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

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Organized trading in commodity futures markets in the United States dates back to the mid 1860s. 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.

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The introduction of the cheddar cheese and nonfat 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 AM until 10:30 AM central time. In contrast, the futures market trades every business day from 2:15 PM to 3:15 PM eastern time. It might be reasonable to expect that cheese price information is now being delivered to cash market participants more frequently, and that intraweek futures trading may influence the Friday cash prices in Green Bay.

This study 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 study 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.

[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

In his book *Starting Out in Futures Trading,* 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 updated continually. If the changes in prices accurately reflect 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 sys-

[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.

tematically 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 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 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 one 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 one 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, the futures price for a later delivery period would be expected to increase. Also, one would expect the cash price which is finally observed

[3]For a more complete discussion on efficiency studies as they relate to futures markets, see Leuthold, pp. 114–116; and Garcia, Leuthold, Fortenbery, and Sarassoro (1988).

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 futures price changes as the distant delivery date nears 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.

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 tends 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 focuses 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 tend to lead live cattle cash prices. Ollerman and Farris (1985) 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 suggest that futures trading does impact cash markets, and that futures trading increases cash market pricing efficiency, but also increases 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 to 1984. They studied pair-wise relationships between various cash markets, and between cash and futures markets. They concluded that none of the markets studied determine prices independent of the other markets, suggesting that price information flows among markets. Their data showed that the information flow among 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 are 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 were 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 are 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 considered. In a later article, Zapata and Fortenbery (1996) 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.

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. 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 but which are pricing an identical asset, ought to exhibit a linear relationship between themselves which is deterministic. 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.

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 is perfectly anticipated and the information is reflected already in past prices, or that new prices are not responding to new market information and are inefficient.

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:

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

[4]This does not mean that basis levels cannot be different 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.

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 are for different delivery locations, A would include transportation costs between the markets. If they are 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 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.

An important implication of eq. (1) is that the matrix of long-run relationships (i.e., the number of cointegrating vectors) be of reduced rank relative to a vector autoregressive model of the data. This suggests the existence of cointegration can be rejected for one of two reasons; there is a rejection of any cointegrating vectors, or the number of identified cointegrating vectors is not less than the number of variates being considered. For the bivariate model example described above, a finding of cointegration requires the detection of a single, statistically significant cointegrating vector.[5]

COINTEGRATION RESULTS FOR CHEDDAR CHEESE

A unique characteristic of cash and futures markets for cheddar cheese is that they did not trade simultaneously during the sample period studied.[6] 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

[5]For a complete discussion of the implications of detecting as many cointegrating vectors as variables considered in the system, see Engle and Granger (1987). For a complete discussion of the necessary and sufficient conditions for a finding of cointegration see Granger and Weis (1983).

[6]The CSCE has proposed moving the futures trading hours for cheddar cheese to correspond to those of their other contracts. If this were to happen, the cheese futures and the cash market in Greenbay would be open simultaneously on Fridays. Should this happen, it would be useful to test the hypothesis that market structure may be the cause of what appears to be pricing inefficiency. Do to the timing of this decision, however, it is beyond the scope of this study.

with futures trading. However, cheese futures initially traded between 2:15 PM and 3:15 PM Eastern Standard Time. The NCE cash market only trades on Fridays between 10:00 AM and 10:30 AM 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 intraweek. 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 which then provides 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, and futures respond 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).

The dynamics of cheddar cheese price discovery are investigated using the maximum likelihood estimation technique outlined in Johansen and Juselius (1990). The Johansen and Juselius approach entails the compilation of two statistical tests—the trace test and the λmax test. Both test statistics must be significant to identify cointegration between two series. A complete discussion of the Johansen and Juselius technique, including calculation of the test statistics, is provided in Appendix A.

Examination of price dynamics in the cash and futures markets for cheddar cheese is conducted for the period, June, 1993 through July, 1995. This sample period coincides with the introduction of the cheddar cheese futures contract. The estimation utilizes cash price 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. Appendix B provides a complete description of the cheddar cheese futures contract, including historical trade volume.

The first step in testing for cointegration is to verify that the price series considered are nonstationary. Cheddar cheese cash and futures prices are tested for nonstationarity using Phillips–Perron tests for unit

TABLE I

Cointegration Tests for Nearby Futures and NCE Cash Prices for Cheddar Cheese

H_2[a]	*Trace*	λ*max*	*Series*	*Beta*	*Alpha*
		Test Results for Futures and Cash Prices (k= 2)[b]			
		Thursday Futures, Friday Cash			
$r \leq 1$	15.5648	15.5648	Futures	1.00	−0.055
$r \leq 0$	17.7056	32.2740	Cash	−1.211	0.154
		Friday Futures, Friday Cash			
$r \leq 1$	15.5149	15.5149	Futures	1.00	−0.001
$r = 0$	16.7506	32.2654	Cash	−1.278	0.143
		Monday Futures, Friday Cash			
$r \leq 1$	13.6211	13.6211	Futures	1.00	−0.059
$r \leq 0$	15.9734	29.5945	Cash	−1.020	0.116

Notes: [a]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.
[b]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 (1990)] for 1 and 2 common stochastic trends are, respectively, Trace (9.904, 20.168) and λmax (9.094, 15.752).

roots.[7] Test results suggest that cash and futures prices are nonstationary of order one. This suggests that both cash and futures prices behave as stochastic trend variables during the interval over which cheddar cheese futures contracts have been traded.

Results of cointegration tests between cash and futures prices for cheddar cheese are presented in Table I, and Figures 1(a) through 1(c) show plots of the actual cheese basis behavior over the sample period. Note that both the trace and the λmax tests are significant at the 5% level, but suggest that the futures/cash cheese basis follows at least two separate stochastic trends. This violates the conditions for cointegration described by Granger and Weis (1983) and leads to a finding of no cointegration in cash and futures markets for cheddar cheese. Figures 1(a) through 1(c) are plots of the cheese basis between cash and futures prices for cheddar cheese over time. Recall the expectation for cointegrated markets would be a stationary basis, with any short-run divergence from the mean basis level being transitory. Figure 1(a) depicts the relationship between Thursday futures and Friday cash prices. Figure 1(b) shows the relationship between Friday cash and Friday futures prices (remember that the futures market trades after the cash market has closed), and Figure 1(c) illustrates Friday cash and the following Monday futures price relationship.

[7]Tabulated results for Phillips–Perron test statistics are available from the authors.

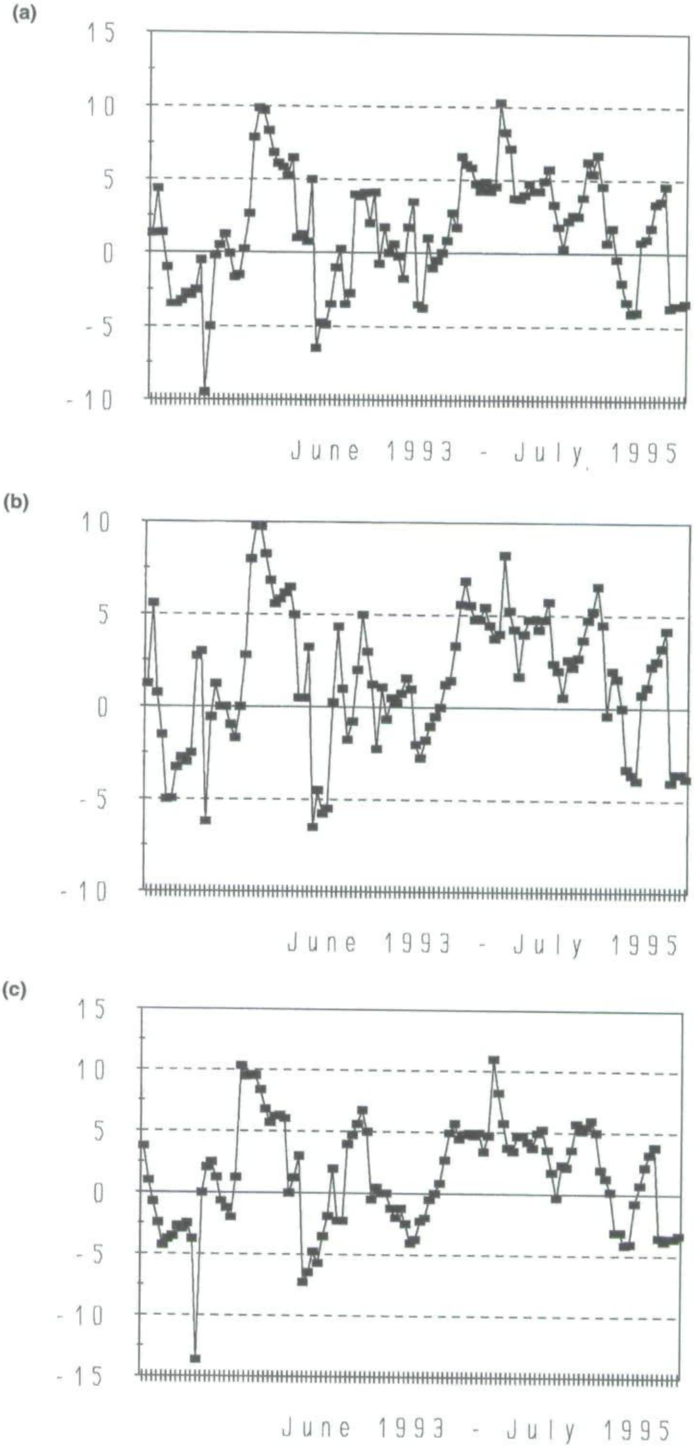

FIGURE 1
Cheddar Cheese Basis: (a) Cash Minus Thursday Futures Price; (b) Cash Minus Friday Futures Prices; (c) Cash Minus Monday Futures Prices.

Note that all cash/futures price pairs considered in Figures 1(a) through 1(c) appear to be nonstationary; i.e., their mean and variance appear to change over time, and do not depict 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) the basis represents a nonstationary process because eq. (1) is misspecified, and there is at least one more nonstationary component which contributes to the generation of Z.

To address this possibility, 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 eq. (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 relationship between the futures and the cash prices, such as storage costs) are not explicitly included in 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 (1996)].

Results generated from introducing interest rates into the cointegration model do not differ appreciably from those in the bivariate formulation and, therefore, are not reported here. These results are available from the authors.

It is interesting to note that the hypothesis of cointegration is not supported regardless 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, or 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 find that the two markets are closely related, with futures often leading cash markets in price discovery. One exception is the live cattle study of Bessler and Covey (1991). While they find weak evidence of cointegration within their initial sample, they infer a lack of cointegration with out-of-sample data based on the ability of a restricted vector autoregression model to outperform the cointegration model in out-of-sample forecasts of cash prices. They note that their forecast results are inconsistent with expectations in cointegrated systems, and conclude that the cash market for live cattle is inefficient. However, efficiency conclusions for cheddar cheese 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 will exist between the cash and futures markets.[8] Further, the Bessler and Covey (1991) study analyzed only one year of data as well. Fortenbery and Zapata (1993) showed that even in a mature market it is possible to reject cointegration when using only one year of data, even though a longer time series would show cointegration does exist.

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. 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

[8]A recent article by Lamm (1994) 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. 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.

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 presented in Table II (unit root tests verify that all fertilizer prices considered behave as nonstationary series). Cointegration tests for NH3 and DAP cash and futures markets reveal evidence of a significant cointegrating relationship. The identified lag structures in Table II suggests that futures markets for both fertilizer products lead cash markets in price discovery. The NH3 cash market responds to futures within ten trading days (the lag structure is two, but NH3 is observed weekly because daily cash data are not available), while the DAP cash market adjusts to changes in futures prices within three trading days (the DAP data are daily). To determine whether trading experience beyond the first year of the futures market is necessary to achieve a long-run equilibrium relationship, a test for cointegration using just the first year of DAP futures trading is conducted. This test also supports the cointegration hypothesis, and is presented in Table II, with the first year basis illustrated in Figure 2. These results suggest that at least some markets are capable of establishing a long-run equilibrium relatively quickly.

Based on the results above it appears that the cheddar cheese cash and futures markets have not developed an efficient pricing relationship. There may be several reasons why this is true. First, it is possible that arbitrage opportunities which appear to exist are somewhat illusory. Since the cash and futures markets for cheddar cheese did not previously trade simultaneously, it cannot be assumed that they were always trading on the same information set. If the information set changes substantially between the closing of one market and the open of the other, then the closing prices in the two markets would be expected to behave differently. Further, even if potential arbitrage profits exists, the risk associated with having to enter the markets one at a time may well negate the potential rewards from successful arbitrage. This suggests that what appears to be market pricing inefficiency may result from the institutional structure of the two markets rather than prices in either or both markets not responding efficiently to new market information.

A second explanation of the results above may rest with the trade volume in the cheese futures market. Over the two-year study period, trade volume has been exceptionally low, with the total number of daily traded contracts often being in single digits (see Fig. B1 in Appendix B). Low trade volume increases risks to potential hedgers and speculators because the assurance of efficient contract liquidation is reduced. With-

TABLE II

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

H_2[a]	*Trace*	*λmax*	*Series*	*Beta*	*Alpha*
	Test Results for Futures and Cash Prices, Anhydrous Ammonia ($k = 2$)[b]				
$r \leq 1$	1.9879	1.9879	Futures	1.00	−0.003
$r = 0$	25.5109	24.5230	Cash	−0.78	0.325
	Test Results for Futures and Cash Prices, Diammonium Phosphate, First Year of Futures Trading ($k = 2$)				
$r \leq 1$	1.6157	1.6157	Futures	1.00	−0.009
$r \leq 0$	22.673	21.0573	Cash	−1.01	0.063
	Test Results for Futures and Cash Prices, Diammonium Phosphate, January 1, 1992 through May 1994 ($k = 3$)				
$r \leq 1$	0.5634	0.5634	Futures	1.00	−0.007
$r \leq 0$	52.4413	51.8779	Cash	−0.89	0.097

Notes: [a]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.
[b]There are two series ($p = 2$), therefore $2\text{-}r$ 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 (1990)] for 1 and 2 common stochastic trends are, respectively, Trace (9.904, 20.168) and λmax (9.094, 15.752).

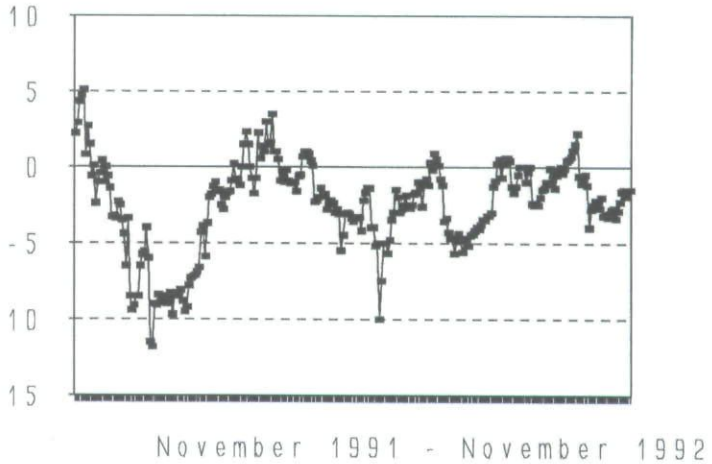

FIGURE 2
Diammonium Phosphate Basis: Cash Minus Futures Prices.

out sufficient volume to assure all potential traders that contract obligations can be offset without entering the delivery process, it becomes less clear whether futures prices represent an assimilation of market value, or simply values expressed only by the minority of potential market participants who desire physical delivery. Without sufficient volume, the con-

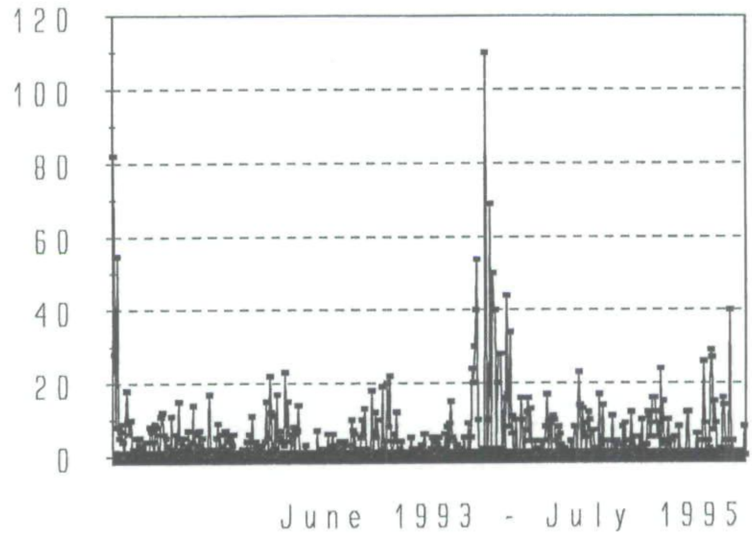

FIGURE 1B
Daily Trade Volume for Cheddar Cheese Futures Contracts.

tract becomes unattractive to most hedgers and small-scale speculators, limiting their input in determining prices. The lack of volume may also be related to the unique institutional design of the cash and futures markets.

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 for 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. Whether this results from pricing inefficiency in the cash and/or futures market, or results from the unique institutional design of the two cheese markets is less clear.

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. The cheese markets have had two years to establish this relationship.

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. If a strong price relationship between cash and futures markets does not emerge, it would be appropriate to question whether the institutional structure of either cash or futures markets for cheddar cheese restricts efficient pricing behavior. Until and unless the cash and futures markets for cheddar cheese exhibit an identifiable long-run equilibrium relationship, hedging opportunities using the cheddar cheese futures contract appear limited. Results suggest that the price basis for cheddar cheese does not behave in a predictable, stationary way. It is, therefore, not clear that trading price risk for basis risk in the cheddar cheese markets results in an overall risk-reducing exercise.

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 (1985)]. Initial efforts to test this hypothesis consisted of estimating a static regression between cash and futures prices given by

$$S_t = \alpha + \beta F_t + e_t \tag{1}$$

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 (1981)]. 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 (1991); Fortenbery and Zapata (1993)]. The model specifies a relationship between cash price (S_t) and futures (F_t) that when solved for the price difference results in:

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

The larger δ 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 δ is close to one, then cash and futures prices do not converge rapidly and their difference is assumed to be stable. If δ 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 (1983). Garbade and Silber (1983) 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:

$$F_t' = F_t - r\tau_k \tag{3}$$

where r is the prevailing interest rate and τ_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 (1983) assume that r is flat and stationary. Cointegration applications based on eq. (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 (1985); Kitchen and Denalby (1987)]. Rather then debate the interest rate question here, cointegration tests are conducted two ways. First, the traditional assumption is made that interest rates are stationary.

Bivariate cointegration analysis between cash and futures prices consistent with eq. (2) are then conducted. Second, interest rates are introduced into the estimation process.

Cointegration and Error-Correction Representation

If an equilibrium relationship exists between cash and futures markets, then $y_t = (\ln S_t \ \ln F_{t-k})'$[9] 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); Phillips (1988)], the vector autoregressive model with Gaussian errors is given by

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

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

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

or

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

where

$$\Gamma_i = -(I_K - \Pi_I - \ldots - \Pi_p), i = 1,2, \ldots, p - 1 \tag{7}$$

and

$$\Pi = -I + \Pi_t + \ldots + \Pi_p \tag{8}$$

Equation (5) is used if μ can be absorbed into the cointegration relation and eq. (4) otherwise [Johansen (1991)].

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

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

$$H_r = \Pi = BC \tag{9}$$

or

$$H_r^* = \Pi = BC \text{ and } \mu = BC_0 \tag{10}$$

where B and C' are $k \times r$ matrices and C_0 is an $r \times 1$ 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 Π is zero, the EC term disappears and the classical VAR in differences is the appropriate structure. If the rank of Π equals the number of variables in the system (k) then a VAR in levels should be estimated.

The procedure for testing cointegration is detailed in Johansen and Juselius. They present trace and λmax test statistics for testing cointegration, and provide critical values for each in Appendix Tables A1 and A2 of their paper. To conclude that a cointegrating vector exists, one must detect statistical significance in both the trace test and the λmax test.

APPENDIX B: FUTURES CONTRACT SPECIFICATIONS

Futures contracts for cheddar cheese and nonfat 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 42,000 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. Therefore, 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 1B illustrates cheddar cheese trade volume from contract inception through December, 1994. Note that volume was 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.

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