# AN EVALUATION OF PRICE LINKAGES BETWEEN FUTURES AND CASH MARKETS FOR CHEDDAR CHEESE

by

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# An Evaluation of Price Linkages Between Futures and Cash Markets for Cheddar Cheese

Organized trading in commodity futures markets in the United States dates back to the mid 1880's. Since 1970, however, trade volume has increased dramatically. In addition, the variety of futures contracts available for trade has substantially increased. Coupled with increased trade volume there has been considerable debate as to the impacts of futures trading on cash markets. Two arguments often made in support of futures trading are that futures markets facilitate price discovery and that they provide an environment for the management of price risk (hedging). The extent to which individual futures markets have served as efficient centers of price discovery and risk management, however, has been the focus of considerable research. In general, debate has centered around the extent to which futures markets provide price leadership to cash markets, and whether cash market participants are better or worse off as the result of futures trading.

The introduction of the cheddar cheese and non-fat dry milk futures contracts at the Coffee, Sugar, and Cocoa Exchange in New York has brought this debate to the dairy industry. The cheddar cheese market provides a particularly interesting study of the role of futures markets in facilitating cash price discovery and risk management for several reasons. First, the cheese futures market is relatively new, with trade beginning in June 1993. This allows for some examination of the extent to which cash and futures markets can become integrated in terms of pricing market information over a relatively short trading horizon. Second, the cheese futures market allows for physical delivery against a futures contract anywhere in the U.S. This eliminates the spatial considerations which often affect cash and

futures relationships.[1] Third, and perhaps most interesting, prior to the introduction of futures, cheddar cheese prices were largely determined at the National Cheese Exchange in Green Bay, Wisconsin. This exchange only trades Fridays from approximately 10:00 A.M. until 10:30 A.M. central time. In contrast, the futures market trades every business day from 2:15 P.M. to 3:15 P.M. eastern time. As such, it might be reasonable to expect that cheese price information is now being delivered to cash market participants more frequently, and that intra-week futures trading may influence the Friday cash prices in Green Bay.

This report evaluates whether the newly developed cheddar cheese futures contract is contributing to price discovery in the cheddar cheese cash market, and the extent to which the cash and futures markets for cheddar cheese are placing similar values on new market information.

The report proceeds with a general discussion of the theoretical relationships expected to exist between efficient cash and futures markets for like commodities. This provides a basis from which to evaluate the performance of the cheddar cheese markets. A brief review of the most recent research in the performance of agricultural futures markets follows the theoretical discussion. The third section specifically addresses whether the cheddar cheese futures market currently serves as a price discovery center for the cash cheddar cheese market, or whether the cash market leads the futures market in price discovery. This includes a measure of the information flow between the cash and futures markets. Implications of the research findings are discussed in the last section.

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[1] Many futures contracts for agricultural commodities specify a delivery location. The relationship between futures prices and cash prices for such a commodity can be expected to be influenced by the transportation costs between the two market locations.

**Social Benefits of Futures Markets, and Futures / Cash Market Relationships**

Powers has identified four social benefits of futures trading. These include competitive price discovery, hedging (or management) of industry price risks, facilitation of financing, and more efficient resource allocation. The first two, price discovery and hedging, have tended to receive the most attention from both supporters and detractors of futures markets, and are often presented as the justification for futures trading.

The price discovery benefit of futures trading is predicated on the assumption that futures prices reflect the combined views of a large number of buyers and sellers, all expressing their perceptions of the future value of some commodity. This does not imply that the futures price is necessarily a forecast of the price that will exist in the cash market at some future date, but rather the price at which individuals are willing to accept an immediate obligation to either make or take delivery of the traded commodity on the expiration date of the futures contract.[2] The futures price can be viewed as an assimilation of opinions concerning future supply and demand conditions which are based on the information available at the time the price is recorded. As the delivery period approaches (i.e. the date at which the futures contract requires delivery of the physical commodity), the information available to market traders changes, and so do their perceptions of future supply and demand. This change in supply and demand perceptions results in a change in the futures price. By continually recording changes in market agents' supply/demand perceptions, prices for future delivery periods are continually being updated. If the changes in prices accurately reflect

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[2] In reality the delivery date is usually spread over some time interval. For example, in grain markets the delivery period usually lasts about three weeks. Thus, while an individual contract expires on a specific day, delivery may take place anytime during the last three weeks of a grain contract's trading life.

changes in actual supply/demand perceptions, then the benefits from allowing futures trading presumably accrue not only to the direct futures market participants, but also to anyone else with an interest in the future value of the traded commodity. If futures prices accurately reflect market participants' current supply/demand expectations for a future delivery period, the market is considered to be efficient. If the futures market is an efficient pricing mechanism, it suggests that no individual market participant would be able to consistently use available market information to make more accurate projections of the future supply/demand conditions, and thus systematically earn futures trading profits by arbitrage between the current futures price and the price that the current supply/demand information suggests should exist. While there has been some disagreement in empirical research, the general consensus appears to be that most agricultural futures markets price current information about future supply/demand conditions efficiently.[3]

Whether futures prices are being generated in an efficient manner holds implications for futures/cash price relationships. If futures market price discovery is efficient, then firms and individuals involved in the production, processing, and/or exchange of a commodity traded in a futures market are able to utilize the information generated through futures trading to guide their cash market decisions. By having a public forum in which the willingness of market traders to commit to future delivery periods is recorded, firms are able to plan their marketing and production activities in a way that maximizes efficiency and reduces overall operating costs. For example, if a commodity needed as an input to a production process is

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[3] For a more complete discussion on efficiency studies as they relate to futures markets, see Leuthold, pg 114-116; and Garcia, Leuthold, Fortenbery, and Sarassoro.

being traded in an active futures market, the recording of relative prices for different delivery periods can aid a producing firm in timing the optimal purchase of the needed input. If the futures market reports lower prices in later months relative to prices for delivery in nearby months, the producer may wish to minimize purchases of the input in the short run. Without an active futures market, such information would be more difficult to obtain. If, however, futures prices are inefficient, firms could not use futures market information to confidently assess the relative values of a cash commodity in different delivery periods.

The second major benefit of futures trading, the facilitation of price risk management, is also dependent on the degree to which futures prices are efficiently responding to new information about supply/demand conditions. If futures are efficient, then we would expect a strong relationship between the futures price which exists at contract expiration and the cash price for that same delivery period. It is the notion that this futures/cash price relationship is predictable which leads to the value of futures markets as risk management vehicles. If futures markets are efficient pricing mechanisms, then we would expect that futures prices respond to new market information in the same way as cash prices. In other words, if new market information becomes available which suggests the future supply of a given commodity is going to be tighter than previously expected, we would expect the futures price for a later delivery period to increase, and we would expect the cash price which is finally observed in the later period to be higher given the new information than it would have been without the new supply information. The difference between futures and cash prices is referred to as the basis. For the futures market to serve as a successful risk management vehicle, the basis must be predictable. This is not the same as saying the cash price must be predictable. The

futures price currently recorded may not be an accurate forecast of the cash price which will actually exist at a future delivery date, but its changes as we approach the distant delivery date must be highly correlated with observed changes in cash prices if the futures market is to provide risk management opportunities. If a high level of correlation exists, then a producer could hedge the price of a product he/she would like to sell on a future date by selling in the futures market now with a contract delivery period approximately equal to the date on which the actual production will be available for sale in the cash market. If futures and cash markets move together, meaning they respond in like fashion to new market information, any loss in one market (futures or cash) will be offset by gains in the other market. At the end of the hedge period, the producer would buy back his or her obligation to make delivery in the futures market and deliver the actual commodity in the cash market. If both markets responded to new market information over the production period in like fashion, the producer's net selling price is the same price he/she attempted to guarantee when the hedge was initially placed. If one or the other markets are inefficient, meaning that the prices they record do not accurately reflect market supply/demand conditions, then new information may not impact both futures and cash markets similarly, and the potential hedger would not have confidence that the losses or gains in the futures market would be exactly offset by a gain or loss in the cash market, and the risk management role of futures markets would not be served.

Note that a necessary condition for the futures market to effectively serve both its price discovery and risk management roles is that the futures and cash markets respond to new market information similarly. If they do not, then the basis, or the expected relationship

between the futures and cash prices, is not predictable.

**Recent Tests of Futures and Cash Market Linkages in Agricultural Commodities**

For futures markets to provide efficient price discovery they must exhibit a close relationship with the prices recorded in the cash market. Tests of the futures/cash price relationships for various commodities have been numerous. In recent times, the focus has tended to be on whether futures and cash markets price new information the same, and whether futures lead or follow cash price changes. While the literature is extensive, the discussion here focuses on the most recent work.

Recent research has focused on measuring directional causality between futures and cash markets, and speeds of price adjustment in the trailing market. In 1985, Ollerman and Farris investigated the lead-lag relationship between live cattle futures and cash prices. Their objective was to identify in which market price discovery originated. Using daily data from 1966 through 1982, they tested for lead/lag relationships in nearby live cattle futures contract prices traded at the Chicago Mercantile Exchange and Omaha cash prices for choice steers in the 1100 to 1300 pound range. Based on Granger causality tests, they concluded that futures prices tended to lead live cattle cash prices. Ollerman and Farris also found that cash prices tended to respond to changes in futures prices within one business day. This led them to conclude that futures markets serve as the center of price discovery for live cattle markets.

Brorsen, Ollerman, and Farris (1989) extended the above study by examining the direct impact of futures trading on the live cattle cash market. This was done by employing regression techniques to measure the effects of futures trading on the variability and volatility of cash cattle prices. Their results suggested that futures trading did impact cash markets, and

led them to conclude that futures trading had increased cash market pricing efficiency, but also increased short-run cash price risk.

Koontz, Garcia, and Hudson (1990) Examined live cattle cash and futures markets for dominant-satellite relationships. Specifically, they measured the degree to which the spatial nature of pricing performance had changed over time. They compared prices in several cash markets with live cattle futures prices for the period 1973-1984. They studied pair-wise relationships between various cash markets, and between cash and futures markets. They concluded that none of the markets studied determined prices independent of the other markets, suggesting that price information flowed between markets. The information flow between all markets was completed within a week. They also found that cash markets had generally decreased their reliance on futures as the initial price discovery center, but did find that end-of-week futures prices had a strong influence on cash prices early in the following week.

In 1991, Bessler and Covey introduced cointegration analysis to the question of live cattle price discovery. A major advantage of cointegration analysis is that it allows for the possibility that prices for identical commodities in two different markets may respond differently to new market information in the short run, but would return to a long run equilibrium if both were efficient. There are several reasons one might expect asymmetric responses from different markets in the short run. One is that the markets may have different access times to the information being delivered. Another is that the information may be interpreted differently initially. However, because the markets are for the same commodity, arbitrage opportunities between the markets would eventually result in a multi-market

consensus concerning the value of new information.

Bessler and Covey applied cointegration analysis to the live cattle markets for a period stretching from August 1985 to August 1986. Their results are mixed. They found slight evidence of cointegration between nearby futures (i.e. those closest to expiration) and cash prices (meaning there was weak evidence that cash and futures were maintaining a long run equilibrium relationship with respect to pricing new information), but no evidence of cointegration when more distant futures contracts were considered. Based on their results, they concluded that cash markets for live cattle were inefficient.

Fortenbery and Zapata (1993) suggested a possible reason for the inconsistent results of Bessler and Covey might be the lack of an explicit storage relationship between cash and futures markets for livestock. They applied cointegration analysis to cash and futures markets for corn and soybeans. In addition, they investigated a much longer time series, employing crop year data from 1980 to 1990. They conducted their cointegration tests on a year by year basis, as well as for the aggregate period. When years were aggregated, evidence of cointegration was detected for all cash and futures market pairs considered. Year by year tests revealed less consistent results. They noted, however, that the years in which bivariate cointegration between futures and cash markets did not hold tended to be years in which there were either high interest rates or substantial carrying charges between futures contract delivery months ( implying large price differences between delivery dates). They suggested that in years where the costs of maintaining inventory are high ( either because of high interest rates or large carrying charges between delivery dates), a more appropriate specification of the relationship between cash and futures prices would explicitly include interest rates. The

inclusion of interest rates takes into account the opportunity cost of holding inventory between the current delivery period priced in the cash market and the delivery period specified by the futures contract being considered. In a later paper, Zapata and Fortenbery (1993) introduced interest rates as an explicit argument in the cointegration model and found that interest rates can be important in describing the price discovery relationship between futures and cash markets for storable commodities.

**Measuring Price Performance in the Cheddar Cheese Market**

Building on previous research, the price linkages of the cheddar cheese cash and futures markets are investigated using cointegration analysis. Cointegration analysis offers several advantages in addressing market performance. First, cointegration analysis measures the extent to which two markets have achieved a long run equilibrium. Since the cheddar cheese futures market is new it might be reasonable to ask: Have the cash and futures markets for cheddar cheese achieved the long run equilibrium expected to exist between two markets pricing the same commodity and utilizing the same market information?

Another distinct advantage of the cointegration technique is that it explicitly allows for divergences from equilibrium in the short run. This is in contrast to most regression approaches to measuring market price performance (see Appendix A: Technical Appendix). In most regression models, it is assumed that the prices in different markets for identical commodities respond immediately and identically to changes in market information.

Conceptually, cointegration analysis is consistent with the theoretical relationships discussed by Garbade and Silber (1983). The basic notion is that two price series which exhibit stochastic behavior ( meaning that the price changes from one time period to the next

appear random), but which are pricing an identical asset ought to exhibit a linear relationship between themselves which is deterministic (meaning that the difference between the two prices over time should not be stochastic). This is analogous to saying that the direction and magnitude of future price changes cannot be anticipated based on previous price changes, but that the future difference between two prices for an identical commodity can be anticipated. Whether any individual price series behaves as a stochastic series is a testable hypothesis. However, Labys and Granger (1970) conclude most commodity futures prices approximate stochastic processes. Stochastic price behavior does not mean that prices are not responding to new information. What it does mean is that, a priori, the quantity and value of new market information is not known, and thus market participants cannot determine in which direction prices will change prior to gaining new market information. It also suggests that past prices are not a good indicator of prices which will exist in the future. If they were, it would imply that either the value of new market information was perfectly anticipated, and thus the information had already been reflected in past prices, or that new prices are not responding to new market information, and are thus inefficient.

If prices are efficient, the difference between two prices for an identical commodity should not be stochastic. If it is, then the two prices disagree on changes in the value of the traded commodity resulting from changes in market information. In the short run, market information may not be priced identically in two separate markets, but as long as arbitrage can take place between the two markets, they should exhibit a long run equilibrium in which the price differences represent the costs of transacting between the two markets.

Cointegration analysis represents an attempt to determine whether two markets are

pricing information similarly by investigating the properties of the price differences between the two markets. The difference between the price in a futures market and the price in a cash market for the same commodity, as noted before, is the basis. Cointegration tests of futures/cash price relationships are measures of the extent to which the basis is "stationary" over time. A variable is said to be stationary when its mean and variance do not change over time, and the covariance of values generated at different points in time depends only on the time interval considered, and not on time itself. As discussed earlier, a necessary condition for a futures market to fulfill its price discovery and risk management role is for the basis to be predictable, which implies it is stationary; i.e., its mean and variance do not change with time.[4] For a more complete and mathematical interpretation of stationarity see Granger and Newbold (1986).

The relationship described above can be formalized with a mathematical representation as follows:

$$Z_t = CP_t - (A)\, FP_t \tag{1}$$

where $Z_t$ is called the cointegrating relation, CP is a cash price for immediate delivery, FP is the current futures price for some unspecified delivery period, and A represents the various links between futures and cash markets. For example, if the cash price and the futures price were for different delivery locations, A would include transportation costs between the markets. If they were for different delivery periods, A would include costs of storage between the current delivery period and the period associated with FP. If Z is stationary, then

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[4] This does not mean that we do not experience different basis levels at different points in time, but rather that the basis generating process is not a function of time, and thus the parameter values of the process generating the basis do not change through time.

for any time t, cash price minus futures price times A equals 0, implying the value of $Z_t = 0$ for any t. In the very short run, however, cash and futures markets may not price new information identically, meaning it is possible for short periods of time to observe Z not equal to zero. However, since arbitrage can occur between cash and futures markets, one would expect quick movements back to equilibrium so that the observance of a continuum of cash/futures price pairs would reveal an average value of Z across all observations equal to zero.

The dynamics of cheddar cheese price discovery are investigated using cointegration estimation for the period June 1993 through May 1994. This time period coincides with the introduction of the cheese futures contract. Maximum likelihood estimates of cointegration, outlined in Johansen and Juselius (1990), are generated to test for cash and futures price relationships. The estimation utilizes data from the National Cheese Exchange (NCE) in Green Bay, Wisconsin, and cheese futures prices traded at the Coffee, Sugar, and Cocoa Exchange in New York. A complete discussion of the Johansen and Juselius technique is provided in Appendix A. The statistical results of applying cointegration estimation to the cheese market are also contained in Appendix A. In addition, a complete description of the cheddar cheese futures contract, including historical trade volume, is provided in Appendix B.

A unique characteristic of cash and futures markets for cheddar cheese is that they do not trade simultaneously. In addition, trading sessions in both the cash and futures markets are quite short. In most commodity markets, cash and futures trading activities can occur simultaneously. In grains, for example, most cash markets are accepting delivery and pricing cash transactions concurrent with futures trading. However, cheese futures only trade between

2:15 P.M. and 3:15 P.M. Eastern Standard Time. The NCE cash market only trades on Fridays between 10:00 A.M. and 10:30 A.M. Central Time. Since the cash market only operates for about 30 minutes once a week, it might seem reasonable for the futures to lead in the pricing of any information which becomes available intra-week. If important market information became available midweek, one might expect such information to be reflected in subsequent futures prices, which would then lead the cash pricing process on the next Friday.

On the other hand, some observers suggest that the NCE cash market is sufficiently thin as to be potentially manipulated by individual traders. In this case, one might expect NCE to be the center of price discovery, with the futures traders showing a reluctance to commit to future delivery dates until an NCE price for current delivery has been established.

Both of these price discovery possibilities are tested. This is done by testing for cointegration between Thursday futures and Friday cash (testing the hypothesis that futures respond to information, and then provide a price signal to cash traders on the following Friday), testing for cointegration between Friday cash and Friday futures (which tests the hypothesis that cash prices lead futures, but futures respond almost within that trading day), and testing Friday cash and the following Monday futures ( which would be consistent with the hypothesis that cash leads futures with futures experiencing some lag time in responding to cash prices).

In addition, the effects of interest rates on the cash/futures relationship for cheddar cheese is explicitly studied. This allows for the possibility that any failure to find cointegration between cash and futures prices in a bivariate framework can be explained by a nonstationary component in the temporal link between the cash delivery date and the

expiration date of the futures contract. This is analogous to suggesting that Z in equation (1) behaves as a nonstationary series because of the failure to explicitly account for a third factor determining its value. If interest rates (or some other measure of the temporal relation between the futures and the cash prices, such as storage costs) are not explicitly introduced to the cointegration model, the researcher is assuming that the variable is either stationary and thus has no impact on the dynamic behavior of Z, or is not significant in determining Z. If, however, interest rates are nonstationary and important, they may bias test statistics used to test for a stationary Z when ignored. Given that the cash and futures prices considered here are for different delivery periods, any temporal dynamics affecting the carrying charges between the cash delivery date and the futures delivery date may be important. An important component of the carrying charge is interest rates. To the extent that interest rates are simply the "price" of capital, it might be reasonable to suspect that interest rates, like many other prices, are themselves nonstationary, implying they should be explicitly accounted for in measuring for cointegration between cash and futures prices (Zapata and Fortenbery).

Results of bivariate cointegration tests between cash and futures prices for cheddar cheese are shown in figures 1A through 1C.[5] These are plots of Z, or the cointegrating relations between cash and futures prices for cheddar cheese over time. Recall the expectation for cointegrated markets would be a value of Z equal to zero, with any divergence from zero being transitory. Figure 1A depicts the relationship between Thursday futures and

[5] The bivariate tests have been re-estimated using data through December 1994. Results are essentially no different than those reported here. The specific results for the more recent data are available from the authors.

Friday cash prices. Figure 1B shows the relationship between Friday cash and Friday futures prices (remember that the futures market trades after the cash market has closed), and figure 1C illustrates Friday cash and the following Monday futures price relationship. Note that all cash/futures price pairs considered in figures 1A through 1C reveal a Z which tends to persist in either the negative or positive hemisphere of the graph; cash and futures prices for cheese do not quickly return to a stationary basis relationship. This suggests that either 1) cash and/or futures markets for cheddar cheese are inefficient, 2) cash and futures markets for cheddar cheese have not achieved a long run equilibrium, or 3) Z in equation (1) represents a nonstationary process because equation (1) is misspecified, and there is at least one more nonstationary component which contributes to the generation f Z (see the technical appendix).

Results of trivariate cointegration tests which explicitly introduce interest rates into the cointegration model are shown in figures 2A through 2C. If the introduction of interest rates stabilizes the cash/futures basis, then one would again expect the cointegration relations to vary around zero, with no persistent tendency to be either negative or positive. Note that in figures 2A through 2C, the cointegration relations (Z) again show tendencies to persist in either the positive or negative hemisphere. This provides evidence that the results shown in figures 1A through 1C are not the result of ignoring storage costs.[6]

It is interesting to note that the hypothesis of cointegration is not supported regardless

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[6] This result was expected. Zapata and Fortenbery's examination of grain markets has shown that interest rates tend to be important in periods when there is considerable inflation (high and volatile nominal interest rates) or large carrying charges in the market. Since this analysis only considers contracts within two months of maturity, carrying charges are at a minimum. The period studied (June 1993 to June 1994) is also a period of historically low and flat interest rates.

of which futures trading days are considered. There is no evidence to conclude that the futures market leads the cash market in cheddar cheese price discovery, nor that the cash market leads futures in price discovery. The results suggest that there is currently no measurable flow of price information between the two markets. It appears that cash and futures markets for cheddar cheese show substantial independence in pricing new market information.

The results for the cheddar cheese markets seem to be inconsistent with the general findings of previous research. As noted earlier, most studies of cash/futures relationships in agricultural markets have tended to find that the two markets are closely related, with futures often leading cash markets in price discovery. One exception was the live cattle study of Bessler and Covey. They interpreted the lack of cointegration in their study to be evidence of price inefficiency in the cash market for live cattle (Bessler and Covey). However, such a conclusion here may be premature. As noted earlier, cointegration analysis is an attempt to identify a long run relationship between a cash and futures market. Given the relative infancy of the cheddar cheese futures market, it may be that sufficient time has not passed for the two markets to have established a long run equilibrium. It may take some time for traders in the two markets to determine exactly what relationship should exist between the cash and futures markets.[7] Further, the Bessler and Covey study only analyzed one year of data as well, and

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[7] A recent paper by Lamm supports this hypothesis. He suggests that the current trading environment for cash and futures markets of cheddar cheese provides significant opportunities for profitable arbitrage between the two markets. If this is true, one would expect that the exploitation of arbitrage profits over time would be a primary force in establishing a stable, long-run equilibrium between cash and futures markets for cheddar cheese. As such, it may be that traders have not yet gained sufficient experience in identifying and exploiting arbitrage opportunities between the cash and futures markets for cheddar cheese.

as shown by Fortenbery and Zapata its is possible to reject cointegration even in a mature market using as little as one year of data when in fact a longer time series would imply cointegration does exist between cash and futures prices.

To examine the extent to which market infancy might contribute to a lack of support for the cointegration hypothesis in the cheddar cheese market, the same cointegration methodology is applied to the futures and cash markets for two fertilizer products (to our knowledge, no one else has investigated the pricing performance of the fertilizer futures markets). Futures contracts for two fertilizer products were recently introduced at the Chicago Board of Trade. The first is a contract on anhydrous ammonia (NH3) and the second on diammonium phosphate (DAP). Both of these commodities have active and well established cash markets. Futures trading of NH3 began in late 1992. The DAP futures contract began trading in late 1991. Examining these markets is useful because one (NH3) has a trading history not much longer than the cheddar cheese contract, while the other (DAP) has an additional year and a half of trading experience.

The results of applying the same cointegration tests used in the cheddar cheese market to the fertilizer markets are shown in figure 3 (the statistical results are reported in the technical appendix). Results for both fertilizer products are similar, thus we only illustrate the results for DAP. Note that in the case of DAP the cointegration hypothesis is supported. The cointegration relation shows a strong tendency to move quickly back to zero in those instances when deviations from zero occurred. To determine whether trading experience beyond the first year of the futures market was necessary to achieve a long run equilibrium relationship, we also tested for cointegration using just the first year of DAP futures trading.

This test also supported the cointegration hypothesis. These results suggest that at least some markets are capable of establishing a long run equilibrium relatively quickly. However, it would still be premature to conclude that the cheddar cheese cash and futures markets are not capable of developing an efficient pricing relationship. As noted above, previous work has shown that even in markets where a long run equilibrium is detected over a number of years, analyses involving a single year may not identify the equilibrium relationship. However, the results presented here also suggest that the cash and futures markets for cheddar cheese ought to be closely monitored over the next several months to determine whether they begin to show evidence of becoming more integrated. If they do not, then policy analysts ought to begin to question whether there are institutional or market structure constraints which prohibit the cash and futures markets from behaving in an efficient pricing manner.

**Conclusions**

The purpose of this analysis is to examine whether cash and futures markets for cheddar cheese have established a long run equilibrium relationship in terms of pricing behavior, and whether one market dominates as the center for price discovery. The establishment of a long run equilibrium is a necessary condition in concluding that cash and futures markets are both serving as efficient pricing centers. Establishing a long run equilibrium with cash markets is important if cheddar cheese futures markets are to be of service in providing price risk management opportunities to the dairy industry, and price discovery information to cash market participants.

Based on cointegration tests, research presented here finds no evidence of a stable long-run relationship between cash and futures markets for cheddar cheese. However, it is

argued that this should not yet be interpreted as prima facia evidence of market inefficiencies in either the cash or futures markets. It may be that the markets have not gained sufficient trading experience to establish a long run equilibrium relationship. Examination of two other commodities, however, shows that relatively new futures markets in the first year of trading can become closely linked to the cash market. Previous research has also shown, however, that even when a long run equilibrium is known to exist, a single year of data may not be sufficient to identify the relationship between cash and futures markets.

The results do suggest that there is reason to closely monitor the pricing behavior and price relationships of cash and futures markets for cheddar cheese in coming months. If a strong price relationship between cash and futures markets does not emerge in the coming months, it would be appropriate to begin to question whether the institutional structure of either cash or futures markets restricts efficient pricing behavior. Our results are consistent with Lamm; arbitrage opportunities likely exist between cash and futures markets for cheddar cheese. However, if both markets are structured in a way to allow for efficient pricing behavior, we would expect arbitrage opportunities to be exploited and in the process cash and futures markets to become more integrated in their pricing of new market information.

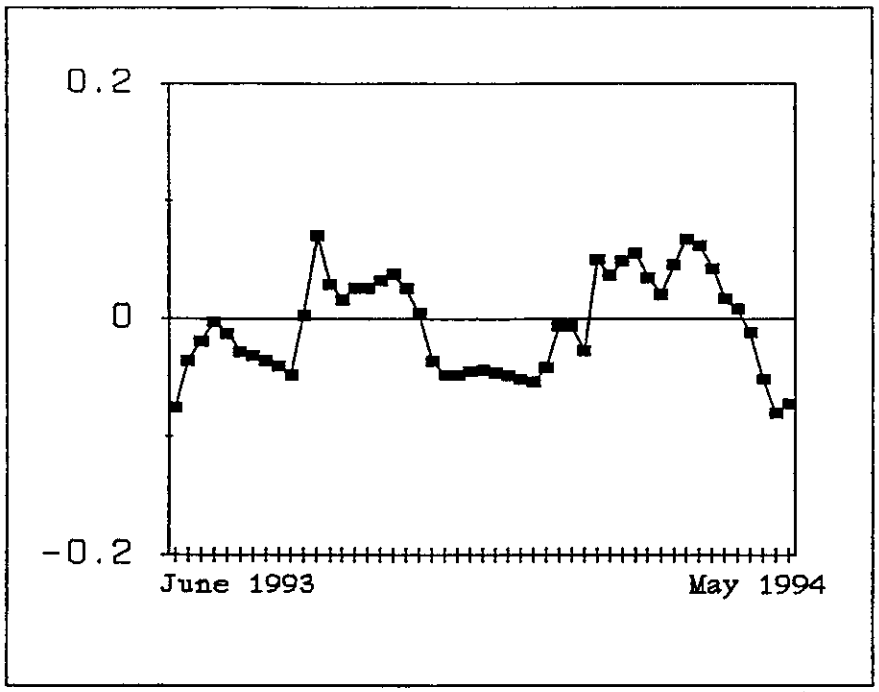


**Figure 1A Cointegrating Relations: Thursday Futures and Friday Cash.**

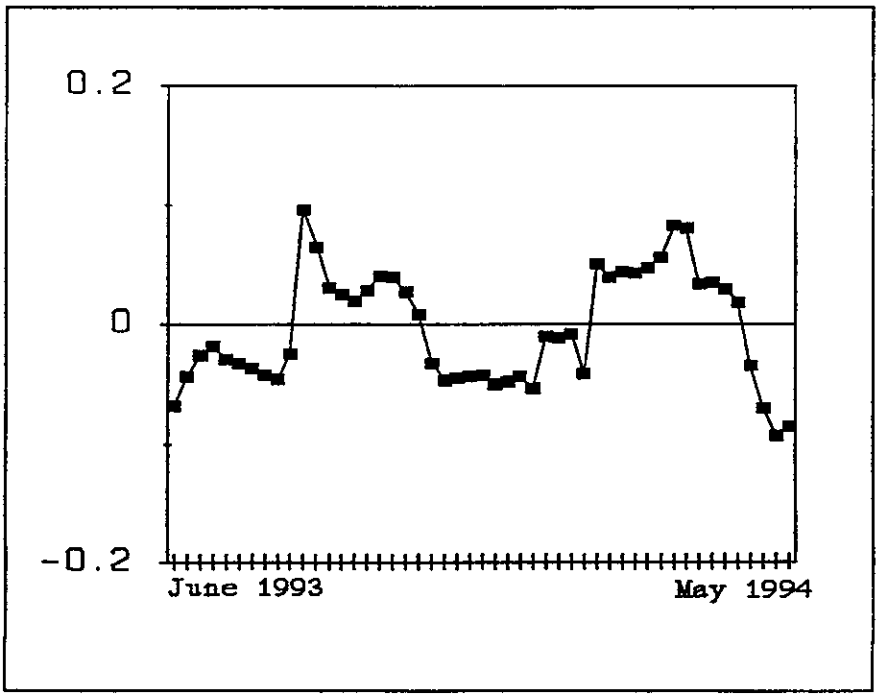


**Figure 1B Cointegrating Relations: Friday Futures and Friday Cash**

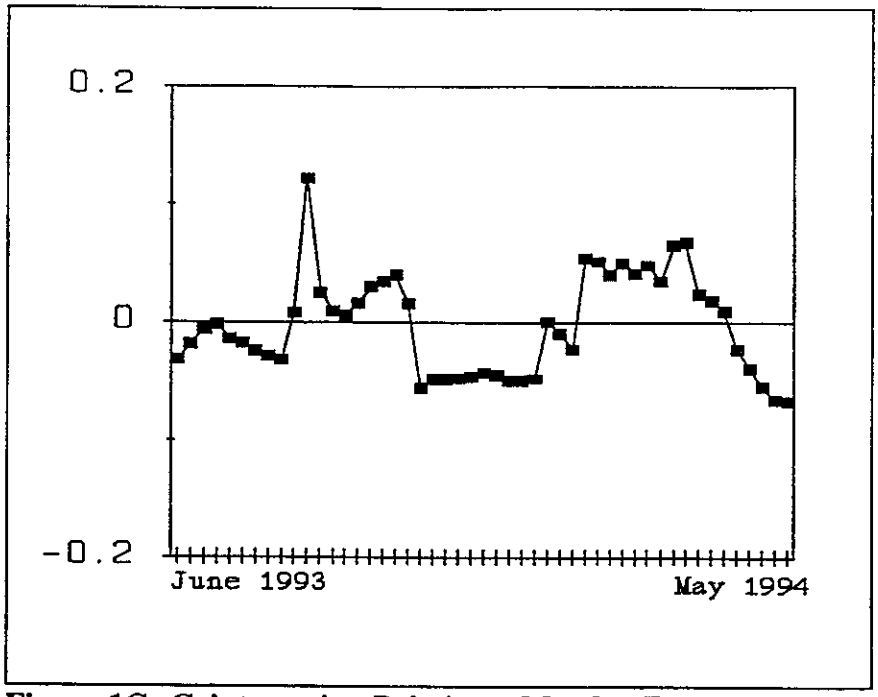


**Figure 1C Cointegrating Relations: Monday Futures and Friday Cash**

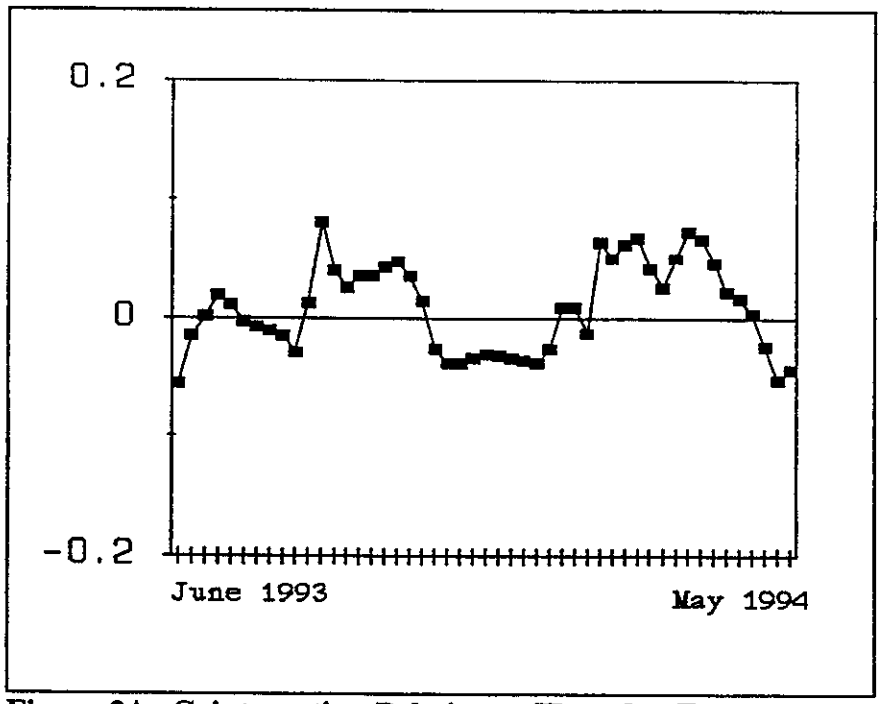


**Figure 2A Cointegrating Relations: Thursday Futures, Friday Cash, and T-Bill Rates**

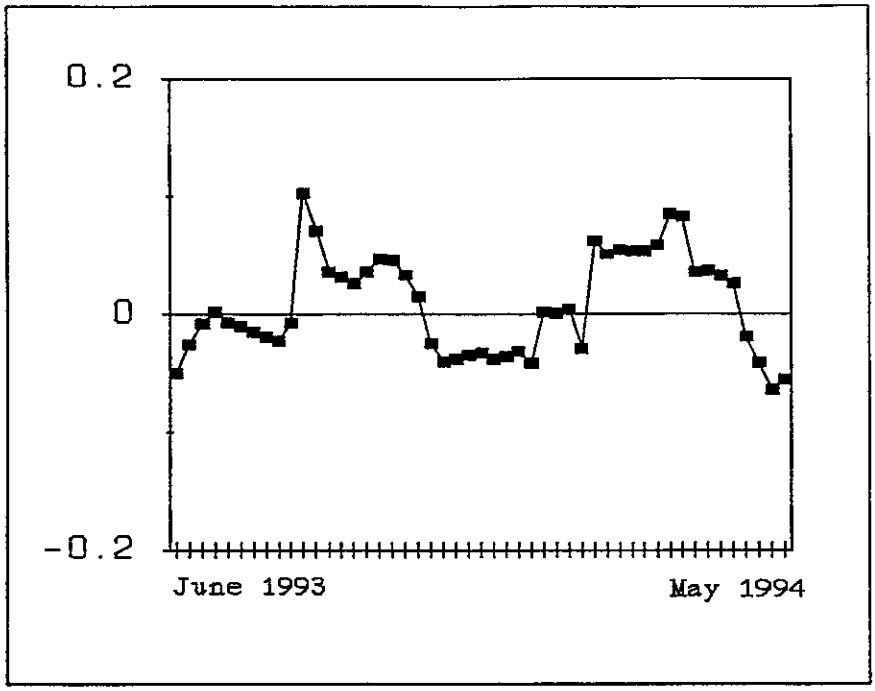


**Figure 2B Cointegrating Relations: Friday Futures, Friday Cash, and T-Bill**

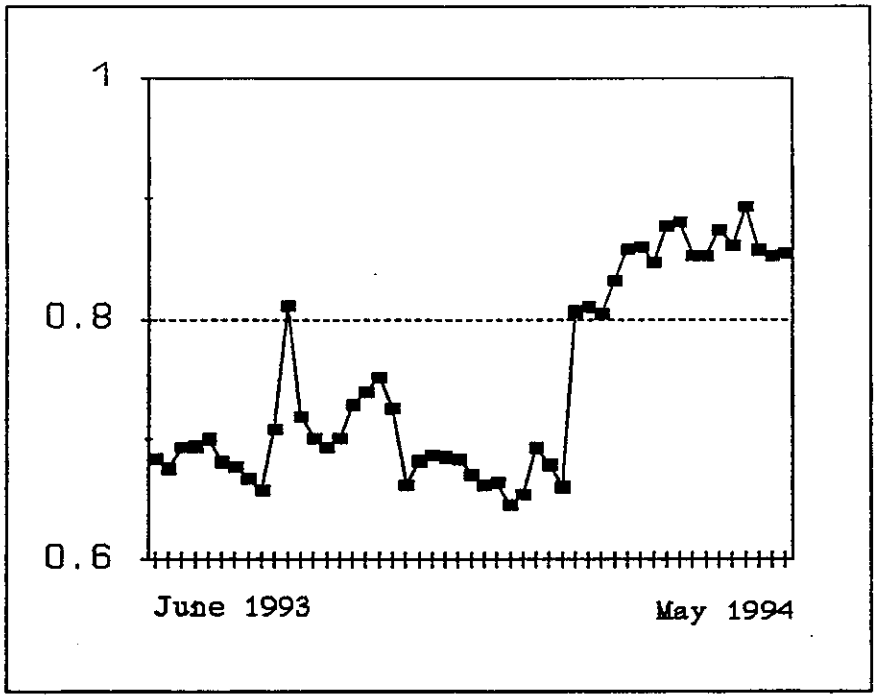


**Figure 2C Cointegrating Relations: Monday Futures, Friday Cash, and T-Bill Rates**

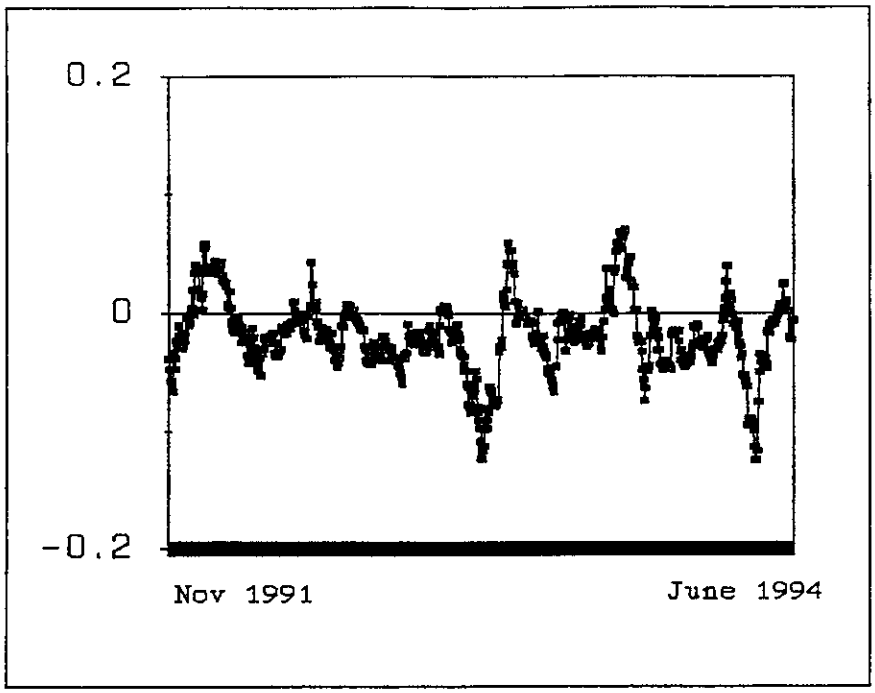


**Figure 3 Cointegrating Relations: Diammonium Phosphate Futures and Cash Prices**

# APPENDIX A: TECHNICAL APPENDIX

## PRICE DISCOVERY AND COINTEGRATION

The hypothesis (associated with market efficiency) that futures prices are unbiased predictors of future cash prices implies a hypothesis of joint equilibrium between the two price series (and rationality of expectations) (Racer). Initial efforts to test this hypothesis consisted of estimating a static regression between cash and futures prices given by

(1) $$S_t = \alpha + \beta F_t + e_t$$

where the S is the spot price, F is a futures price, and $e_t$ measures the stochastic difference between cash and futures. This relationship assumes that new information will affect both cash and futures markets instantaneously (i.e., one market does not lead the other) and that new information will affect both markets in the same way. However, it can be shown under some plausible assumptions that particular changes in information, such as a decline in interest rates, can cause changes in cash prices that move in the opposite direction of those for futures prices (Dewbre). Further, movement to long run equilibrium may not occur instantaneously. The realization that prices may take some time to adjust to a new long run equilibrium after the introduction of new market information has led to the application of cointegration theory to market relationships.

The cointegration model most often used in the study of agricultural commodity markets has been a bivariate regression between cash and futures prices (Bessler and Covey, Fortenbery and Zapata). The model specifies a relationship between cash price ($S_t$) and futures ($F_t$) that when solved for the price difference results in:

(2) $$F_t - S_t = \alpha + \delta(F_{t-1} - S_{t-1}) + \varepsilon_t.$$

The larger $\delta$ in the above equation the greater the range of allowed disparity between futures and cash price changes before the two series are brought back to equilibrium. If $\delta$ is close to one, then cash and futures prices do not converge rapidly, and their difference is assumed to be stable. If $\delta$ is small, prices will converge quickly because only a small fraction of the price difference on day t-1 will persist to day t.

Equation (2) is based on the theoretical market relationship outlined by Garbade and Silber. Garbade and Silber, however, specified the cash/futures relationship as being between a cash price and the cash equivalent futures price. The cash equivalent futures price is measured as:

(3) $$F_t' = F_t - r\tau_k$$

where r is the prevailing interest rate and $\tau_k$ represents the interval between the current time period and the maturity date of the futures contract. In their work on price discovery, Garbade and Silber assume that r is flat and stationary. Cointegration applications based on equation (2) have implicitly made the same assumption. If interest rates are flat and stationary, then failure to discount the observed futures price to its cash equivalent would have no effect on the finding of a cointegrating vector between cash and futures, although it might be argued that some information has been lost. If interest rates are not stationary, then failure to explicitly account for their influence on commodity prices will bias cointegration results against a finding of cointegration. This may lead to a conclusion of cash and/or futures market inefficiency when in fact the real problem is one of model misspecification.

The potential importance of interest rates on commodity prices has been addressed by other research (Schuh and Frankel (1984,1986); Racer; Kitchen and Denalby). Rather then debate the interest rate question here, we simply conduct cointegration tests two ways; first we make the traditional assumption that interest rates are stationary and conduct bivariate cointegration analysis between cash and futures prices consistent with equation (2), and second we explicitly introduce interest rates in the estimation process.

**Cointegration and Error-Correction Representation**

If an equilibrium relationship exists between cash and futures markets then $y_t = (\ln S_t \; \ln F_{t-k})'$[1] is cointegrated with $Cy_t = z_t$, where $z_t$ is an stationary error term about a mean of zero, suggesting that in equilibrium $Cy_t = 0$. In the above characterization, ln refers to natural logs, F is the futures price, and C is the cash price. Using Granger's representation theorem, an error-correction model (ECM) can be specified. By the recent asymptotic results in cointegration theory (Johansen (1988), and Phillips), the vector autoregressive model with Gaussian errors is given by

$$(4) \qquad y_t = \mu + \Pi_1 y_{t-1} + \ldots + \Pi_{p-1} y_{t-p+1} - \Pi_p y_{t-p} + e_t$$

where t=1,2, ...,T, and $e_1,...,e_T$ are independent Gaussian variables in k dimensions with mean zero and variance $\Omega$. This model can be reparameterized in ECM as

$$(5) \qquad \Delta y_t = \mu + \Gamma_1 \Delta y_{t-1} + \ldots + \Gamma_{p-1} \Delta y_{t-p+1} - \Pi y_{t-p} + e_t$$

or

---

[1] If interest rates are nonstationary and impact on the equilibrium relationship between cash and futures markets, then $y_t = (\ln S_t \; \ln F_t \; \ln r_t)'$.

(6) $\Delta y_t = \Gamma_1 \Delta y_{t-1} + \ldots + \Gamma_{p-1} \Delta y_{t-p+1} - B[C, \eta][y'_{t-p}\ 1]' + e_t,$

where

(7) $\Gamma_i = -(I_K - \Pi_1 - \ldots - \Pi_p), \quad i=1,2, \ldots, p-1,$

and

(8) $\Pi = -I + \Pi_1 + \ldots + \Pi_p.$

Equation (5) is used if $\mu$ can be absorbed into the cointegration relation and equation (4) otherwise (Johansen 1991).

These specifications are convenient since the hypothesis of cointegration implies restrictions on the $\Pi$ matrix leaving the other parameters free. The hypothesis of at most r cointegrating relations is formulated as the restriction

(9) $H_r = \Pi = BC$

or

(10) $H_r^* = \Pi = BC$ and $\mu = BC_0$

where B and C' are kxr matrices and $C_0$ is an rx1 vector. Hypotheses (9) and (10) correspond to models (4) and (5), respectively, based on the data considered. The integer value of r depends on the number of variables in the system, and therefore lies between zero and k. When the rank of $\Pi$ is zero, the EC term disappears and the classical VAR in differences is the appropriate structure. If the rank of $\Pi$ equals the number of variables in the system (k) then a VAR in levels should be estimated.

The procedure for testing cointegration can be outlined as follows:

1. Specify a VAR representation as in equation (4).

2. Define $\Delta Y = [\Delta y_1, \Delta y_2, \ldots, \Delta y_T]$ as a KxT matrix of first differences with variables on the rows and observations on the columns, $X_t = [\Delta y'_{t-1}, \Delta y'_{t-2}, \ldots, \Delta y'_{t-p+1}]'$ a K(p-1)x1 matrix of lagged differences for one observation, $X = [X_1, \ldots, X_T]$ a K(p-1)xT matrix of lagged differences for all observations, $Y_{-p} = [y_{1-p}, \ldots, y_{T-p}]$ a KxT matrix of data on lagged levels, $\Gamma = [\Gamma_1, \ldots, \Gamma_{p-1}]$ a Kx(K(p-1)) a matrix of coefficients on lagged changes, and $E = [e_1, \ldots, e_T]$ a KxT matrix of residuals. Obtain the residuals, $R_0 = \Delta YM$ and $R_1 = Y_{-p}M$, that is by regressing $\Delta Y$ on X and $Y_{-p}$ on X, respectively.

3. Compute the second-moment matrices $S_{ij} = T^{-1}R_iR'_j$ with i,j=0,1 and find the eigenvalues, $\lambda_1 \geq \lambda_2 \geq \ldots \geq \lambda_K$, between $R_0$ and $R_1$ by solving the determinantal equation

$$|\lambda S_{kk} - S_{k0}S_{00}^{-1}S_{0k}| = 0.$$

4. Compute the Trace test by

$$\text{Trace Test} = -T\Sigma_i \ln(1 - \lambda_i), \quad i=r+1,\ldots, K$$

This is used for testing the null hypothesis of K or less cointegrating vectors.

Johansen and Juselius also suggest using a maximal eigenvalue test which uses the $(r+1)^{th}$ largest eigenvalue, and therefore called the Maximal Eigenvalue Test (or $\lambda$max Test) given by

$$\lambda\text{max Test} = -T\ln(1 - \lambda_{r+1}),$$

Critical values for testing the number of cointegrating relations are tabulated in Johansen and Juselius (see Appendix tables A2 and A3). To conclude that a

cointegrating vector exists one must detect statistical significance in both the trace test and the λmax test.

**Cointegration Results for Cheddar Cheese**

The first step in testing for cointegration is to verify that the price series considered are nonstationary. Cheddar cheese cash and futures prices were tested for nonstationarity using Phillips-Perron tests for unit roots.[2] Test results suggest that cash and futures prices are nonstationary of order one. This suggests that both cash prices and futures prices behave as stochastic trend variables during the interval over which cheddar cheese futures contracts have been traded. Results from testing for cointegration between cash and futures prices for cheddar cheese are presented in table 1. Note that while either the trace or λmax test are sometimes significant at the 5 percent level, there is no instance in which both test statistics are significant. This leads to a finding of no cointegration in cash and futures markets for cheddar cheese. The residuals from the cointegration regressions are illustrated in figures 1A through 1C in the body of the main text.

To test the potential impact of interest rates on the relationship between cash and futures markets for cheddar cheese, we use daily rates of return to 90 day Treasury Bills (T-Bills). Phillips-Perron unit root tests suggest that interest rates (as measured by 90 day T-Bills) also behave as a nonstationary series. This leads to the specification of a trivariate cointegration model, the results of which are also presented in table 1. Again, test statistics suggest that there is no evidence of cointegration. The residuals from the trivariate cointegration model are presented in figures 2A through 2C in the body of the main text.

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[2] Tabulated results for Phillips-Perron tests statistics are available from the authors.

Cointegration tests are also conducted for the anhydrous ammonia markets and the diammonium phosphate markets. These results are presented in table 2. Again, unit root tests suggest cash and futures prices for both commodities behave as nonstationary series. Cointegration results for the NH3 and DAP cash and futures markets reveal evidence of a significant cointegrating relationship. In addition, this relationship was developed for DAP in the first year of futures trading. Both the trace and $\lambda$max test statistics for NH3 and DAP are significant at the 5 percent level. The identified lag structures suggest that the futures market for both fertilizer products leads the cash markets. The NH3 cash market responds to futures within 10 trading days (the lag structure is two, but the NH3 data is observed weekly), while the DAP cash market adjusts to changes in futures within 3 trading days (the DAP data represent daily prices).

Table 1. Cointegration Tests for Nearby Futures and NCE cash prices for Cheddar Cheese.*

| $H^{**}_2$ | Trace | λmax | Series | Beta | Alpha |
|---|---|---|---|---|---|
| | | Test Results for Futures and Cash Prices (k=2)[1] | | | |
| r<=1 | 6.2697 | 6.2697 | Futures | 1.00 | -0.34 |
| r =0 | 20.7875 | 14.5178 | Cash | -0.11 | -0.06 |
| | | Test Results for Futures Prices, Cash Prices, and T-Bill Rates (k=2)[2] | | | |
| r<=2 | 2.2814 | 2.2814 | Futures | 1.00 | -0.392 |
| r<=1 | 9.9111 | 7.6296 | Cash | -0.265 | -0.022 |
| r =0 | 34.8124 | 24.9014 | T-Bill Rates | -0.04 | -0.245 |

NOTES:

* These results are for Friday futures and Friday cash prices, and correspond to Figure 2B. Results using futures prices on other days are similar, and are available from the authors.

** Indicates a constant has been added to the EC term in the estimated model. All residuals behave as white noise at k lags using the Box-Ljung Q-statistics.

1) There are two series (p=2), therefore 2-r is the number of stochastic trends between futures and cash prices, with r being the number of cointegrating relations (r = 1 or 0). Critical 95% Quantiles (Johansen and Juselius) for 1 and 2 common stochastic trends are, respectively, Trace (9.904, 20.168) and λmax (9.094, 15.752).

2) There are three series (p=3), therefore 3-r is the number of stochastic trends between futures and cash prices and T-Bill rates, with r being the number of cointegrating relations (r=2,1, or 0). Critical 95% Quantiles (Johansen and Juselius) for 1, 2, and 3 common stochastic trends are, respectively , Trace (9.904, 20.168, 35.068), and λmax (9.904, 15.752, 21.894).

Table 2. Cointegration Tests for Nearby Futures and Cash Prices for the Anhydrous Ammonia and Diammonium Phosphate Markets.

| $H^*_2$ | Trace | λmax | Series | Beta | Alpha |
|---|---|---|---|---|---|
| | | Test Results for Cash and Futures Markets, Anhydrous Ammonia[1] | | | |
| r<=1 | 1.9879 | 1.9879 | Futures | 1.00 | -0.003 |
| r =0 | 26.5109 | 24.5230 | Cash | -0.78 | 0.325 |
| | | Test Results for Cash and Futures Markets, Diammonium Phosphate, First Year of Futures Trading | | | |
| r<=1 | 1.6157 | 1.6157 | Futures | 1.00 | -0.009 |
| r =0 | 22.6730 | 21.0573 | Cash | -1.01 | 0.063 |
| | | Test Results for Cash and Futures Markets, Diammonium Phosphate, January 1, 1992 through May 1994 | | | |
| r<=0 | 0.5634 | 0.5634 | Futures | 1.00 | -0.007 |
| r =0 | 52.4413 | 51.8779 | Cash | -0.89 | 0.097 |

NOTES:

1) There are two series (p=2), therefore 2-r is the number of stochastic trends between futures and cash prices, with r being the number of cointegrating relations (r = 1 or 0). Critical 95% Quantiles (Johansen and Juselius) for 1 and 2 common stochastic trends are, respectively, Trace (9.904, 20.168) and λmax (9.094, 15.752).

## APPENDIX B: FUTURES CONTRACT SPECIFICATIONS

Futures contracts for cheddar cheese and non-fat dry milk were introduced at the Coffee, Sugar, and Cocoa Exchange in June 1993. Contract specifications for both contracts have undergone some change since their initial introduction. The original cheddar cheese contract was for 40,000 pounds of 40 pound blocks. Beginning with the November 1994 contract, contract size was reduced to 10,500 pounds. This was done to make the contract more attractive to small hedgers, corresponding more closely with the cheese equivalent of an individual dairy producer's expected monthly milk production. However, to make delivery of cheddar cheese against a futures contract position requires 42,000 pounds of cheese. As such, deliveries of physical commodities against futures positions can only be done in increments of four contracts each. The delivery months for cheddar cheese futures contracts are February, May, July, September, and November. Delivery is priced in cents per pound FOB at the seller's location. Thus, cheese can be delivered against a futures position anywhere in the United States. This is a somewhat unique contract specification. Most commodity futures contracts specify specific delivery locations for traders wishing to make delivery of the physical commodity against a futures position. In addition to quantity, the cheddar cheese futures contracts specifies quality characteristics for delivery including moisture, color, and age. Only cheese up to 60 days old and manufactured in United States Department of Agriculture approved plants can be delivered.

Figure B1 illustrates cheddar cheese trade volume from contract inception through December 1994. Note that volume had been relatively steady until October 1994. The large spike in October trade volume corresponds to the reduction in contract size for cheddar cheese

futures contracts. It is interesting to note that volume rather quickly returned to its previous trading level following the contract size reduction. This suggests that while the same number of contracts are being traded on a daily basis, they represent a significant reduction in total cheese traded.

Specifications of the non-fat dry milk futures contract have also undergone change since their initial introduction in June 1993. The original contract size for non-fat dry milk was 44,000 pounds of Extra Grade or better in 25-Kilo bags. Beginning with the November 1994 contract, this was changed to an 11,000 pound contract, but delivery must be made in increments of 4 contracts, or 44,000 pounds. The original delivery specifications were for FOB in the Western Region of the United States, with a 3.5 cent per pound premium for delivery in the Central United States, and a 5 cent per pound premium for delivery in the eastern region. These specifications were recently changed to reduce the transportation differentials to 1/2 cent per pound in the central region, and 1.5 cents per pound in the eastern region. The non-fat dry milk contract has the same delivery months as cheddar cheese, and also specifies technical characteristics including a provision that delivered milk cannot be more than six months old. Trade volume for non-fat dry milk is illustrated in Figure B2. Note the absence of any trade following October 1994. This has been attributed to dissatisfaction with the original delivery location requirements, and trade did resume in early 1995.

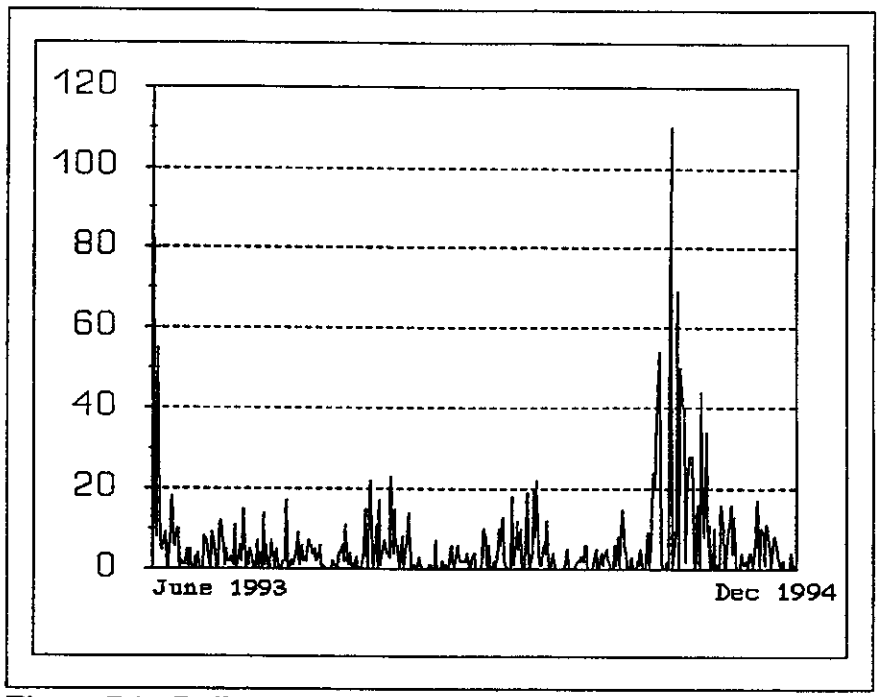


**Figure B1. Daily Trade Volume for Cheddar Cheese Futures Contracts.**

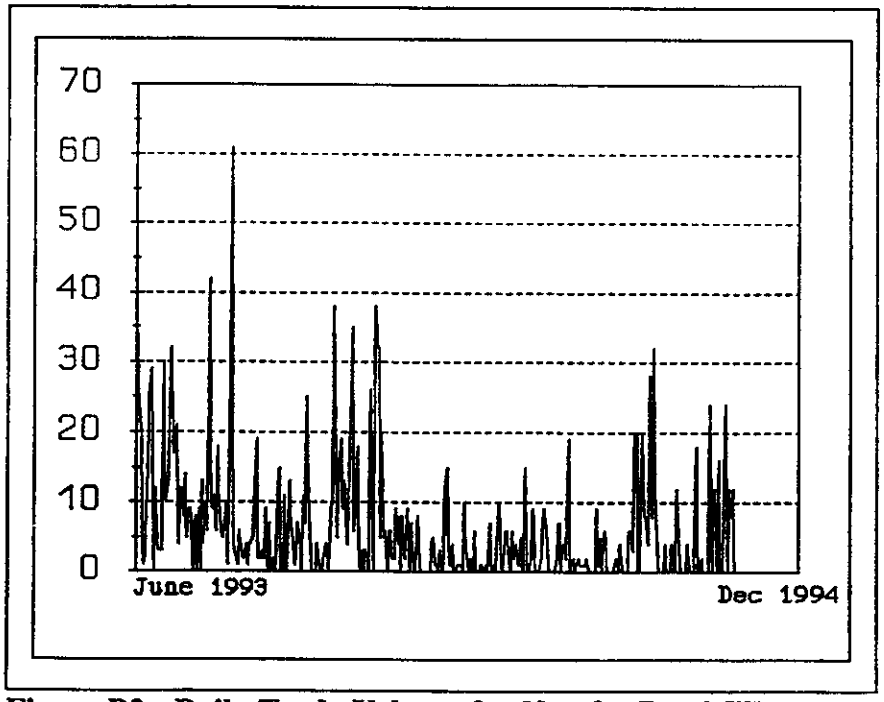


**Figure B2. Daily Trade Volume for Non-fat Dry Milk Futures Contracts.**

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