags of 1 to 5. However, the F-statistics for lags 3 to 5 are not significant at the 1 percent level. Moreover, if filtered series are used in the direct Granger's model, the results would agree with the Sims' test, that FT did not cause CF (See Table B.3).

For the December contract, both models suggest FT caused CF for lags 4 to 7 and FT did not cause CF for lags 1 and 2. The causality seems to prevail for the longer lag periods in this contract month. Hence, the results show that the causal relationships change within the lag length used in the tests.

One-Way Causality Test from CF to FT

Tables 7 and 8 suggest that there was causality running from CF to FT in the March delivery period. For the other periods, both the direct Granger's model and the Sims' model show that there was no causality from CF to FT in May, July, September and December. The test statistics for lag 1 and lead 3 for December in Table 7 and Table 8 respectively are not significant at the 1 percent level.

A Summary of the Causal Relationships

Based on the above analysis, a summary of the causality findings is given in Table 9. The data assert that the line of causality between the two price series varied over the time periods tested. There was bidirectional causality, or feedback, between the futures and cash forward prices for the March contract. Strong one-way causality from futures to cash forward was found for prices based on the September delivery period. Conversely, the tests suggest that there were little or no causal relationships during the May and July periods. Lastly, some causality occurred in the longer lags of the December contract.

To explain the above pattern of causality found in the data, the September delivery period is a useful starting point. September corresponds to the "new crop" delivery period, and is therefore a logical forward pricing period for wheat farmers seeking to price a growing crop for sale at harvest. The fact that the producers have the option to hedge their crops either in the futures or the cash forward

Table 9
Summary of Causal Relationships Between
Futures and Cash Forward Markets

Delivery Month	FT ====> CF	CF ====> FT
March	Yes	Yes
May	No	No
July	No	No
September	Yes	No
December	(Yes,No)[a]	No

[a]Causality exists to prevail in lags of 4 to 7 days only.

markets may influence how the country elevators offer their prices. To the extent that increased forward pricing activity occurs for September delivery, grain merchandisers may rely more heavily upon the futures market to establish forward contract quotes. That is, merchandisers may use the futures to hedge purchases if farm sales exceed normal export sales volume. This pricing behavior would tend to substantiate a line of causality from the futures market to the cash forward price.

In post harvest pricing decisions, wheat producers have additional storage months available for forward pricing. Some causality was indicated from the futures price to cash forward price in December and March contracts, but none in May and July delivery periods. The lack of causality suggests that arbitrage may occur over periods of less than even one day between the futures and cash forward markets, especially during the late season (May and July) delivery periods corresponding to reduced market activity.

The feedback from cash forward price to the futures price in the March delivery period may indicate arbitrage activity in the two markets. As the crop year progresses, the inefficiency of the March cash forward contract, as noted in Table 3, may create profit opportunities through speculative positions in the futures market.

Summary

The white wheat futures market was found efficient, under the random walk hypothesis, for all five delivery periods in 1985. There was evidence that price changes in the cash forward market of white wheat for the same time periods, except December, were nonrandom. Causality test results revealed that causal relations between the two markets varied over time. Futures prices seemed to cause cash forward prices in September, December, and March delivery periods. There was little or no causal link between the two prices in May and July. Feedback from cash forward prices to futures prices occurred in March.

V. SUMMARY AND CONCLUSIONS

This research has examined the price relationships in the cash forward and futures markets for PNW white wheat. The temporal price relationships were evaluated for each market and between the two markets. The research aimed at providing the participants in the white wheat market a comparative analysis tool for evaluating the appropriateness of these two forward pricing markets in sales decisions.

Summary

Pacific Northwest white wheat prices fluctuated dramatically by historical standards in the 1972-1978 period. Although the price volatility has moderated since 1979, the variability is still significant. Wheat farmers can reduce this price risk by using forward pricing mechanisms such as cash forward and futures contracts. Prior to 1985, white wheat was not deliverable against a futures contract on any commodity exchange. As a result, cash forward contracts have been the traditional marketing alternative for white wheat growers. The white wheat futures contract began trading at the MGE on September 10, 1984. In the initial year of trading, this new futures market suffered from low trading volume and open interest, and can be considered a thin market.

Farmers use cash forward and futures markets to reduce price risk and as information inputs to farm management plans, it is of interest to explore the pricing efficiency in each market, and assess causal relations between the two price series. Better understanding of the price movements in these respects could help farmers to better allocate resources in their production and sales decisions. Pricing efficiency was examined by the random walk model of the efficient market hypothesis. Causal relationships were evaluated using Granger's definition of causality.

In order to explore these relationships, this research used daily price series data. The futures prices were the closing prices of the white wheat futures contracts traded at the MGE. The cash forward prices were obtained from a major export elevator in Portland. The study covered five different future delivery time periods: March, May, July, September, and December of 1985.

Efficient Market Test

According to Fama, prices in an efficient market reflect all available information. An efficient market should follow a martingale or a fair game process in which profit above normal cannot be obtained using the information available. The most widely used test is the random walk model which is the weak form test for the market efficiency. The information set in the random walk is the historical price series. The model is designed to determine the presence of systematic behavior in prices. The random walk hypothesis holds when successive price changes are independent.

This research conducted the random walk test using the serial correlation method by finding the autocorrelation coefficient suggested by Box and Jenkins. The daily price series was transformed into the return series by calculating the first differences between the natural logarithm of daily prices. The return series was then used to find the autocorrelation functions from 1 to 24 day lags, or in some cases from 1 to N/4, where N is the number of observations.

The results from this statistical test show that the futures market for white wheat over the investigated period was efficient under the random walk hypothesis. In almost all cases, the autocorrelation coefficients were not significant. In contrast, in all delivery time periods except December, the autocorrelation coefficients for the cash forward market exhibited nonrandomness in price changes. This may suggest inefficiency in the cash forward market. However, the statistical analysis used here did not evaluate mechanical trading rules that may be used to increase expected profit in the cash forward market. In fact, evidence of nonrandomness in price may be consistent with the notion of an efficient market.

Causality Test

To evaluate the relationship between the cash forward market and the futures market, Granger's definition of causality was used to determine such relationship. For bivariate time series X and Y, if optimum predictions of X conditional on past values of X and Y are significantly better than optimum predictions conditional on past values of X alone, then Y is said to "Granger cause" X. To test causality, this research used two parallel models; the direct Granger's test and the Sims' test.

To test whether futures price (FT) causes cash forward price (CF), the direct Granger's model is implemented by regressing the current value of CF on past values of CF and FT. If the coefficients of FT are significant as a group, FT is said to cause CF in Granger's sense. The statistic for significance testing is the F-statistic. Similarly, to test whether CF causes FT, current value of FT are regressed on past values of FT and CF. A significant joint F-statistic on coefficients of past CF infers that CF causes FT.

From the Granger's definition, Sims developed a parallel test for causality. The basic premise of the Sims' test is that if and only if causality runs one-way from Y to X, then in a regression of X on past, current, and future values of Y, the future values of Y should have zero coefficients. Hence, in the case that the future values of Y are statistically significant, the null hypothesis is rejected and the causality would be established from X to Y. This premise of the Sims' test was applied to test whether FT causes CF and vice versa. The test for significance of the future values of the exogenous variables is also the F-test.

The causality testings, under the direct Granger's and the Sims' tests, were conducted both from the original prices series and the filtered series. The filtering was performed by the first difference method. The filtered series obtained were used to estimate the direct Granger's and

Sims' models wherever autocorrelation in the residuals occurred in the unfiltered series. The direct Granger's tests were performed for the lags from 1 to 7 days. The number of leads and lags were also from 1 to 7 in the Sims' test.

In general, the direct Granger's test and the Sims' test revealed the same results. The data exhibited strong one-way causality running from FT to CF in the September contract as was hypothesized for the "new crop" delivery period. There were indications of a weak causality from FT to CF in the longer lags (4-7 days) of the December contract. Causality from FT to CF also was detected for the March delivery period. Lack of forward pricing activities for the May and July contracts could contribute to the absence of causal link between the two prices. In general, causality from CF to FT was not expected and this was confirmed by the data, except for the March delivery period. Arbitrage activity was suspected as causing the feedback from CF to FT in the March contract.

Conclusions

From the above findings, some implications can be drawn concerning pricing decisions by wheat growers and merchandisers. Based on the efficient market analysis, the findings suggest that no trading rules could be established to increase expected profits by speculating in the white wheat futures market. Measures of pricing efficiency indicate that this market performed well in reflecting information on the supply and demand of white wheat. Market participants could rely on the price quotes as efficient signals for allocating resources in production and sales activities. This does not assert that the prices are necessarily accurate forecasts of future market conditions; it implies only that the daily process of price determination fairly reflects available information.

In contrast, the indications that inefficiency may be present in the cash forward market suggest that profitable trading rules may be developed to take advantage of the nonrandomness in prices over time. The magnitude of profits depends upon costs and benefits of the trading plan. The potential to capture profits implies that inefficiency occurs from the cost of information, which creates some uninformed market participants. In addition, Leuthold and Hartman (1980) pointed out other possible causes for market inefficiency, including: (a) irrational traders; (b) wealth limitations; (c) risk aversion; (d) misinterpretation of information; and (e) transaction costs. Uninformed market participants is only one possibility. Thus, trading schemes to exploit the nonrandomness in price may not be successful.

Another implication that can be drawn from the inefficiency in the cash forward price is that white wheat growers and other market participants cannot rely on this price for their planning. If they routinely look at this price as a basis for their production and marketing decisions, they may receive false signals due to an inefficiently determined price. Serial dependence in prices that does not reflect true and timely information could lead to inappropriate decisions. For example, the cash forward price might be slow to respond to changing crop conditions that influence price expectations for future time periods, causing growers to miss favorable forward pricing opportunities.

This research found causality running from futures prices to cash forward prices in the "new crop" delivery period which also lingered into the first two storage month delivery periods of December and March. This causality is thought to exist because of merchandising patterns of the domestic grain trade. Buyers offer cash forward contracts based on expected future selling price. Farm level marketing activity is greatest for harvest and immediate post-harvest delivery, encouraging buyers to seek price references, or hedges as they contract with farmers for future delivery. Thus, a grain exporter might first establish an export tender based on futures prices, taking a long position if the tender is successful. The export bid is therefore based on futures prices. Similarly, a grain merchandiser or exporter offers cash forward contracts to growers based on a hedged position in the futures market, or on the known export sale price. In merchandising arrangements relying upon a hedged position, the futures market is used as a temporary substitute for the actual cash transaction. The transaction entered into is based on the price protection offered by the futures market, creating the logical direction of causality from the futures to the cash forward market. Thus, this research indicated that futures prices played an active role in cash forward pricing for some delivery time periods of 1985.

Looking back to Granger's definition of causality, there is a link between causation and prediction. In regression analysis to forecast one economic variable, the forecast might be improved if a causal variable can be identified and included in the regression equation. In this case, the findings suggest that to forecast cash forward price for the September contract, including the futures prices for the same delivery month would improve forecasting performance. Alternatively, the cash forward price in most delivery time periods except March is not suitable as an exogenous variable in the forecasting equation for the futures price.

This research found that the cash forward market for white wheat may be less efficient than the new futures market in terms of pricing. However, the flexibility of the cash forward market in adapting to the needs of domestic wheat growers may explain their preference for this market as a forward pricing mechanism, especially if price risk is seen by market participants as relatively modest.

Lack of trading in the new futures market has raised questions about the need for its existence. This analysis determined that, despite low trading volume, the market was functioning satisfactorily in terms of pricing efficiency, and that futures prices were used as a reference by the cash forward market in some delivery time periods. Nevertheless, the value of this service by the futures market could not be quantified, and has questionable economic benefits in this market condition. In the prevailing situation, the cash forward market appears sufficient for the needs of forward pricing.

Intuitively, the existence of a futures market will streamline and bring about efficient pricing behavior in a cash forward market. This is because the ability to quote a firm bid to the farmer for forward delivery is predicated on the existence of an active futures market (Paul et al., 1985). There are some expectations that provisions in the new farm program will reduce reliance of the wheat market on the loan rate, thus creating a more market-determined price. Then, the interest in forward pricing would be expected to increase, and both cash forward and futures markets may be needed.

Suggestions for Future Research

A number of questions were posed and avenues of investigation opened during this research that remain unanswered. This final section will present some ideas for future research.

From the price information obtained from the MGE, it was noted that during the time period investigated there were many days with no trading in the futures market. Thus, the closing price in that market may not have accurately reflected activity in the market. Since no information about the trading volume in the cash forward market was available, this research used daily closing prices to conduct the study. Future research may attempt to look at just those trading days having activities.

The finding from this research suggests that inefficiency may exist in the cash forward market. However, no attempt was made to measure the magnitude of the inefficiency, or its impact on resource allocation. Estimation of a mechanical trading rule to determine potential profits above normal could be attempted based on the prevailing nonrandomness in prices.

Lastly, continued research is needed to determine whether the relationships discovered here persist, if and when the futures market for white wheat matures. The thin market characteristics could be influencing the absence of causality from the futures price to the cash forward price in May and July contracts. They also may affect the feedback from the cash forward price to the futures price in March. In general, the temporal price patterns identified in this research raise further unanswered questions concerning both the causes and consequences of such price behavior.

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APPENDICES

APPENDIX A

Table A.1
Daily Cash Forward Price Quotes for 1985 Contracts

Observation[a]	Mar	May	Jul	Sept	Dec
1	3.87	3.81	3.63	3.62	3.59
2	3.89	3.81	3.63	3.61	3.58
3	3.91	3.81	3.63	3.61	3.58
4	3.90	3.82	3.63	3.61	3.58
5	3.88	3.85	3.63	3.61	3.59
6	3.88	3.87	3.63	3.61	3.59
7	3.89	3.87	3.63	3.61	3.59
8	3.91	3.88	3.64	3.61	3.61
9	3.92	3.90	3.64	3.61	3.63
10	3.92	3.89	3.64	3.61	3.64
11	3.90	3.87	3.66	3.61	3.63
12	3.89	3.89	3.63	3.62	3.64
13	3.88	3.89	3.63	3.62	3.65
14	3.87	3.87	3.63	3.62	3.65
15	3.88	3.87	3.61	3.66	3.64
16	3.88	3.88	3.62	3.61	3.64
17	3.87	3.90	3.62	3.61	3.64
18	3.88	3.92	3.62	3.61	3.65
19	3.88	3.92	3.62	3.61	3.66
20	3.88	3.92	3.58	3.60	3.67
21	3.88	3.93	3.58	3.60	3.67
22	3.87	3.94	3.60	3.60	3.67
23	3.87	3.95	3.60	3.60	3.67
24	3.88	3.96	3.61	3.00	3.65
25	3.87	3.66	3.71	3.57	3.65
26	3.88	3.95	3.61	3.58	3.65
27	3.88	3.93	3.62	3.58	3.65
28	3.87	3.98	3.62	3.59	3.66
29	3.85	3.93	3.62	3.59	3.67
30	3.83	3.93	3.63	3.59	3.67
31	3.81	3.93	3.64	3.60	3.67
32	3.80	3.93	3.64	3.60	3.68
33	3.78	3.93	3.78	3.60	3.69
34	3.81	3.95	3.63	3.60	3.69
35	3.81	3.95	3.63	3.62	3.70
36	3.82	3.93	3.63	3.60	3.71
37	3.82	3.93	3.62	3.60	3.71
38	3.83	3.93	3.62	3.61	3.70
39	3.84	3.93	3.59	3.61	3.70
40	3.84	3.92	3.59	3.61	3.71
41	3.84	3.90	3.59	3.60	3.71
42	3.84	3.89	3.59	3.60	3.75
43	3.85	3.88	3.59	3.58	3.75
44	3.85	3.84	3.59	3.58	3.75
45	3.85	3.85	3.72	3.58	3.76

Table A.1 (continued)

Observation[a]	Mar	May	Jul	Sept	Dec
46	3.83	3.86	3.59	3.58	3.77
47	3.82	3.86	3.59	3.58	3.77
48	3.81	3.84	3.60	3.58	3.77
49	3.81	3.86	3.60	3.58	3.78
50	3.82	3.88	3.60	3.58	3.79
51	3.82	3.90	3.61	3.59	3.79
52	3.83	3.91	3.63	3.60	3.80
53	3.83	3.94	3.63	3.60	3.79
54	3.84	3.90	3.63	3.60	3.79
55	3.84	3.92	3.63	3.61	3.79
56	3.83	3.92	3.63	3.63	3.79
57	3.83	3.91	3.63	3.63	3.79
58	3.83	3.93	3.62	3.63	3.79
59	3.83	3.95	3.62	3.63	3.79
60	3.81	3.93	3.62	3.63	3.79
61	3.81	3.90	3.62	3.63	3.81
62	3.81	3.91	3.62	3.63	3.80
63	3.81	3.89	3.62	3.63	3.80
64	3.81	3.90	3.62	3.63	3.81
65	3.83	3.90	3.62	3.63	3.81
66	3.82	3.89	3.62	3.63	3.81
67	3.83	3.83	3.62	3.63	3.79
68	3.84		3.62	3.63	3.78
69	3.85		3.60	3.63	3.78
70	3.86		3.59	3.63	3.77
71	3.85		3.58	3.63	3.77
72	3.85		3.54	3.63	3.77
73	3.85		3.53	3.62	3.78
74	3.86		3.54	3.61	3.79
75	3.85		3.54	3.60	3.80
76	3.84		3.52	3.56	3.80
77	3.84		3.50	3.55	3.80
78	3.84		3.49	3.56	3.81
79	3.85		3.49	3.56	3.82
80	3.85		3.48	3.54	3.82
81	3.86			3.52	3.82
82	3.86			3.51	3.82
83	3.86			3.51	3.80
84	3.86			3.51	3.81
85	3.86			3.50	3.81
86	3.88			3.50	3.80
87	3.90			3.52	3.80
88	3.92			3.52	3.80
89	3.93			3.51	3.80
90	3.94			3.51	3.81
91	3.96			3.50	3.82

Table A.1 (continued)

Observation[a]	Mar	May	Jul	Sept	Dec
92	3.95			3.48	3.83
93	3.93			3.47	3.83
94	3.92			3.47	
95	3.92			3.47	
96	3.90			3.48	
97	3.90			3.49	
98	3.91			3.49	
99	3.93			3.48	
100	3.95			3.47	
101	3.95			3.47	
102	3.95			3.48	
103	3.96			3.49	
104	3.97			3.49	
105	3.98			3.49	
106	3.99			3.51	
107				3.53	
108				3.54	
109				3.54	
110				3.55	
111				3.56	
112				3.56	
113				3.55	
114				3.55	
115				3.57	
116				3.58	
117				3.59	
118				3.60	
119				3.61	
120				3.61	
121				3.61	
122				3.61	
123				3.60	
124				3.61	
125				3.63	
126				3.65	
127				3.65	

Source: Columbia Grain Company, Portland, Oregon.

[a]Observation Period : Mar: 10/29/84-3/29/85 May: 2/26/85-5/31/85

Jul: 4/08/85-7/31/85 Sept: 4/01/85-9/30/85

Dec: 8/20/85-12/31/85

Table A.2
Daily Futures Price Quotes for 1985 Contracts

Observation[a]	Mar	May	Jul	Sept	Dec
1	3.8950	3.9600	3.6200	3.6350	3.7500
2	3.8950	3.9350	3.6200	3.6350	3.7450
3	3.9100	3.9300	3.6200	3.6350	3.7450
4	3.8700	3.9150	3.6200	3.6350	3.7450
5	3.8600	3.8700	3.6200	3.6350	3.7350
6	3.8400	3.8650	3.6200	3.6350	3.7250
7	3.8600	3.8700	3.6200	3.6350	3.7300
8	3.8650	3.8700	3.6200	3.6350	3.7300
9	3.8600	3.8800	3.6200	3.6350	3.7300
10	3.8600	3.8600	3.6200	3.6350	3.7275
11	3.8650	3.8600	3.6350	3.6350	3.7100
12	3.8625	3.8600	3.6200	3.6700	3.7100
13	3.8650	3.8600	3.6200	3.6500	3.7100
14	3.8650	3.8600	3.6200	3.6500	3.7200
15	3.8600	3.8550	3.6200	3.6500	3.7300
16	3.8650	3.8550	3.6200	3.6500	3.7300
17	3.8650	3.8500	3.6200	3.6400	3.7300
18	3.8625	3.8400	3.6200	3.6400	3.7400
19	3.8625	3.8450	3.6200	3.6400	3.7400
20	3.8750	3.8700	3.6200	3.6400	3.7375
21	3.8750	3.8700	3.6700	3.6400	3.7375
22	3.8750	3.8700	3.6700	3.6100	3.7350
23	3.8900	3.8900	3.6700	3.6100	3.7350
24	3.9000	3.8925	3.6700	3.6100	3.7425
25	3.8900	3.8925	3.6700	3.6100	3.7450
26	3.8900	3.9000	3.6600	3.6250	3.7525
27	3.8900	3.9025	3.6400	3.6300	3.7575
28	3.8900	3.8950	3.6400	3.6300	3.7600
29	3.8750	3.8925	3.6400	3.6350	3.7600
30	3.8725	3.8975	3.6400	3.6350	3.7600
31	3.8750	3.8925	3.6400	3.6350	3.7600
32	3.8875	3.8950	3.6400	3.6350	3.7600
33	3.9050	3.9100	3.6400	3.6350	3.7600
34	3.9200	3.9225	3.6400	3.6350	3.7600
35	3.9200	3.9125	3.6400	3.6350	3.7550
36	3.9100	3.9150	3.6400	3.6350	3.7500
37	3.9200	3.9250	3.6400	3.6350	3.7500
38	3.9175	3.9200	3.6400	3.6350	3.7500
39	3.9250	3.9250	3.6400	3.6650	3.7450
40	3.9100	3.9300	3.6400	3.6650	3.7450
41	3.9100	3.9150	3.6400	3.6600	3.7500
42	3.9150	3.9300	3.6400	3.6600	3.7550
43	3.9300	3.9450	3.6400	3.6600	3.7500
44	3.9200	3.9325	3.6400	3.6600	3.7500
45	3.9275	3.9250	3.6400	3.6600	3.7600

Table A.2 (continued)

Observation[a]	Mar	May	Jul	Sept	Dec
46	3.9200	3.9300	3.6400	3.6600	3.7500
47	3.9000	3.9225	3.6400	3.6600	3.7600
48	3.8950	3.9400	3.6575	3.6600	3.7600
49	3.9150	3.9425	3.6700	3.6600	3.7550
50	3.9050	3.9225	3.6700	3.6600	3.7500
51	3.9100	3.9225	3.6700	3.6600	3.7450
52	3.9050	3.9200	3.6900	3.6600	3.7300
53	3.9050	3.9425	3.6900	3.6600	3.6900
54	3.9150	3.9425	3.6900	3.6500	3.6900
55	3.9075	3.9375	3.6900	3.6500	3.7050
56	3.9075	3.9450	3.6900	3.6550	3.7200
57	3.9125	3.9450	3.6900	3.6500	3.7050
58	3.9075	3.9225	3.6900	3.6575	3.7100
59	3.9050	3.9275	3.6900	3.6575	3.7100
60	3.9000	3.9300	3.6900	3.6550	3.7250
61	3.8900	3.9325	3.6900	3.6500	3.7300
62	3.8925	3.9225	3.6900	3.6500	3.7300
63	3.8750	3.9050	3.6900	3.6300	3.7300
64	3.8525	3.8675	3.6900	3.5900	3.7400
65	3.8275	3.8400	3.6900	3.5900	3.7400
66	3.8250	3.8425	3.6850	3.6100	3.7400
67	3.8050	3.8150	3.6950	3.6200	3.7300
68	3.8225	3.8500	3.7000	3.6000	3.7250
69	3.8400	3.8500	3.7000	3.6000	3.7250
70	3.8375	3.8500	3.7000	3.6000	3.7200
71	3.8350	3.8500	3.6900	3.6100	3.7450
72	3.8300	3.8500	3.6800	3.6100	3.7475
73	3.8375	3.8500	3.6700	3.6100	3.7475
74	3.8500	3.8750	3.6700	3.6300	3.7000
75	3.8500	3.8750	3.6800	3.6300	3.7100
76	3.8700	3.8900	3.6800	3.6300	3.7100
77	3.8525	3.8775	3.6500	3.6300	3.6900
78	3.8600	3.8700	3.6500	3.6250	3.7000
79	3.8700	3.8800	3.6500	3.6250	3.7000
80	3.8650	3.8700	3.6700	3.6300	3.7000
81	3.8400	3.8350	3.6625	3.6300	3.6850
82	3.8175	3.8350	3.6600	3.6400	3.6800
83	3.8125	3.8150	3.6500	3.6400	3.6800
84	3.8150	3.8200	3.6500	3.6400	3.6800
85	3.8350	3.8550	3.6500	3.6050	3.7000
86	3.8525	3.8600	3.6500	3.6100	3.7100
87	3.8400	3.8500	3.6500	3.6100	3.7000
88	3.8475	3.8575	3.6550	3.5900	3.7100
89	3.8425	3.8675	3.6600	3.6000	3.7150
90	3.8300	3.8350	3.6600	3.6050	3.7300
91	3.8275	3.8425	3.6800	3.6050	3.7300

Table A.2 (continued)

Observation[a]	Mar	May	Jul	Sept	Dec
92	3.8275	3.8425	3.6800	3.5900	3.7300
93	3.8300	3.8400	3.6500	3.5900	3.7300
94	3.8250	3.8400	3.6500	3.5900	3.7250
95	3.8175	3.8400	3.6500	3.6050	3.7225
96	3.8050	3.8350	3.6500	3.6200	3.7150
97	3.8150	3.8500	3.6300	3.6200	3.7100
98	3.8225	3.8425	3.6300	3.6300	3.7100
99	3.8250	3.8575	3.6300	3.6300	3.7050
100	3.8250	3.8650	3.6100	3.6300	3.7050
101	3.8300	3.8600	3.6050	3.6400	3.7050
102	3.8275	3.8600	3.6050	3.6500	3.7050
103	3.8450	3.8775	3.6050	3.6500	3.7050
104	3.8550	3.8800	3.6200	3.6550	3.6950
105	3.8400	3.8500	3.6200	3.6550	3.6900
106	3.8350	3.8650	3.6200	3.6550	3.6900
107	3.8325	3.8600	3.6200	3.6400	3.6725
108	3.8325	3.8650	3.6200	3.6300	3.6450
109	3.8450	3.8650	3.6200	3.6300	3.6450
110	3.8450	3.8675	3.6200	3.6300	3.6225
111	3.8450	3.8600	3.6500	3.6300	3.6250
112	3.8450	3.8750	3.6500	3.6300	3.6350
113	3.8450	3.8600	3.6500	3.6300	3.6325
114	3.8500	3.8450	3.6500	3.6300	3.5825
115	3.8750	3.8525	3.6500	3.6300	3.5825
116	3.8700	3.8550	3.6500	3.6300	3.5950
117	3.8600	3.8300	3.6500	3.6250	3.5950
118	3.8750	3.8425	3.6400	3.6150	3.5800
119	3.8700	3.8450	3.6400	3.5900	3.5800
120	3.8750	3.8450	3.6400	3.5800	3.5950
121	3.8950	3.8550	3.6200	3.5500	3.6000
122	3.9400	3.8700	3.6300	3.5500	3.5950
123	3.9700	3.9100	3.6300	3.5600	3.6000
124	3.9850	3.9000	3.6100	3.5575	3.6000
125	3.9825	3.9150	3.6100	3.5050	3.5925
126	3.9750	3.9100	3.6100	3.5050	3.5925
127	3.9100	3.8850	3.6100	3.5150	3.5900
128	3.9275	3.9050	3.6000	3.5150	3.6000
129	3.9400	3.9000	3.5900	3.5150	3.6000
130	3.9200	3.9100	3.5400	3.5150	3.6100
131	3.9500	3.9200	3.5400	3.5200	3.6100
132	3.9550	3.9375	3.5400	3.5200	3.6100
133	3.9550	3.9375		3.5200	3.6000
134		3.9650		3.5200	3.6050
135		3.9700		3.5150	3.6050
136		3.9650		3.4950	3.6150
137		3.9500		3.4800	3.5900

Table A.2 (continued)

Observation[a]	Mar	May	Jul	Sept	Dec
138		3.9750		3.4800	3.5900
139		3.9700		3.4800	3.5900
140		3.9700		3.4800	3.5900
141		3.9600		3.4800	3.6050
142		3.9675		3.4800	3.6150
143		3.9550		3.4800	3.6200
144		3.9550		3.4800	3.6400
145		3.9550		3.4800	3.6450
146		3.9550		3.4800	3.6250
147		3.9400		3.4800	3.6350
148		3.9500		3.4800	3.6400
149		3.9500		3.4600	3.6500
150		3.9500		3.4600	3.6400
151		3.9400		3.4700	3.6450
152		3.9100		3.4900	3.6450
153		3.9225		3.5400	3.6550
154		3.9200		3.5500	3.6500
155		3.9200		3.5500	3.6500
156		3.9250		3.5500	3.6700
157		3.9150		3.5500	3.6550
158		3.8850		3.5500	3.6650
159		3.8500		3.5500	3.6600
160		3.8700		3.5500	3.6650
161		3.8700		3.5500	3.6700
162		3.8600		3.5500	3.6700
163		3.8450		3.5500	3.6700
164		3.8600		3.5500	3.6700
165		3.8600		3.5500	3.6900
166		3.8800			3.6900
167		3.8800			3.6950
168		3.8900			3.7200
169		3.8900			3.7200
170		3.8950			3.7100
171		3.9000			3.7100
172		3.9000			3.7100
173		3.8950			3.7300
174		3.9200			3.7600
175		3.9200			3.7500
176		3.8900			3.7500
177					3.7800
178					3.7800
179					3.7700
180					3.7700
181					3.7800
182					3.7900
183					3.7850

Table A.2 (continued)

Observation[a]	Mar	May	Jul	Sept	Dec
184					3.8100
185					3.8000
186					3.7900
187					3.7925
188					3.7925
189					3.7925
190					3.7900
191					3.7850
192					3.7850
193					3.8150
194					3.8000
195					3.7900
196					3.7900
197					3.8100
198					3.8000
199					3.7900
200					3.7900
201					3.7800
202					3.7750
203					3.7900
204					3.7900
205					3.7950
206					3.7950
207					3.7950
208					3.7950
209					3.7950
210					3.7950
211					3.7950
212					3.7950
213					3.7950
214					3.7950
215					3.7950
216					3.7950
217					3.7950
218					3.7950

Source: The Minneapolis Grain Exchange.

[a]Observation Period : Mar: 9/10/84-3/20/85 May: 9/10/84-5/21/85

Jul: 1/11/85-7/22/85 Sept: 1/24/85-9/19/85

Dec: 2/08/85-12/19/85

APPENDIX B

Table B.1
Test Results for Causality from Futures to Cash Forward for March Contract[a]

	The Direct Granger's Test		The Sims' Test	
	Values of α_2's from		Values of α_{2i} (i=-1 to -q) from	
	Eq.(3.2)	Eq.(3.2a)	Eq.(3.6)	Eq.(3.6a)
q = 7[b]				
α_{21}	.50	.45	.39	.43
	(4.66)*	(4.44)*	(2.08)*	(4.19)*
α_{22}	-.20	.23	.04	.10
	(-1.57)	(1.98)	(.23)	(1.03)
α_{23}	.04	.26	.02	-.03
	(.32)	(2.19)*	(.13)	(-.26)
α_{24}	-.02	.20	.02	.02
	(-.18)	(1.72)	(.12)	(.21)
α_{25}	.06	.32	.12	.11
	(.45)	(2.71)*	(.68)	(1.04)
α_{26}	-.15	.13	-.04	-.06
	(-1.20)	(1.08)	(-.22)	(-.55)
α_{27}	-.08	.10	-.11	.12
	(-.66)	(.86)	(-.95)	(1.19)
F-test[c]	3.73*	3.56*	3.25*	3.45*
	(7,76 df)	(7,76 df)	(7,68 df)	(7,68 df)
Q-test[d]	13.58	17.67	57.44*	18.77
R^2	.94	.35	.94	.56
q = 6				
α_{21}	.47	.43	.40	.39
	(4.69)*	(4.31)*	(2.03)*	(3.32)*
α_{22}	-.21	.20	-.02	.03
	(-1.69)	(1.78)	(-.11)	(.24)
α_{23}	.06	.24	.05	.03
	(.47)	(2.09)*	(.27)	(.23)
α_{24}	-.07	.21	.10	.01
	(-.57)	(1.86)	(.51)	(.13)
α_{25}	.10	.27	.11	.06
	(.83)	(2.30)*	(.55)	(.48)
α_{26}	-.21	.08	-.19	-.10
	(-2.02)*	(.68)	(-1.50)	(-.87)
F-test	4.39*	3.74*	3.34*	2.56*
	(6,79 df)	(6,79 df)	(6,72 df)	(6,72 df)
Q-test	12.38	19.52	47.22*	16.29
R^2	.94	.33	.93	.54
q = 5				
α_{21}	.43	.42	.40	.42
	(4.50)*	(4.43)*	(1.91)	(3.60)*
α_{22}	-.15	.18	-.01	-.04
	(-1.24)	(1.77)	(-.06)	(-.31)
α_{23}	.01	.24	.10	.02
	(.05)	(2.23)*	(.50)	(.19)
α_{24}	-.06	.17	.12	.04
	(-.54)	(1.64)	(.57)	(.39)

Table B.1 (continued)

	Eq. (3.2)	Eq. (3.2a)	Eq. (3.6)	Eq. (3.6a)
α_{25}	-.03	.24	-.14	.09
	(-.28)	(2.28)*	(-1.03)	(.77)
F-test	4.79*	4.70*	3.25*	2.97*
	(5,82 df)	(5,82 df)	(5,76 df)	(5,76 df)
Q-test	14.50	19.20	68.25*	14.40
R^2	.94	.32	.92	.49
<u>q = 4</u>				
α_{21}	.41	.37	.41	.39
	(4.40)*	(4.00)*	(1.96)	(3.42)*
α_{22}	-.13	.19	.00	-.04
	(-1.11)	(1.91)	(.00)	(-.32)
α_{23}	.02	.19	.11	.06
	(.15)	(1.86)*	(.55)	(.48)
α_{24}	-.11	.09	-.03	.09
	(-1.13)	(.87)	(-.20)	(.83)
F-test	5.63*	4.78*	4.25*	3.48*
	(4,85 df)	(4,85 df)	(4,80 df)	(4,80 df)
Q-test	15.86	21.82	108.85*	14.08
R^2	.94	.26	.92	.46
<u>q = 3</u>				
α_{21}	.41	.36	.37	.38
	(4.64)*	(3.99)*	(1.76)	(3.37)*
α_{22}	-.13	.20	.02	-.03
	(-1.20)	(2.06)*	(.10)	(-.28)
α_{23}	-.06	.17	.08	.06
	(-.61)	(1.81)	(.61)	(.55)
F-test	7.88*	6.11*	5.18*	4.27*
	(3,88 df)	(3,88 df)	(3,84 df)	(3,84 df)
Q-test	16.76	20.10	151.32*	17.30
R^2	.93	.25	.91	.46
<u>q = 2</u>				
α_{21}	.41	.36	.33	.38
	(4.74)*	(4.15)*	(1.58)	(3.31)*
α_{22}	-.16	.15	.18	.06
	(-1.73)	(1.66)	(1.36)	(.53)
F-test	12.34*	8.92*	9.78*	6.45*
	(2,91 df)	(2,91 df)	(2,88 df)	(2,88 df)
Q-test	17.74	19.13	143.29*	19.24
R^2	.93	.22	.91	.41
<u>q = 1</u>				
α_{21}	.33	.32	.59	.42
	(4.59)*	(3.79)*	(4.61)*	(3.85)*
Q-test	43.29*	15.09	131.66*	22.92
R^2	.92	.21	.91	.36

[a]t-statistic is given in parenthesis below each coefficient.
[b]For the Sims' Test, q is for the future variables.
[c]Joint F-test on all α_2's in (3.2) or (3.2a), but on the leads or the future variables in (3.6) or (3.6a).
[d]27 degrees of freedom for all Q-test.
* Significant at 5% level.

Table B.2
Test Results for Causality from Futures to Cash Forward for May Contract[a]

	The Direct Granger's Test		The Sims' Test	
	Values of α_2's from		Values of α_{2i} (i=-1 to -q) from	
	Eq.(3.2)	Eq.(3.2a)	Eq.(3.6)	Eq.(3.6a)
q = 7[b]				
α_{21}	.58	.88	.16	.13
	(1.09)	(1.64)	(1.69)	(2.11)*
α_{22}	.19	.75	.13	.11
	(.28)	(1.41)	(1.36)	(1.69)
α_{23}	-.78	.12	.09	.05
	(-1.18)	(.23)	(.99)	(.88)
α_{24}	.84	.89	.16	.09
	(1.22)	(1.69)	(1.72)	(1.56)
α_{25}	-.02	.80	.10	.03
	(-.03)	(1.52)	(1.01)	(.57)
α_{26}	-.38	.25	.04	-.03
	(-.54)	(.47)	(.47)	(-.51)
α_{27}	-.14	-.72	.04	-.05
	(-.27)	(-1.39)	(.43)	(-1.31)
F-test[c]	1.01	1.64	2.37*	1.43
	(7,37 df)	(7,37 df)	(7,29 df)	(7,29 df)
Q-test[d]	5.50	6.33	89.37*!	7.84!
R^2	.22	.53	.59	.34
q = 6				
α_{21}	.52	.67	.16	.14
	(1.07)	(1.28)	(1.74)	(2.28)*
α_{22}	.24	.93	.13	.11
	(.38)	(1.85)	(1.40)	(1.85)
α_{23}	-.79	.11	.10	.07
	(-1.24)	(.20)	(1.05)	(1.19)
α_{24}	.87	.87	.15	.12
	(1.32)	(1.71)	(1.61)	(2.18)*
α_{25}	-.04	.69	.09	.06
	(-.06)	(1.34)	(.93)	(1.16)
α_{26}	-.50	.21	.04	.01
	(-1.02)	(.40)	(.44)	(.33)
F-test	1.25	1.52	2.60*	1.48
	(6,40 df)	(6,40 df)	(6,33 df)	(6,33 df)
Q-test	6.10	7.02	119.22*!	10.49!
R^2	.22	.49	.55	.30
q = 5				
α_{21}	.55	.72	.16	.11
	(1.16)	(1.53)	(1.70)	(1.93)
α_{22}	.18	.91	.15	.09
	(.29)	(1.91)	(1.59)	(1.59)
α_{23}	-.75	.02	.10	.05
	(-1.21)	(.04)	(.98)	(.95)
α_{24}	.87	.81	.13	.10
	(1.36)	(1.67)	(1.43)	(2.02)*

Table B.2 (continued)

	Eq.(3.2)	Eq.(3.2a)	Eq.(3.6)	Eq.(3.6a)
α_{25}	-.48	.62	.08	.05
	(-1.01)	(1.27)	(.88)	(1.15)
F-test	1.34	1.94	2.78*	1.44
	(5,43 df)	(5,43 df)	(5,37 df)	(5,37 df)
Q-test	6.40	6.60	134.51*	5.36
R^2	.21	.48	.50	.22
<u>q = 4</u>				
α_{21}	.50	.76	.17	.13
	(1.10)	(1.64)	(1.88)	(2.13)*
α_{22}	.22	.80	.14	.09
	(.37)	(1.71)	(1.52)	(1.62)
α_{23}	-.76	-.10	.09	.04
	(-1.26)	(-.21)	(.99)	(.67)
α_{24}	.48	.73	.13	.07
	(1.05)	(1.53)	(1.52)	(1.58)
F-test	1.50	1.96	3.19*	1.73
	(4,46 df)	(4,46 df)	(4,41 df)	(4,41 df)
Q-test	6.46	8.67	153.25*	7.55
R^2	.20	.45	.49	.19
<u>q = 3</u>				
α_{21}	.47	.68	.16	.10
	(1.05)	(1.46)	(1.79)	(1.79)
α_{22}	.27	.71	.14	.06
	(.46)	(1.50)	(1.60)	(1.17)
α_{23}	-.30	-.22	.10	-.01
	(-.67)	(-.46)	(1.12)	(-.31)
F-test	1.91	1.47	3.08*	1.54
	(3,49 df)	(3,49 df)	(3,45 df)	(3,45 df)
Q-test	4.92	10.17	166.82*	8.77
R^2	.20	.39	.46	.15
<u>q = 2</u>				
α_{21}	.48	.56	.18	.10
	(1.11)	(1.19)	(2.12)*	(2.06)*
α_{22}	-.02	.65	.16	.07
	(-.04)	(1.36)	(1.82)	(1.65)
F-test	2.93	1.55	4.53*	2.28
	(2,52 df)	(2,52 df)	(2,49 df)	(2,49 df)
Q-test	4.76	12.86	178.75*	8.73
R^2	.23	.33	.47	.12
<u>q = 1</u>				
α_{21}	.56	.49	.22	.04
	(3.18)*	(1.04)	(2.44)*	(1.11)
Q-test	5.66	8.05	181.85*	7.60
R^2	.25	.27	.42	.05

[a]t-statistic is given in parenthesis below each coefficient.
[b]For the Sims' Test, q is for the future variables.
[c]Joint F-test on all α_2's in (3.2) or (3.2a), but on the leads or the future variables in (3.6) or (3.6a).
[d]21 df except where indicated by ! which have 18 df.
* Significant at 5% level.

Table B.3
Test Results for Causality from Futures to Cash Forward for July Contract[a]

	The Direct Granger's Test		The Sims' Test	
	Values of α_2's from		Values of α_{2i} (i=-1 to -q) from	
	Eq.(3.2)	Eq.(3.2a)	Eq.(3.6)	Eq.(3.6a)
q = 7[b]				
α_{21}	.88	.85	.12	.12
	(2.21)*	(2.06)*	(1.32)	(1.99)
α_{22}	-.08	.72	.10	.07
	(-.15)	(1.73)	(1.02)	(1.17)
α_{23}	.00	.47	.09	.03
	(.00)	(.99)	(.93)	(.62)
α_{24}	.01	.48	.07	.03
	(.02)	(1.02)	(.72)	(.59)
α_{25}	.09	.49	.04	.05
	(.15)	(1.04)	(.42)	(.96)
α_{26}	-.91	-.36	.05	-.01
	(-1.48)	(-.77)	(.51)	(-.16)
α_{27}	.42	.25	.14	.03
	(.93)	(.54)	(1.49)	(.81)
F-test[c]	2.01	1.54	1.69	.90
	(7,52 df)	(7,52 df)	(7,44 df)	(7,44 df)
Q-test[d]	15.63	16.16	176.85*!	9.79!
R^2	.35	.45	.49	.30
q = 6				
α_{21}	.84	.82	.15	.09
	(2.21)*	(2.03)*	(1.62)	(1.68)
α_{22}	-.03	.49	.08	.05
	(-.07)	(1.21)	(.85)	(1.01)
α_{23}	.00	.41	.05	.03
	(.00)	(.87)	(.54)	(.68)
α_{24}	.11	.29	.09	.04
	(.17)	(.61)	(.97)	(.86)
α_{25}	-.01	.36	.11	.02
	(-.02)	(.75)	(1.17)	(.51)
α_{26}	-.48	-.78	.08	-.03
	(-1.10)	(-1.77)	(.94)	(-.66)
F-test	2.25	1.51	2.23	.74
	(6,55 df)	(6,55 df)	(6,48 df)	(6,48 df)
Q-test	18.20	16.38	192.43*!	12.86!
R^2	.34	.39	.48	.23
q = 5				
α_{21}	.84	.64	.14	.08
	(2.23)*	(1.57)	(1.55)	(1.59)
α_{22}	-.07	.37	.10	.06
	(-.14)	(.90)	(1.16)	(1.14)
α_{23}	-.09	.27	.05	.03
	(-.15)	(.56)	(.56)	(.58)
α_{24}	.22	.35	.09	.03
	(.37)	(.73)	(1.05)	(.75)

Table B.3 (continued)

	Eq. (3.2)	Eq. (3.2a)	Eq. (3.6)	Eq. (3.6a)
α_{25}	-.51	.05	.13	.02
	(-1.21)	(.12)	(1.56)	(.62)
F-test	2.50*	.75	3.02*	.58
	(5,58 df)	(5,58 df)	(5,52 df)	(5,52 df)
Q-test	16.40	21.90	212.93*	10.74!
R^2	.32	.32	.48	.20
q = 4				
α_{21}	.82	.61	.12	.06
	(2.20)*	(1.54)	(1.32)	(1.26)
α_{22}	-.14	.30	.12	.04
	(-.28)	(.74)	(1.31)	(.93)
α_{23}	.03	.23	.13	.03
	(.05)	(.49)	(1.45)	(.78)
α_{24}	-.33	.14	.11	.03
	(-.81)	(.33)	(1.32)	(.72)
F-test	2.75*	.77	3.75*	.47
	(4,61 df)	(4,61 df)	(4,56 df)	(4,56 df)
Q-test	22.88	22.26	219.27*	15.30
R^2	.30	.30	.45	.14
q = 3				
α_{21}	.77	.55	.13	.06
	(2.12)*	(1.43)	(1.43)	(1.30)
α_{22}	-.05	.25	.14	.03
	(-.10)	(.64)	(1.55)	(.78)
α_{23}	-.39	.04	.17	.01
	(-1.04)	(.09)	(1.98)	(.42)
F-test	3.44*	.82	4.99*	.56
	(3,64 df)	(3,64 df)	(3,60 df)	(3,60 df)
Q-test	22.50	23.21	228.45*	16.16
R^2	.29	.29	.44	.14
q = 2				
α_{21}	.72	.52	.19	.07
	(2.06)*	(1.38)	(1.96)	(1.61)
α_{22}	-.35	.12	.21	.03
	(-.98)	(.33)	(2.30)*	(.72)
F-test	4.95*	1.03	6.47*	1.31
	(2,67 df)	(2,67 df)	(2,64 df)	(2,64 df)
Q-test	17.87	25.41	213.82*	14.31
R^2	.27	.28	.44	.15
q = 1				
α_{21}	.42	.18	.29	.05
	(3.45)*	(.50)	(2.99)*	(1.40)
Q-test	17.40	31.44	219.94*	16.09
R^2	.26	.21	.45	.13

[a]t-statistic is given in parenthesis below each coefficient.
[b]For the Sims' Test, q is for the future variables.
[c]Joint F-test on all α_2's in (3.2) or (3.2a), but on the leads or the future variables in (3.6) or (3.6a).
[d]24 df except where indicated by ! which have 21 df.
* Significant at 5% level.

Table B.4
Test Results for Causality from Futures to Cash Forward for September Contract[a]

	The Direct Granger's Test		The Sims' Test	
	Values of α_2's from		Values of α_{2i} (i=-1 to -q) from	
	Eq.(3.2)	Eq.(3.2a)	Eq.(3.6)	Eq.(3.6a)
q = 7[b]				
α_{21}	1.46	1.61	.11	.09
	(3.00)*	(3.22)*	(2.66)*	(3.92)*
α_{22}	-1.32	.06	.07	.05
	(-1.66)	(.10)	(1.79)	(2.24)*
α_{23}	-.01	.13	.08	.06
	(-.01)	(.24)	(2.03)*	(2.61)*
α_{24}	.27	.24	.12	.09
	(.33)	(.45)	(2.86)*	(3.90)*
α_{25}	1.73	1.92	.12	.09
	(2.12)*	(3.60)*	(3.05)*	(4.22)*
α_{26}	-1.02	.76	.06	.03
	(-1.24)	(1.36)	(1.53)	(1.41)
α_{27}	-.61	-.15	.04	.00
	(-1.18)	(-.27)	(.95)	(.00)
F-test[c]	5.50*	4.67*	13.58*	5.32*
	(7,98 df)	(7,98 df)	(7,90 df)	(7,90 df)
Q-test[d]	5.73	8.42	390.20*	20.01
R^2	.49	.52	.85	.32
q = 6				
α_{21}	1.44	1.58	.11	.09
	(2.98)*	(3.18)*	(2.74)*	(3.99)*
α_{22}	-1.37	.09	.07	.05
	(-1.76)	(.17)	(1.75)	(2.28)*
α_{23}	.07	-.03	.09	.06
	(.09)	(-.06)	(2.11)*	(2.70)*
α_{24}	.20	.22	.12	.09
	(.24)	(.41)	(2.90)*	(4.16)*
α_{25}	1.92	1.91	.13	.10
	(2.44)*	(3.63)*	(3.17)*	(4.76)*
α_{26}	-1.74	.57	.07	.03
	(-3.58)*	(1.06)	(1.73)	(1.91)
F-test	6.28*	5.28*	15.18*	6.40*
	(6,101df)	(6,101df)	(6,94 df)	(6,94 df)
Q-test	6.06	9.82	401.87*	19.77
R^2	.49	.51	.85	.32
q = 5				
α_{21}	1.47	1.61	.12	.09
	(2.96)*	(3.25)*	(2.84)*	(3.74)*
α_{22}	-1.33	-.13	.08	.04
	(-1.65)	(-.25)	(1.91)	(1.91)
α_{23}	-.17	-.05	.09	.05
	(-.20)	(-.09)	(2.17)*	(2.22)*
α_{24}	.89	.13	.13	.07
	(1.09)	(.25)	(3.09)*	(3.68)*

Table B.4 (continued)

	Eq.(3.2)	Eq.(3.2a)	Eq.(3.6)	Eq.(3.6a)
α_{25}	-.22	1.91	.14	.07
	(-.43)	(3.82)*	(3.41)*	(4.50)*
F-test	4.61*	5.76*	16.36*	6.89*
	(5,104df)	(5,104df)	(5,98 df)	(5,98 df)
Q-test	5.33	10.78	403.66*	19.85
R^2	.42	.49	.83	.29
q = 4				
α_{21}	1.49	1.50	.14	.07
	(3.06)*	(2.87)*	(3.05)*	(2.71)*
α_{22}	-1.39	-.14	.10	.01
	(-1.75)	(-.26)	(2.24)*	(.62)
α_{23}	-.04	-.33	.11	.01
	(-.06)	(-.58)	(2.55)*	(.38)
α_{24}	.57	.53	.15	.02
	(1.15)	(1.00)	(3.49)*	(1.13)
F-test	6.05*	2.55*	15.20*	3.06*
	(4,107df)	(4,107df)	(4,102df)	(4,102df)
Q-test	5.27	11.76	375.28*	17.30
R^2	.42	.40	.80	.15
q = 3				
α_{21}	1.56	1.48	.16	.05
	(3.25)*	(2.85)*	(3.38)*	(2.14)*
α_{22}	-1.63	-.23	.13	.00
	(-2.17)*	(-.41)	(2.68)*	(.00)
α_{23}	.67	-.32	.15	-.01
	(1.39)	(-.60)	(3.11)*	(-.50)
F-test	8.53*	3.04*	14.66*	3.03*
	(3,110df)	(3,110df)	(3,106df)	(3,106df)
Q-test	4.26	12.68	358.99*	17.78
R^2	.42	.38	.76	.09
q = 2				
α_{21}	1.36	1.55	.20	.05
	(2.95)*	(2.98)*	(3.90)*	(2.46)*
α_{22}	-.74	-.54	.17	.00
	(-1.59)	(-1.02)	(3.34)*	(.00)
F-test	14.40*	4.50*	17.07*	4.20*
	(2,113df)	(2,113df)	(2,110df)	(2,110df)
Q-test	3.21	12.20	375.67*	19.44
R^2	.41	.36	.71	.08
q = 1				
α_{21}	.68	1.22	.28	.05
	(6.16)*	(2.29)*	(5.09)*	(2.82)*
Q-test	2.67	16.80	425.87*	19.26
R^2	.39	.26	.63	.07

[a]t-statistic is given in parenthesis below each coefficient.
[b]For the Sims' Test, q is for the future variables.
[c]Joint F-test on all α_2's in (3.2) or (3.2a), but on the leads or the future variables in (3.6) or (3.6a).
[d]30 df for all Q-test.
* Significant at 5% level.

Table B.5
Test Results for Causality from Futures to Cash Forward for December Contract[a]

	The Direct Granger's Test		The Sims' Test	
	Values of α_2's from		Values of α_{2i} (i=-1 to -q) from	
	Eq.(3.2)	Eq.(3.2a)	Eq.(3.6)	Eq.(3.6a)
q = 7[b]				
α_{21}	.12	.12	.12	.15
	(1.06)	(.90)	(.64)	(1.09)
α_{22}	-.12	-.06	-.16	-.19
	(-.91)	(-.45)	(-.85)	(-1.35)
α_{23}	.15	.08	-.01	-.07
	(1.13)	(.55)	(-.08)	(-.47)
α_{24}	.10	.08	.13	.21
	(.79)	(.61)	(.70)	(1.44)
α_{25}	.07	.10	.03	.10
	(.57)	(.75)	(.17)	(.69)
α_{26}	.17	.18	-.02	.00
	(1.32)	(1.46)	(-.12)	(.00)
α_{27}	.05	.06	.26	-.12
	(.41)	(.46)	(1.99)	(-.83)
F-test[c]	2.69*	.56	5.72*	.81
	(7,64 df)	(7,64 df)	(7,56 df)	(7,56 df)
Q-test[d]	20.45!	21.69!	18.88!	18.17!
R^2	.99	.04	.99	.35
q = 6				
α_{21}	.14	.09	.11	.11
	(1.18)	(.72)	(.58)	(.78)
α_{22}	-.08	-.83	-.21	-.15
	(-.59)	(-.62)	(-1.13)	(-1.10)
α_{23}	.07	.00	.03	.04
	(.57)	(.00)	(.14)	(.26)
α_{24}	.11	.08	.10	.12
	(.85)	(.64)	(.55)	(.84)
α_{25}	.03	.08	.01	.05
	(.27)	(.65)	(.06)	(.37)
α_{26}	.19	.19	.27	.04
	(1.72)	(1.63)	(2.06)*	(.27)
F-test	2.87*	.73	6.14*	.47
	(6,67 df)	(6,67 df)	(6,60 df)	(6,60 df)
Q-test	19.36!	17.81!	21.79!	19.62!
R^2	.99	.04	.99	.27
q = 5				
α_{21}	.17	.10	.05	.11
	(1.51)	(.75)	(.28)	(.82)
α_{22}	-.12	-.09	-.15	-.14
	(-.95)	(-.68)	(-.79)	(-1.07)
α_{23}	.08	-.04	.03	.03
	(.64)	(-.30)	(.18)	(.27)
α_{24}	.09	.03	.05	.12
	(.69)	(.20)	(.28)	(.93)

Table B.5 (continued)

	Eq.(3.2)	Eq.(3.2a)	Eq.(3.6)	Eq.(3.6a)
α_{25}	.14	.01	.31	.06
	(1.23)	(.10)	(2.38)*	(.45)
F-test	2.62*	.37	6.34*	.57
	(5,70 df)	(5,70 df)	(5,64 df)	(5,64 df)
Q-test	28.35	19.49!	21.64!	18.50!
R^2	.99	.00	.98	.27
<u>q = 4</u>				
α_{21}	.17	.09	.11	.11
	(1.57)	(.77)	(.59)	(.90)
α_{22}	-.12	-.08	-.13	-.13
	(-.94)	(-.68)	(-.67)	(-1.05)
α_{23}	.08	-.04	-.02	.04
	(.61)	(-.32)	(-.11)	(.35)
α_{24}	.17	.03	.38	.11
	(1.54)	(.23)	(2.93)*	(.91)
F-test	2.99*	.46	6.84*	.71
	(4,73 df)	(4,73 df)	(4,68 df)	(4,68 df)
Q-test	26.95	22.33	27.22!	19.90!
R^2	.99	.00	.98	.26
<u>q = 3</u>				
α_{21}	.17	.11	.20	.15
	(1.54)	(.96)	(.96)	(1.21)
α_{22}	-.14	-.08	-.19	-.11
	(-1.08)	(-.70)	(-.93)	(-.92)
α_{23}	.17	-.03	.36	-.03
	(1.62)	(-.25)	(2.59)*	(-.22)
F-test	2.36	.67	4.91*	.71
	(3,76 df)	(3,76 df)	(3,72 df)	(3,72 df)
Q-test	24.90	22.95	28.49!	17.25!
R^2	.99	.00	.98	.23
<u>q = 2</u>				
α_{21}	.17	.11	.06	.17
	(1.60)	(1.05)	(.26)	(1.36)
α_{22}	-.03	-.07	.24	-.11
	(-.25)	(-.63)	(1.57)	(-.92)
F-test	2.01	.95	3.25*	1.19
	(2,79 df)	(2,79 df)	(2,76 df)	(2,76 df)
Q-test	25.69	24.57	47.40*	22.87
R^2	.99	.00	.97	.17
<u>q = 1</u>				
α_{21}	.12	.13	.32	.15
	(1.66)	(1.27)	(2.00)*	(1.23)
Q-test	26.80	24.29	67.60*	25.27
R^2	.99	.00	.97	.16

[a]t-statistic is given in parenthesis below each coefficient.
[b]For the Sims' Test, q is for the future variables.
[c]Joint F-test on all α_2's in (3.2) or (3.2a), but on the leads or the future variables in (3.6) or (3.6a).
[d]27 df except where indicated by ! which have 24 df.
* Significant at 5% level.

Table B.6
Test Results for Causality from Cash Forward to Futures for March Contract[a]

	The Direct Granger's Test		The Sims' Test	
	Values of β_2's from		Values of β_{2i} (i=-1 to -q) from	
	Eq.(3.4)	Eq.(3.4a)	Eq.(3.8)	Eq.(3.8a)
q = 7[b]				
β_{21}	.56	.47	.20	.22
	(2.83)*	(2.51)*	(1.51)	(3.14)*
β_{22}	-.63	-.21	-.11	-.09
	(-2.82)*	(-1.04)	(-.83)	(-1.32)
β_{23}	.06	-.12	.04	.00
	(.28)	(-.63)	(.27)	(.00)
β_{24}	.20	.05	.07	.08
	(.85)	(.28)	(.56)	(1.31)
β_{25}	-.26	-.31	-.16	-.14
	(-1.09)	(-1.58)	(-1.29)	(-2.17)*
β_{26}	.37	.00	-.02	-.02
	(1.59)	(.00)	(-.18)	(-.33)
β_{27}	-.03	.13	.13	.10
	(-.20)	(.83)	(1.65)	(1.61)
F-test[c]	2.40*	2.33*	1.47	4.04*
	(7,76 df)	(7,76 df)	(7,68 df)	(7,68 df)
Q-test[d]	9.23	9.01	67.48*	25.76
R^2	.93	.27	.94	.60
q = 6				
β_{21}	.65	.49	.20	.20
	(3.45)*	(2.68)*	(1.49)	(2.84)*
β_{22}	-.63	-.20	-.05	-.08
	(-2.91)*	(-1.04)	(-.35)	(-1.21)
β_{23}	.06	-.14	-.08	-.03
	(.28)	(-.78)	(-.62)	(-.50)
β_{24}	.20	.05	.10	.07
	(.89)	(.25)	(.77)	(1.02)
β_{25}	-.18	-.25	-.15	-.14
	(-.80)	(-1.34)	(-1.20)	(-2.08)*
β_{26}	.19	.10	.11	.01
	(1.19)	(.62)	(1.40)	(.20)
F-test	2.70*	2.59*	1.08	3.42*
	(6,79 df)	(6,79 df)	(6,72 df)	(6,72 df)
Q-test	8.45	8.52	77.63*	25.68
R^2	.92	.26	.93	.57
q = 5				
β_{21}	.54	.55	.34	.20
	(3.04)*	(3.16)*	(2.54)*	(2.97)*
β_{22}	-.66	-.13	-.14	-.09
	(-3.02)*	(-.74)	(-1.10)	(-1.48)
β_{23}	.13	-.73	.00	-.01
	(.57)	(-.42)	(.00)	(-.20)
β_{24}	.16	.11	-.03	.05
	(.73)	(.63)	(-.27)	(.78)

Table B.6 (continued)

	Eq. (3.4)	Eq. (3.4a)	Eq. (3.8)	Eq. (3.8a)
β_{25}	.02	-.11	.06	-.13
	(.09)	(-.73)	(.66)	(-2.14)*
F-test	2.57*	2.83*	1.47	4.34*
	(5,82 df)	(5,82 df)	(5,76 df)	(5,76 df)
Q-test	7.09	9.03	89.68*	25.13
R^2	.92	.23	.92	.57
q = 4				
β_{21}	.51	.48	.20	.25
	(2.89)*	(2.92)*	(1.48)	(4.03)*
β_{22}	-.66	-.21	-.06	-.10
	(-3.11)*	(-1.23)	(-.46)	(-1.64)
β_{23}	.06	-.09	-.05	-.02
	(.25)	(-.54)	(-.40)	(-.28)
β_{24}	.34	.04	.07	.03
	(2.16)*	(.26)	(.73)	(.43)
F-test	4.16*	3.00*	.89	4.54*
	(4,85 df)	(4,85 df)	(4,80 df)	(4,80 df)
Q-test	8.39	7.75	146.40*	24.70
R^2	.92	.20	.91	.54
q = 3				
β_{21}	.50	.42	.18	.22
	(2.92)*	(2.59)*	(1.40)	(3.40)*
β_{22}	-.64	-.29	-.10	-.08
	(-3.03)*	(-1.74)	(-.78)	(-1.26)
β_{23}	.24	-.28	.04	-.05
	(1.53)	(-1.90)	(.43)	(-.73)
F-test	3.72*	5.15*	.78	4.32*
	(3,88 df)	(3,88 df)	(3,84 df)	(3,84 df)
Q-test	12.51	9.06	184.24*	22.25
R^2	.91	.16	.91	.50
q = 2				
β_{21}	.42	.46	.19	.19
	(2.57)*	(2.94)*	(1.56)	(3.13)*
β_{22}	-.35	-.23	-.07	-.10
	(-2.37)*	(-1.57)	(-.88)	(-1.62)
F-test	3.75*	5.78*	1.31	5.56*
	(2,91 df)	(2,91 df)	(2,88 df)	(2,88 df)
Q-test	16.55	12.60	173.86*	20.61
R^2	.91	.13	.91	.47
q = 1				
β_{21}	.05	.36	.11	.19
	(.43)	(2.54)*	(1.33)	(3.00)*
Q-test	17.30	18.29	152.71*	18.68
R^2	.90	.08	.91	.44

[a] t-statistic is given in parenthesis below each coefficient.
[b] For the Sims' Test, q is for the future variables.
[c] Joint F-test on all β_2's in (3.4) or (3.4a), but on the leads or the future variables in (3.8) or (3.8a).
[d] 27 df for all Q-test.
* Significant at 5% level.

Table B.7
Test Results for Causality from Cash Forward to Futures for May Contract[a]

	The Direct Granger's Test		The Sims' Test	
	Values of β_2's from		Values of β_{2i} ($i=-1$ to $-q$) from	
	Eq.(3.4)	Eq.(3.4a)	Eq.(3.8)	Eq.(3.8a)
$q = 7$[b]				
β_{21}	-.05	-.02	-.04	-.19
	(-.96)	(-.43)	(-.05)	(-.23)
β_{22}	.00	.01	-.04	-.03
	(.00)	(.13)	(-.04)	(-.03)
β_{23}	-.02	.02	.66	.46
	(-.33)	(.25)	(.75)	(.50)
β_{24}	-.07	-.01	-.34	-.18
	(-1.37)	(-.10)	(-.39)	(-.20)
β_{25}	-.02	.00	-.27	-.17
	(-.43)	(.00)	(-.30)	(-.20)
β_{26}	.02	.07	.75	.64
	(.48)	(.98)	(.88)	(.72)
β_{27}	-.08	.02	-1.21	-.43
	(-1.61)	(.36)	(-1.99)	(-.51)
F-test[c]	.86	.38	1.03	.17
	(7,37 df)	(7,37 df)	(7,29 df)	(7,29 df)
Q-test[d]	9.48	8.08	7.06!	20.94!
R^2	.87	.11	.37	.21
$q = 6$				
β_{21}	-.04	-.02	-.45	-.25
	(-.83)	(-.48)	(-.56)	(-.32)
β_{22}	.00	.01	.44	.12
	(.00)	(.09)	(.57)	(.15)
β_{23}	-.02	.02	.23	.20
	(-.46)	(.27)	(.30)	(.25)
β_{24}	-.05	-.02	-.56	-.47
	(-1.06)	(-.24)	(-.68)	(-.50)
β_{25}	-.03	-.01	.07	-.12
	(-.51)	(-.10)	(.08)	(-.14)
β_{26}	.02	.05	-.28	.76
	(.45)	(1.05)	(-.47)	(.95)
F-test	.43	.48	.46	.29
	(6,40 df)	(6,40 df)	(6,33 df)	(6,33 df)
Q-test	7.12	7.65	6.08!	20.04!
R^2	.86	.10	.28	.16
$q = 5$				
β_{21}	-.04	-.03	-.17	-.31
	(-.76)	(-.53)	(-.24)	(-.41)
β_{22}	-.01	-.01	.19	.31
	(-.27)	(-.11)	(.27)	(.42)
β_{23}	-.04	-.01	.16	.12
	(-.75)	(-.15)	(.23)	(.17)
β_{24}	-.06	-.04	-.19	-.44
	(-1.26)	(-.72)	(-.28)	(-.59)

Table B.7 (continued)

	Eq.(3.4)	Eq.(3.4a)	Eq.(3.8)	Eq.(3.8a)
β_{25}	-.04	-.05	-.32	-.20
	(-.72)	(-.97)	(-.59)	(-.27)
F-test	.77	.30	.37	.18
	(5,43 df)	(5,43 df)	(5,37 df)	(5,37 df)
Q-test	4.84	7.28	6.58	18.92
R^2	.84	.06	.25	.13
q = 4				
β_{21}	-.05	.00	-.29	-.30
	(-1.00)	(.00)	(-.47)	(-.43)
β_{22}	-.01	.03	.20	.19
	(-.17)	(.47)	(.31)	(.29)
β_{23}	-.04	.02	.22	.17
	(-.87)	(.36)	(.35)	(.25)
β_{24}	-.07	.00	-.49	-.18
	(-1.40)	(.00)	(-1.02)	(-.28)
F-test	1.08	.12	.42	.11
	(4,46 df)	(4,46 df)	(4,41 df)	(4,41 df)
Q-test	4.46	3.51	6.13	20.15
R^2	.84	.03	.24	.11
q = 3				
β_{21}	-.05	.00	-.25	-.11
	(-.97)	(.00)	(-.42)	(-.18)
β_{22}	-.01	.03	.15	.28
	(-.30)	(.58)	(.25)	(.43)
β_{23}	-.05	.03	-.30	.28
	(-.97)	(.57)	(-.66)	(.45)
F-test	.79	.21	.38	.14
	(3,49 df)	(3,49 df)	(3,45 df)	(3,45 df)
Q-test	4.54	3.74	5.52	16.88
R^2	.85	.01	.23	.08
q = 2				
β_{21}	-.05	-.01	-.20	-.21
	(-1.04)	(-.25)	(-.36)	(-.37)
β_{22}	-.01	.01	-.18	.24
	(-.31)	(.31)	(-.43)	(.43)
F-test	.62	.16	.44	.17
	(2,52 df)	(2,52 df)	(2,49 df)	(2,49 df)
Q-test	4.18	3.89	5.60	16.57
R^2	.85	.01	.24	.05
q = 1				
β_{21}	-.05	-.02	-.44	-.25
	(-1.04)	(-.49)	(-1.08)	(-.48)
Q-test	3.99	3.79	6.11	17.33
R^2	.86	.00	.27	.04

[a]t-statistic is given in parenthesis below each coefficient.
[b]For the Sims' Test, q is for the future variables.
[c]Joint F-test on all β_2's in (3.4) or (3.4a), but on the leads or the future variables in (3.8) or (3.8a).
[d]21 df except where indicated by ! which have 18 df.
* Significant at 5% level.

Table B.8
Test Results for Causality from Cash Forward to Futures for July Contract[a]

	The Direct Granger's Test		The Sims' Test	
	Values of β_2's from		Values of β_{2i} (i=-1 to -q) from	
	Eq.(3.4)	Eq.(3.4a)	Eq.(3.8)	Eq.(3.8a)
q = 7[b]				
β_{21}	.07	.09	1.39	1.51
	(1.34)	(1.77)	(2.56)	(2.88)*
β_{22}	-.08	.01	-.62	-.56
	(-1.50)	(.22)	(-1.14)	(-1.06)
β_{23}	.01	.03	.37	.46
	(.12)	(.49)	(.69)	(.89)
β_{24}	-.04	.01	-.24	-.22
	(-.71)	(.22)	(-.47)	(-.42)
β_{25}	-.01	.01	.21	.16
	(-.23)	(.08)	(.44)	(.37)
β_{26}	-.09	-.07	-.07	-.04
	(-1.62)	(-1.16)	(-.14)	(-.09)
β_{27}	-.04	-.11	-.39	-.92
	(-.83)	(-2.17)*	(-1.17)	(-2.05)*
F-test[c]	1.27	1.81	1.54	1.85
	(7,52 df)	(7,52 df)	(7,44 df)	(7,44 df)
Q-test[d]	12.23	9.41	19.77!	38.27*!
R^2	.91	.21	.38	.34
q = 6				
β_{21}	.08	.10	1.25	1.27
	(1.56)	(2.08)*	(2.30)	(2.38)*
β_{22}	-.07	.04	-.65	-.73
	(-1.30)	(.69)	(-1.19)	(-1.37)
β_{23}	.02	.07	.30	.22
	(.34)	(1.15)	(.58)	(.42)
β_{24}	-.03	.05	-.18	-.24
	(-.59)	(.84)	(-.38)	(-.54)
β_{25}	-.01	.07	.34	.30
	(-.11)	(1.10)	(.72)	(.66)
β_{26}	-.08	.01	-.50	-.17
	(-1.56)	(.18)	(-1.51)	(-.37)
F-test	1.25	1.10	1.44	1.42
	(6,55 df)	(6,55 df)	(6,48 df)	(6,48 df)
Q-test	13.30	13.79	16.03!	42.13*!
R^2	.91	.11	.31	.21
q = 5				
β_{21}	.09	.10	1.26	1.19
	(1.74)	(2.10)*	(2.35)*	(2.25)*
β_{22}	-.06	.04	-.69	-.69
	(-1.17)	(.67)	(-1.35)	(-1.32)
β_{23}	.02	.07	.30	.36
	(.31)	(1.13)	(.64)	(.80)
β_{24}	-.04	.05	-.07	-.11
	(-.68)	(.86)	(-.15)	(-.24)

Table B.8 (continued)

	Eq.(3.4)	Eq.(3.4a)	Eq.(3.8)	Eq.(3.8a)
β_{25}	-.01	.06	-.22	.33
	(-.25)	(1.27)	(-.66)	(.72)
F-test	1.03	1.33	1.28	1.57
	(5,58 df)	(5,58 df)	(5,52 df)	(5,52 df)
Q-test	14.82	13.81	17.83	37.40*!
R^2	.91	.09	.26	.13
q = 4				
β_{21}	.09	.09	1.07	1.26
	(1.86)	(1.96)	(2.11)*	(2.47)*
β_{22}	-.06	.02	-.46	-.51
	(-1.18)	(.42)	(-1.00)	(-1.19)
β_{23}	.02	.04	.34	.32
	(.33)	(.73)	(.75)	(.73)
β_{24}	-.04	.01	-.30	-.08
	(-.70)	(.16)	(-.94)	(-.19)
F-test	1.33	1.30	1.29	1.85
	(4,61 df)	(4,61 df)	(4,56 df)	(4,56 df)
Q-test	15.81	14.24	17.73	40.07*
R^2	.91	.06	.24	.12
q = 3				
β_{21}	.09	.09	.95	.96
	(1.83)	(2.00)*	(2.12)*	(2.28)*
β_{22}	-.06	.02	-.44	-.48
	(-1.31)	(.41)	(-.99)	(-1.14)
β_{23}	.01	.04	.07	.31
	(.24)	(.79)	(.22)	(.72)
F-test	1.65	1.78	1.57	2.14
	(3,64 df)	(3,64 df)	(3,60 df)	(3,60 df)
Q-test	15.26	14.81	18.02	42.70*
R^2	.91	.05	.23	.10
q = 2				
β_{21}	.08	.08	.90	.91
	(1.77)	(1.89)	(2.06)*	(2.25)*
β_{22}	-.07	.00	-.35	-.46
	(-1.50)	(.00)	(-1.15)	(-1.12)
F-test	2.49	2.45	2.24	2.99
	(2,67 df)	(2,67 df)	(2,64 df)	(2,64 df)
Q-test	16.36	13.88	13.85	43.76*
R^2	.91	.04	.28	.10
q = 1				
β_{21}	.08	.08	.50	.89
	(1.68)	(2.26)*	(1.64)	(2.23)*
Q-test	16.62	15.19	13.70	43.68*
R^2	.91	.04	.30	.08

[a]t-statistic is given in parenthesis below each coefficient.
[b]For the Sims' Test, q is for the future variables.
[c]Joint F-test on all β_2's in (3.4) or (3.4a), but on the leads or the future variables in (3.8) or (3.8a).
[d]24 df except where indicated by ! which have 21 df.
* Significant at 5% level.

Table B.9
Test Results for Causality from Cash Forward to Futures for September Contract[a]

	The Direct Granger's Test: Values of β_2's from Eq.(3.4)	Eq.(3.4a)	The Sims' Test: Values of β_{2i} (i=-1 to -q) from Eq.(3.8)	Eq.(3.8a)
q = 7[b]				
β_{21}	.01	.02	.90	.93
	(.52)	(.87)	(1.12)	(1.33)
β_{22}	-.01	.01	-.50	-.51
	(-.69)	(.30)	(-.62)	(-.73)
β_{23}	.00	.02	-.13	-.13
	(.00)	(.65)	(-.17)	(-.18)
β_{24}	-.01	.02	1.13	1.10
	(-.29)	(.74)	(1.39)	(1.56)
β_{25}	-.04	-.01	-1.17	-1.13
	(-2.11)*	(-.45)	(-1.44)	(-1.60)
β_{26}	.01	.00	.58	.51
	(.33)	(.00)	(.74)	(.72)
β_{27}	-.02	.00	-.45	-.15
	(-.79)	(.00)	(-.93)	(-.23)
F-test[c]	.91	.62	.87	.80
	(7,98 df)	(7,98 df)	(7,90 df)	(7,90 df)
Q-test[d]	11.80	9.36	5.53	36.14
R^2	.97	.12	.53	.19
q = 6				
β_{21}	.01	.02	.95	.93
	(.63)	(.95)	(1.21)	(1.35)
β_{22}	-.01	.01	-.50	-.52
	(-.67)	(.50)	(-.63)	(-.76)
β_{23}	.00	.02	-.06	-.09
	(.00)	(.88)	(-.07)	(-.13)
β_{24}	-.01	.02	.97	1.09
	(-.38)	(.92)	(1.22)	(1.58)
β_{25}	-.04	-.01	-.95	-1.11
	(-2.14)*	(-.45)	(-1.23)	(-1.62)
β_{26}	.01	.01	.02	.46
	(.27)	(.32)	(.03)	(.69)
F-test	.97	.81	.89	.97
	(6,101df)	(6,101df)	(6,94 df)	(6,94 df)
Q-test	10.89	9.91	5.97	36.22
R^2	.97	.12	.52	.18
q = 5				
β_{21}	.01	.02	.82	.83
	(.61)	(1.06)	(1.01)	(1.22)
β_{22}	-.01	.01	-.30	-.42
	(-.64)	(.53)	(-.37)	(-.62)
β_{23}	.00	.02	-.20	-.14
	(.00)	(.87)	(-.25)	(-.20)
β_{24}	-.01	.02	1.17	1.12
	(-.44)	(.87)	(1.48)	(1.66)

Table B.9 (continued)

	Eq. (3.4)	Eq. (3.4a)	Eq. (3.8)	Eq. (3.8a)
β_{25}	-.04	-.01	-1.06	-.99
	(-2.14)*	(-.82)	(-2.17)*	(-1.52)
F-test	1.16	.97	1.14	1.10
	(5,104df)	(5,104df)	(5,98 df)	(5,98 df)
Q-test	11.34	9.80	5.37	33.01
R^2	.97	.12	.47	.16
q = 4				
β_{21}	.01	.02	.75	.75
	(.58)	(1.19)	(.92)	(1.09)
β_{22}	-.02	.02	-.46	-.32
	(-.83)	(.79)	(-.57)	(-.47)
β_{23}	.00	.03	.25	-.06
	(.00)	(1.40)	(.32)	(-.08)
β_{24}	-.01	.03	-.17	.86
	(-.59)	(1.76)	(-.35)	(1.31)
F-test	.33	1.05	.24	.76
	(4,107df)	(4,107df)	(4,102df)	(4,102df)
Q-test	11.91	9.99	5.42	34.25
R^2	.97	.11	.44	.10
q = 3				
β_{21}	.01	.01	.67	.74
	(.46)	(.81)	(.83)	(1.09)
β_{22}	-.01	.00	-.36	-.44
	(-.79)	(.05)	(-.46)	(-.65)
β_{23}	.00	.01	.02	.25
	(.00)	(.47)	(.03)	(.38)
F-test	.26	.39	.24	.44
	(3,110df)	(3,110df)	(3,106df)	(3,106df)
Q-test	11.51	11.37	3.97	32.38
R^2	.97	.08	.43	.07
q = 2				
β_{21}	.01	.01	.69	.71
	(.29)	(.64)	(.89)	(1.07)
β_{22}	-.01	.00	-.39	-.37
	(-.65)	(.00)	(-.81)	(-.58)
F-test	.24	.40	.41	.61
	(2,113df)	(2,113df)	(2,110df)	(2,110df)
Q-test	13.16	11.22	4.17	32.21
R^2	.97	.08	.41	.07
q = 1				
β_{21}	.00	.01	.12	.56
	(.00)	(.64)	(.24)	(.87)
Q-test	16.35	13.16	2.99	28.06
R^2	.97	.06	.40	.03

[a]t-statistic is given in parenthesis below each coefficient.
[b]For the Sims' Test, q is for the future variables.
[c]Joint F-test on all β_2's in (3.4) or (3.4a), but on the leads or the future variables in (3.8) or (3.8a).
[d]30 df for all Q-test.
* Significant at 5% level.

Table B.10
Test Results for Causality from Cash Forward to Futures for December Contract[a]

	The Direct Granger's Test		The Sims' Test	
	Values of β_2's from		Values of β_{2i} (i=-1 to -q) from	
	Eq.(3.4)	Eq.(3.4a)	Eq.(3.8)	Eq.(3.8a)
q = 7[b]				
β_{21}	.17	.29	.21	.18
	(1.02)	(1.95)	(1.40)	(1.90)
β_{22}	-.08	.17	.14	.10
	(-.40)	(1.15)	(.92)	(.99)
β_{23}	.12	.34	.17	.14
	(.59)	(2.24)*	(1.06)	(1.27)
β_{24}	-.17	.11	-.03	-.06
	(-.83)	(.69)	(-.19)	(-.51)
β_{25}	-.10	.01	-.12	-.08
	(-.48)	(.06)	(-.78)	(-.68)
β_{26}	-.04	-.06	-.11	-.06
	(-.21)	(-.38)	(-.69)	(-.52)
β_{27}	.04	.21	-.16	.02
	(.25)	(1.38)	(-1.21)	(.17)
F-test[c]	.89	1.65	2.10	.87
	(7,64 df)	(7,64 df)	(7,56 df)	(7,56 df)
Q-test[d]	14.59!	14.78!	65.21*!	19.55!
R^2	.98	.18	.98	.33
q = 6				
β_{21}	.19	.27	.23	.22
	(1.18)	(1.83)	(1.47)	(2.31)*
β_{22}	-.13	.17	.14	.14
	(-.63)	(1.12)	(.90)	(1.43)
β_{23}	.19	.31	.15	.16
	(.94)	(2.09)*	(.95)	(1.59)
β_{24}	-.18	.10	-.07	-.01
	(-.87)	(.63)	(-.42)	(-.13)
β_{25}	-.08	.00	-.12	-.07
	(-.38)	(.00)	(-.78)	(-.70)
β_{26}	-.01	-.03	-.22	-.08
	(-.06)	(-.22)	(-1.71)	(-.81)
F-test	.93	1.59	2.37*	1.44
	(6,67 df)	(6,67 df)	(6,60 df)	(6,60 df)
Q-test	14.79!	16.55!	68.17*!	20.14!
R^2	.98	.14	.98	.32
q = 5				
β_{21}	.18	.26	.25	.21
	(1.15)	(1.81)	(1.56)	(2.35)*
β_{22}	-.09	.14	.14	.13
	(-.45)	(.96)	(.84)	(1.40)
β_{23}	.19	.31	.10	.17
	(.95)	(2.13)*	(.61)	(1.88)
β_{24}	-.18	.10	-.07	.01
	(-.89)	(.66)	(-.41)	(.14)

Table B.10 (continued)

	Eq.(3.4)	Eq.(3.4a)	Eq.(3.8)	Eq.(3.8a)
β_{25}	-.08	.03	-.30	-.06
	(-.53)	(.22)	(-2.25)*	(-.58)
F-test	1.10	1.83	2.54*	1.90
	(5,70 df)	(5,70 df)	(5,64 df)	(5,64 df)
Q-test	18.85	16.34!	68.81*!	18.77!
R^2	.98	.13	.98	.32
q = 4				
β_{21}	.25	.24	.23	.20
	(1.68)	(1.78)	(1.38)	(2.33)*
β_{22}	-.09	.14	.06	.12
	(-.48)	(.98)	(.38)	(1.35)
β_{23}	.23	.31	.14	.19
	(1.18)	(2.17)*	(.86)	(2.19)*
β_{24}	-.28	.12	-.30	.01
	(-1.92)	(.84)	(-2.21)*	(.16)
F-test	2.26	2.37	1.82	2.44
	(4,73 df)	(4,73 df)	(4,68 df)	(4,68 df)
Q-test	14.89	19.91	69.27*!	18.59!
R^2	.98	.13	.98	.31
q = 3				
β_{21}	.26	.26	.23	.20
	(1.77)	(1.85)	(1.35)	(2.20)*
β_{22}	-.11	.14	.08	.10
	(-.55)	(1.02)	(.46)	(1.13)
β_{23}	.00	.37	-.01	.19
	(.00)	(2.71)*	(-.07)	(2.11)*
F-test	1.46	4.03*	1.75	2.83*
	(3,76 df)	(3,76 df)	(3,72 df)	(3,72 df)
Q-test	17.85	16.54	77.28*!	15.78!
R^2	.98	.15	.97	.26
q = 2				
β_{21}	.21	.26	.14	.16
	(1.48)	(1.85)	(.80)	(1.90)
β_{22}	-.02	.14	.17	.08
	(-.11)	(1.01)	(1.25)	(.90)
F-test	2.51	2.28	2.83	2.07
	(2,79 df)	(2,79 df)	(2,76 df)	(2,76 df)
Q-test	29.24	24.24	89.45*	16.43
R^2	.98	.05	.97	.20
q = 1				
β_{21}	.22	.19	.30	.16
	(2.57)*	(1.35)	(2.25)*	(1.88)
Q-test	28.41	33.07	95.32*	15.86
R^2	.98	.00	.97	.19

[a]t-statistic is given in parenthesis below each coefficient.
[b]For the Sims' Test, q is for the future variables.
[c]Joint F-test on all β_2's in (3.4) or (3.4a), but on the leads or the future variables in (3.8) or (3.8a).
[d]27 df except where indicated by ! which have 24 df.
* Significant at 5% level.