Cheddar Cheese and Fluid Milk Cointegration among Cash and Futures Prices: The Evidence for a Long-term Equilibrium Relationship

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The Evidence for a Long-term Equilibrium Relationship

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In the early 1990's, after four decades of relying on government mandated minimum price supports and public stockholding to achieve price risk management, the United States dairy industry is undertaking a shift to a market clearing equilibrium system. A significant component of this new structure is the development of an operational futures market for selected milk and dairy products. In June of 1993 the Coffee, Sugar, & Cocoa Exchange introduced contracts on Nonfat dry milk and Cheddar Cheese. In December of 1995 the CSCE introduced a contract on Fluid milk and this was followed in January 1996 by a similar fluid milk contract trading on the Chicago Mercantile Exchange. This paper examines the extent to which a long-run equilibrium relationship has been established between the cheese and fluid milk futures markets and their cash market counterparts. The existence of a long-run equilibrium is a necessary condition for effective hedging opportunities. Using the time series concept of cointegrated series we concluded that the data support an equilibrium relationship in the cheese markets but provide no support for an equilibrium relationship in the fluid milk market.

Introduction

In the early 1990's, after four decades of relying on government mandated minimum price supports and public stockholding to achieve price risk management, the United States dairy industry is undertaking a shift to a market clearing equilibrium system. Prior to 1990 milk producers and dairy product processors relied on a system of minimum price and a sizable public stockholding to stabilize price movement. In 1982 this stockholding absorbed over 10 percent of annual production. As early as 1984 some economists called for the replacement of this highly inefficient and expensive public system with one based on open market price discovery and the use of futures and options markets for price risk management (Thraen).

The 1985 Food Security Act and its dairy title provisions finally began the long process of elimination of these programs. After a number of expensive and inefficient attempts at quick fixes to the support price / stockholding system, subsequent changes in federal law, while not removing the minimum price level, allowed it to be reduced to a level far below the market clearing equilibrium price point.[1] As a result the level of public stockholding for price stabilization purposes has been eliminated and price volatility in the milk and dairy product markets has increased significantly since 1990. Volatility and dollars at risk in the dairy industry now exceed

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that of grains and livestock in the United States. The process of replacing government intervention with private markets is irrevocably underway in the dairy industry and the success of futures and options markets as a means of price risk management is essential.

A significant component of this new market structure is the development of an operational futures and options market for selected milk and dairy products. In June of 1993 the Coffee, Sugar, & Cocoa Exchange began the trading of futures contracts on Nonfat dry milk and Cheddar Cheese. In December of 1995 the CSCE introduced a contract on Fluid milk and this was followed in January 1996 by a similar fluid milk contract trading on the Chicago Mercantile Exchange. On April 8th the CSCE began trading a variant of the fluid milk contract which is cash settled. Clearly the introduction of these futures markets will play an important role in fluid milk and dairy product markets in the future.

Much has been written about the relationship between futures prices and spot or cash market prices and we will not attempt to add to that literature in this paper (Bessler and Covey, Lu and Luethold, Zapata and Fortenberry, Brenner and Kroner). As Bessler and Covey correctly point out, economic forces tend to keep a pair of related economic series from ranging too far from each other. They cite as an example arbitrage on similar commodities across different markets will keep the relative prices from diverging too far apart. Gardner developed the idea that in an efficient market futures prices are unbiased forecasts or predictors of cash prices in the future. Unexpected shocks are reflected simultaneously in futures prices and in the underlying cash market. While the direction of adjustment and magnitude need not be in the same direction for the futures and cash price they must not diverge indefinitely from their long-term equilibrium relationship. In fact in an efficient market they should realign themselves rather quickly and reestablish their long-term relationship. By specifying the relationship between the cash or spot market price S_t and the futures market price F_t as $S_t - bF_t = e_t$ and imposing conditions on the behavior of e_t, the spot price and futures price are represented as being *cointegrated* and as such they share a common trend to which they return after being perturbed.

In their investigation of the cointegration of the corn and soybean futures and cash markets Lu and Leuthold raise three important questions: Are spot and futures prices cointegrated? If so, what is the meaning of the cointegrating relation? What are the implications for hedging effectiveness and price forecasting? In an efficient futures market the basis should be relatively stable with the futures and the spot price moving closely together as the contract approaches its expiration. As we roll-over at the expiration of one futures contract to the next nearby contract so as to keep the expiration date at a fixed time, we would expect to obtain a stationary series for the basis, i.e., the difference between the spot and futures price.[2] If this were not so there will be an arbitrage opportunity with positive expected profits.

In order for the market participants to be able to effectively hedge against price risk, it is essential that they be able to predict the basis, that is, able to estimate its conditional mean and variance. In an early attempt at addressing these questions for the CSCE cheese contract, Fortenberry and Zapata investigate the presence of a cointegrating relation in the cheese market and conclude that there is little support for the existence of a long-term equilibrium relationship. As a result they suggest that the cheese futures does not offer a viable tool for price risk management. This conclusion may be premature as the Fortenberry and Zapata analysis was based on limited number of data points. The futures market for cheese may not have had sufficient time to establish an equilibrium. Also it is widely accepted that the statistical tests for cointegration lack power in small samples. In this paper we examine the extent to which a long-run relationship has been established in the cheddar cheese futures and cash or spot markets using a much longer time period over which such a relationship could be established. We also investigate the fluid milk futures and cash markets.[3]

Dairy Product Contract History

In June 1993, The Coffee, Sugar and Cocoa Exchange (CSCE) began trading a futures and option contracts for the dairy product cheddar cheese and Nonfat dry milk. On December 12, 1995 the CSCE began trading a contract on Grade A raw milk. The Chicago Mercantile Exchange began trading Grade A futures on January 11, 1996. Both the CSCE and the CME futures contracts were structured to price Class III milk in federal milk marketing orders. The distinction between the two fluid contracts are the delivery point and months.

The Cheese Contract

The cheddar cheese contract calls for FOB delivery of block of cheddar cheese at any point within continental USA. It has to be manufactured only from pasteurized milk and must meet at least the USDA requirements of Grade A. The blocks must be colored and must have a moisture basis of 36.5-39.0%. On the exchange business day following the last trading day, the cheese may not be more than 30 days old. Seller must ship from his manufacturing plant or storage center according to buyer's shipping instructions at any point within continental USA.

The trading block is 10,500 lbs. cheddar cheese in 40-lb blocks. The price quotation is in cents per pound. The delivery months are the current calendar month, next two months and each February, April, June, August, October, and December occurring in the ensuing 12 months. The daily price limit from the previous day's settlement price is 6 cents with variable limits effective under certain conditions. The last trading day is the first Thursday of the delivery month. There are limits to positions but exceptions for purposes of hedging, straddling, and arbitrage may apply. However, there are no price limits on the two closest to expiration (nearby) months.

The Fluid Milk Contract

The CSCE milk contract identifies FOB delivery of one tank load (50,000 lbs.) Grade A raw milk in the Madison-Wisconsin District. The delivery months are the current calendar month, next two months, and each February, April, June, August, October, and December occurring within the forthcoming 12 months. The milk has to meet the requirements for Grade A raw milk with 3.5% butterfat content. The buyer is responsible for picking up the shipment from the seller's plant. The CME fluid milk contract specifications are very similar to those of the CSCE with the exception of the delivery specification.

Cointegration and Futures / Cash Market Analysis

Applied time series analysts have found wide application for the concept of cointegrating relationships when working with non-stationary time-series data. This concept has been widely used in the applied agricultural literature as a tool for investigating the presence of a long-term equilibrium between futures and cash markets.[4] While these time-series concepts are widely used, they are based on sophisticated mathematics of the statistical properties of random variables and their practical interpretation is not altogether transparent to the applied practitioner. We will attempt a brief explanation as it pertains to the important question of whether or not prices observed on futures markets are linked in a predictable way to prices observed on the underlying spot markets.

The statistical analysis proceeds from the specification of what is termed the data generating process (GDP) of a random variable or a vector of random variables of interest to the analyst. In our case these random variables are the spot price and the futures price and any other variables considered to be important. If a particular random variable exhibits what has become known as a common or stochastic trend then its first difference possesses a stationary and invertible autoregressive-moving average or ARMA representation plus a deterministic component. For example, the DGP for a random walk has a common trend because its first difference is a white noise. The DGP for cash market or spot and futures prices are typically found to possess common trends. A crucial implication of this property for empirical work is that the set of appropriate analytical statistical models is restricted since many popular approaches, such as taking first differences to achieve stationarity and standard statistical inference tests, are inappropriate in the presence of non-stationarity.[5]

Recently, much attention has been given to the possibility that two variables which by themselves are non-stationary might share the same common trend, i.e., that the variables might be cointegrated. In this case an error-correction model (ECM) can be specified which will retain the long-term equilibrium properties between the variables (Engle and Granger). Dickey, Jansen and Thorton (DJT) provide an insightful geometric interpretation of the concept of cointegration. Consider the case of three (3) endogenous variables which span the Euclidean R^3 space. In our case these will be (i) the spot market price for a dairy product, (ii) the futures price on the nearby contract, and (iii) the short-term interest rate.

If each of the variables are stationary, that is I(0), then the system converges to a steady-state equilibrium which is represented as a point in R^3. Variation around that point is finite. If the variables are non-stationary I(1), and share a single common trend, the system possesses a long-run equilibrium represented by a line determined by the intersection of the two planes defined by the n-1, i.e., two cointegrating vectors in R^3. The variance about this line is finite. If the number of cointegrating vectors in this system is 1, i.e., $h = 1$ so that $g = n-h = 2$ then there are two common trends shared by the variables in the system. In this case the long-run equilibrium is represented by a plane which is defined by the one cointegrating vector. The variables are unbounded in the plane, but cannot wander too far from the plane. The variance in the plane is infinite but the variance around the plane is finite.

If there are no cointegrating vectors, i.e., $h = 0$ so that $g = n-h = 3$ common trends then the variables are free to wander anywhere in R^3 - they are unbounded! In this later case we would conclude that relevant economic information is being processed in the spot and futures markets differently and that there is no empirical evidence that the futures market is predictably linked to the underlying spot market.

There are many estimation techniques and methods proposed in the time-series and econometric literature for the analysis of non-stationary and possibly cointegrating systems (Hamilton, Banerjee, et.al., Rao). The Johansen-Juselius Full Information Maximum Likelihood (JJ_MLE) procedure based on reduced rank regression has been used extensively in the applied literature and is the method used in this study (Johansen). Briefly stated the JJ-MLE specifies a reduced-form ECM representation for a VAR(p) model for the (nx1) vector $\mathbf{y}_t$:

$$\Delta y_t = \varsigma_1 \Delta y_{t-1} + \varsigma_2 \Delta y_{t-2} + \cdots + \varsigma_p \Delta y_{t-p+1} + \alpha + \varsigma_0 y_{t-1} + \varepsilon_t$$

with

$$E(\varepsilon_t) = 0 \text{ and } E(\varepsilon_t \varepsilon_\tau') = \begin{Bmatrix} \Omega & \text{for } t = \tau \\ 0 & \text{otherwise} \end{Bmatrix}$$

The JJ-MLE method proceeds with the supposition that each individual variable y_{it} in $\mathbf{y}_t$ possess a unit root, i.e., is I(1) with h linear combinations of $\mathbf{y}_t$ being stationary. The imposition of only h stationary linear combinations or h cointegrating relations, implies that ς_0 can be expressed as: $\varsigma_0 = -\mathrm{BA}'$, where $\mathbf{B}$ an (n x h) matrix and $\mathbf{A'}$ an (h x n) matrix. Under the null hypothesis of only h cointegrating relations there will be only h separate linear combinations of the level of $\mathbf{y}_{t-1}$ appearing in the ECM-VAR(p) model.

Under the assumption that the disturbances are Gaussian, the log of the conditional likelihood subject to the constraint of ***h*** cointegrating relations is:[6]

$$L^* = -(Tn/2)\log(2\pi) - (Tn/2) - (T/2)\log|\hat{\sum}_{UU'}| - (T/2)\sum_{i=1}^{h}\log(1-\hat{\lambda}_i).$$

where λ_i is the i^{th} eigenvalue. Testing for ***h*** cointegrating relations requires the application of the likelihood ratio test to L^* for specified values of ***h***.

Empirical Analysis

The investigation of a cointegrating relation between the futures prices and the cas begins with a visual examination of each of the price series over the time span of the analys data used in this analysis consist of the spot and futures prices along with an interest rate se

Cheese Spot and Futures Price Series

In the cheese market we use two different series to represent the spot market. spot cheese prices are taken from the National Cheese Exchange (NCE) and from the average Wisconsin Assembly Point (WAP) price series. Both series are reported by the States Department of Agriculture Dairy Market News service. The futures price used Friday close price as reported on the CSCE. The interest rate is the weekly average of month Treasury Bill rate as reported by the Federal Reserve. Figure 1 shows the transfo price data series for the cheese market over the 186 week period June 1993 through Jar 1997. CSCE depicts the futures price series, NCE the National Cheese Exchange Price, WAP the Wisconsin Assembly Point cheese price series. In Figure 1 the original price series each specified as $100*[\log(y_t)-\log(y_0)]$ which facilitates inspection for the presence of trend in data series. Inspection of Figure 1 for the cheese price series is not indicative of a trending ser

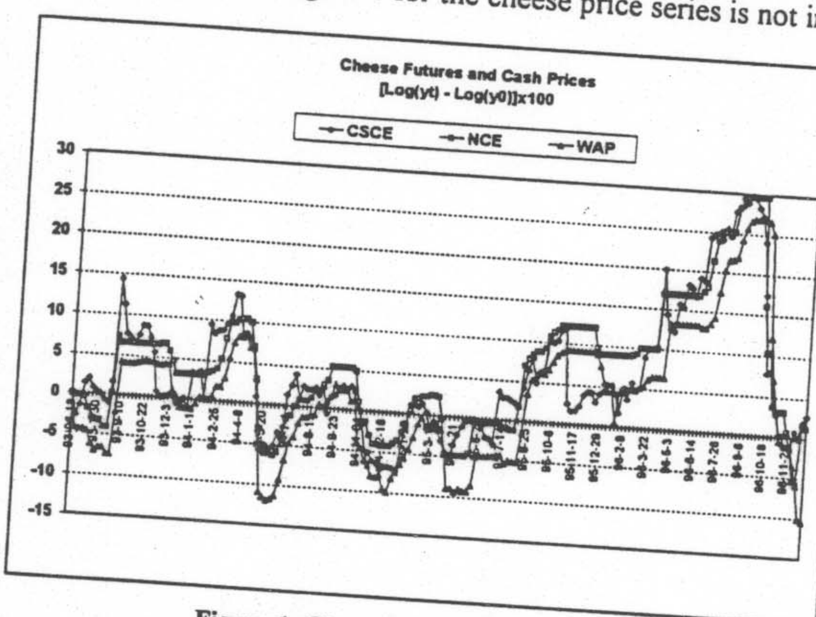

Figure 1. Cheese Market Prices

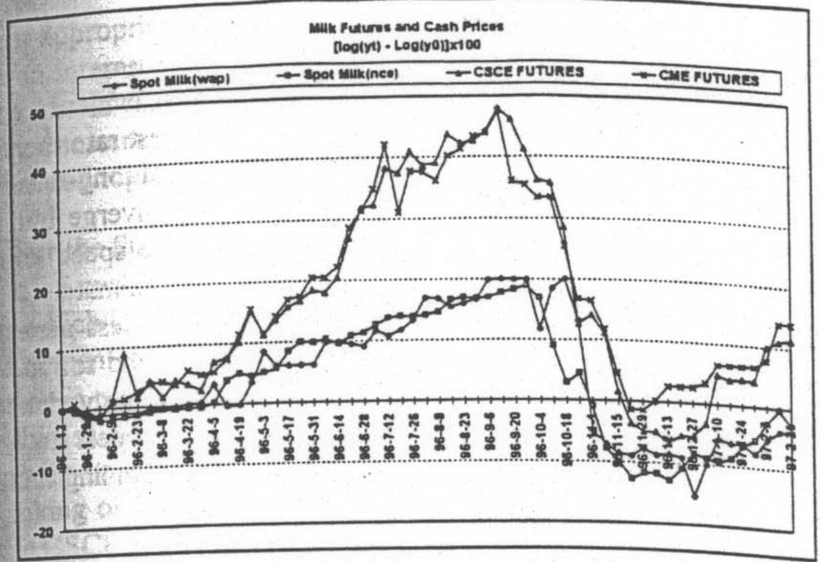

Figure 2. Fluid Milk Prices

<u>Fluid Spot and Futures Price Series</u>

The price variables in the fluid markets include the Friday close on the both the CME and CSCE exchanges. The derivation of a consistent spot market price series posed a challenge. Cash market fluid milk prices are not reported in a manner that is consistent with daily trading futures markets as they are only reported on a monthly basis and with a substantial time lag. However as we move toward a market orientation there are efforts to identify a method of calculating the implied spot price for fluid milk using the wholesale prices of its derivative products cheese, butter, and dry buttermilk powder as the basis for the calculations. The 59 weekly spot prices used in this paper were derived as a formula price consistent with this approach.[7] This spot price series and the CME and CSCE price series appear in Figure 2 with the same transformation as for the cheese series. Visual inspection does not suggest trending over the time period.[8]

<u>Non-stationarity and Unit Roots</u>

The next step is to confirm that each of the price variables are non-stationary and possess a single unit root, i.e. are I(1). This hypothesis was tested with the Augmented Dickey-Fuller (ADF) and the non-parametric Phillips-Perron (PP) test. The general conclusion is that each of the data series is I(1): their levels possess unit roots and their first differences were stationary, i.e, their first differences did not have unit roots.[9]

After verifying the non-stationarity of the basic price series we applied the Johansen-Juselius method to test for the presence of a cointegrating relationship between the futures, cash, and interest rates. Our unit-root results are given in Table 1. The JJ-MLE results for the cheese and fluid milk markets are presented in Table 2.[10]

Equilibrium in the Cheese Markets

In the cheese cash and futures markets there is strong empirical evidence of long-term equilibrium. Considering the vector of cash price, futures price, and interest rate there appears to be at least one cointegrating relation. Therefore there exists a fundamental long-term equilibrium such that shocks can cause the cash market and the futures market to diverge but they return rather quickly back into equilibrium with each other. Estimates of the speed of adjustment parameters indicate that the spot market adjusts to exogenous shocks approximately 4 times faster that does the futures market. Figure 3 depicts the disequilibrium error process generated by the cointegration vector for the NCE price series coint={1, -1.03, -0.399}, and for the WAP spot price series coint={1 -0.999 -0.782}. The disequilibrium error possess a finite variance, does not trend, and is bounded between plus and minus 10.0 cents. There does appear to be relatively large disequilibrium errors associated with the WAP price series at the beginning and end of the data period.

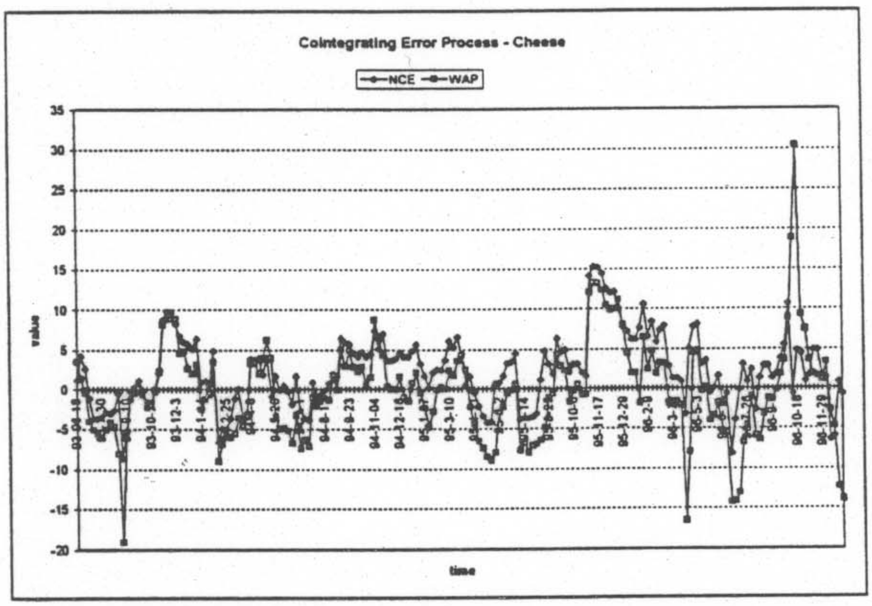

Figure 3. Disequilibrium Error Process in the Cheese Market

The Fluid Markets

Each of the fluid price variables exhibited unit roots for their levels. Expressed as first differences, the ADF tests indicated the presence of unit roots thus implying that the variables may be I(2). An application of the Phillips-Perron test indicated stationarity and therefore the conclusion that each of the price variables are I(1).

In specifying the JJ-MLE model we made a number of determinations based on an understanding of the underlying fluid milk commodity market. Fluid milk is a perishable commodity which is delivered to the market everyday of the year. The idea of cost of carry does not seem appropriate in this market and therefore it is not clear that the relevant system should include an interest rate variable. Also, based on our analysis, we conclude that the appropriate specification of the DGP does not include a vector of constants in the VAR model but does include a constant in the ECM. This specification implies that the fluid spot and futures market prices are tied together by a cointegrating relationship {spot price, futures price, constant}.[11]

For the fluid spot and futures markets cointegration was strongly rejected in the model. In a system of two I(1) variables and no evidence for a cointergrating relation this implies that the process which is determining futures prices on the CME and CSCE contracts is not tied to the process which is determining the spot price on the underlying fluid milk commodity. This conclusion is not surprising and only reinforces the view already expressed in the trade. Because of the physical delivery specifications in either the CME or CSCE contract, the futures market is pricing milk on a highly volatile short-term spot market distinct from the underlying cash market where taking or making delivery can impose significant costs to the contract holder. On April 8, 1997 the CSCE began trading a new futures contract designed to remedy this situation. This new Basic Formula Price (BFP) contract specifies a cash settlement at closing thus releasing the market participants from the highly volatile short-term spot market for fluid milk.

Implications for Efficient Markets and Price Risk Management

The cheese market exhibits a cointegrating relation among the futures and spot markets. The disequilibrium error process is bounded with a finite variance over the data period. This is important because this process reflects the basis for nearby contracts and as such suggests that market participants can use the cheese futures price discovery mechanism as a price risk management tool.

The same cannot be said for the current fluid milk and spot market prices. There is no evidence that these price discovery mechanisms share a long-term equilibrium relationship. Without a cointegrating relation, the disequilibrium error, or the basis, is unbounded and can wander unpredictably over time. Thus the futures price discovery mechanism would not be a reliable mechanism for price risk management to the market participants in the dairy industry.

The following questions remain to be addressed: With evidence of cointegration between futures and cash in the cheese market, what importance does this have for price risk management? Will knowledge of the cointegrating relation improve market participants ability to form optimal hedge ratios? Will knowledge of the cointegrating relationship improve forecasting models for the cheese market?

Turning to the fluid market, the question is: will the new BFP contract succeed as an efficient price discovery mechanism linked to the underlying fluid milk cash market? These are questions which are not yet addressed and remain to be answered for the developing futures markets for milk and dairy products.

TABLE 1. Augmented Dickey-Fuller and Philips-Perron Unit Root Tests for Non-stationarity.

VARIABLE	MODEL TEST	LAGS	C-NT a(1)=0 z -test	C-NT a(1)=0 t- test	C-NT a(0)=0 a(1)=0 F-test	C-T a(1)=0 z test	C-T a(1)=0 t test	C-T a(0)=a(1) F-test	C-T a(0)=0 a(1)=a(2) F-test
	CRIT. DF		-14.1	-2.86	4.59		-3.41	6.25	4.68
	PP		-14.1	-2.86	4.59		-3.41	6.25	4.68
			Fluid Milk Market Prices						
milk spot	ADF	3		-1.90	1.90		-2.20	2.70	1.80
	PP	1	-2.12	-0.99	0.50	-2.60	-1.10	1.08	0.72
cme	ADF	0	-2.73	-1.29	0.91	-2.40	-1.10	1.20	0.80
	PP	1	-2.69	-1.28	0.90	-2.40	-1.14	1.22	0.86
csce	ADF	6		-2.16	2.35		-2.09	2.31	1.56
	PP	1	-2.42	-1.18	0.07	-2.23	-1.10	1.18	0.81
Δmilk spot	ADF	2		-2.40	2.90		-2.48	3.10	2.07
	PP	1	-30.6	-4.30	9.60	-31.2	-4.43	9.87	6.59
Δcme	ADF	2		-2.78	3.91		-2.85	4.10	2.75
	PP	1	-59.2	-7.68	29.5	-60.4	-7.77	30.2	20.1
Δcsce	ADF	3		-1.73	1.51		-1.70	1.50	1.00
	PP	1	-44.6	-6.01	18.1	-45.9	-6.10	18.6	12.4
			Cheese Market Prices						
csce-friday	ADF	10		-2.05	2.10		-2.34	2.79	1.87
	PP	1	-8.51	-2.09	2.18	-10.0	-2.16	2.41	1.61
nce-spot	ADF	11		-1.88	1.78		-2.61	3.41	2.28
	PP	1	-6.72	-1.84	1.71	-7.81	-1.81	1.81	1.21
wap-spot	ADF	13		-1.92	1.87		-2.40	2.91	1.94
	PP	1	-5.97	-1.61	1.34	-6.12	-1.40	1.30	0.89
Δcsce-fr.	ADF	10		-5.08	13.0		-5.01	12.9	8.67
	PP	1	-174	-12.8	82.2	-174.	-12.8	82.0	54.7
Δnce-spot	ADF	12		-4.26	9.14		-4.25	9.05	6.05
	PP	1	-121.	-9.43	44.5	-121.	-9.43	44.4	29.6
Δwap-spot	ADF	12		-4.07	8.48		-4.05	8.28	6.63
	PP	1	-96.5	-8.19	33.5	-97.2	-8.22	33.8	22.5

CNT=Constant, No Trend → $\Delta Y_t = a(0) + a(1)Y_{t-1} + \Sigma_p b(p)\Delta Y_{t-p} + \varepsilon_t$

CT =Constant & Trend → $\Delta Y_t = a(0) + a(1)Y_{t-1} + a(2)t + \Sigma_p b(p)\Delta Y_{t-p} + \varepsilon_t$

ADF=Augmented Dickey-Fuller Unit Root Test; PP =Phillips-Perron Unit Root Test; nce = National Cheese Exchange; wap = Wisconsin Assembly Points; Crit.=Critical values at 95% significance level; Δ = first difference operator

Note: there is no ADF z-test for LAGS>1

TABLE 2: Results of the cointegration Analysis based on the Johansen / Juselius Method

Wisconsin Assembly Point Cash Price Series WAP

Lag (p)	Cointegration Vector: wap	cscef	r	h = 0	h<=1	h<=2	Test
				(15.63)	(9.35)	(2.85)	Max E cv
				(21.74)	(10.45)	(2.85)	Trace cv
3	1.000	-1.000	-0.350	27.32	7.45	3.21	Max E
a-ratio	3.96:1			37.98	10.66	3.21	Trace
2	1.000	-1.030	-0.399	42.02	8.13	3.19	Max E
a-ratio	4.85:1			53.35	11.32	3.19	Trace
1	1.000	-1.103	-0.323	42.56	8.15	2.4	Max E
a-ratio	4.66:1			53.11	10.54	2.4	Trace

National Cheese Exchange Cash Price Series NCE

Lag (p)	Cointegration Vector: wap	cscef	r	h=0	h<=1	h<=2	Test
				(15.63)	(9.35)	(2.85)	Max E cv
				(21.74)	(10.45)	(2.85)	Trace cv
3	1.000	-1.000	-0.721	22.37	6.87	2.7	Max E
a-ratio	2.35:1			31.95	9.58	2.7	Trace
2	1.000	-0.999	-0.822	26.98	7.73	2.87	Max E
a-ratio	1:01			37.58	10.6	2.87	Trace
1	1.000	-1.001	-0.859	27.22	7.56	2.35	Max E
a-ratio	0.99:1			37.12	9.9	2.35	Trace

Fluid Milk - Wisconsin Assembly Point Cash Price Series WAP / CME

Lag (p)	Cointegration Vector: wap	cme	constant	Null Hypotheses: h = 0	h <= 1	Critical Values Test
				(15.63)	(9.39)	
				(21.74)	(10.45)	
3	1.000	-0.580	-5.080	6.86	2.77	Max E
a-ratio	2.57:1			9.62	2.77	Trace
2	1.000	-0.550	-5.520	12.21	2.08	Max E
a-ratio	6.6:1			17.3	2.08	Trace
1	1.000	-0.550	-5.560	12.75	1.87	Max E
a-ratio	9.1:1			14.63	1.87	Trace

Fluid Milk - National Cheese Exchange Cash Price Series NCE / CME

Lag (p)	Cointegration Vector: wap	cscef	constant	Null Hypotheses: h=0	h<=1	Critical Values Test
				(15.63)	(9.39)	
				(21.74)	(10.45)	
3	1.000	-0.710	-2.900	5.22	2.63	Max E
a-ratio	–			7.85	2.63	Trace
2	1.000	-0.580	-4.870	7.22	1.98	Max E
a-ratio	1:4.46			9.2	1.98	Trace
1	1.000	-0.560	-5.160	6.91	1.79	Max E
a-ratio	1:3.38			8.71	1.79	Trace

a-ratio: The ratio of the adjustment coefficient on the cash price to the futures price. Indicates the relative speed with which the cash vs. Futures price returns to equilibrium after being driven from equilibrium.

TABLE 2 (continued): Results of the cointegration Analysis based on the Johansen / Juselius Method

Fluid Milk - Wisconsin Assembly Point Cash Price Series WAP / CSCE						
	Cointegration Vector			**Null Hypotheses**		
				h=0	h<=1	
Lag (p)	wap	cme	constant	(15.63)	(9.39)	Critical Values
				(21.74)	(10.45)	Test
3	1.000	-0.500	-6.600	9.1	2.66	Max E
a-ratio	7.0:1			11.76	2.66	Trace
2	1.000	-0.490	-6.330	12.79	1.75	Max E
a-ratio	5.8:1			17.55	1.75	Trace
1	1.000	-0.490	-6.330	13.38	1.75	Max E
a-ratio	5.8:1			15.13	1.75	Trace
Fluid Milk - National Cheese Exchange Cash Price Series NCE / CSCE						
	Cointegration Vector			**Null Hypotheses**		
				h=0	h<=1	
Lag (p)	wap	cscef	constant	(15.63)	(9.39)	Critical Values
				(21.74)	(10.45)	Test
3	1.000	-0.660	-3.620	4.98	3.52	Max E
a-ratio	1:8.55			8.5	3.52	Trace
2	1.000	-0.790	-6.100	8.21	2.81	Max E
a-ratio	1:32			11.02	2.81	Trace
1	1.000	-0.790	-6.220	8.77	2.67	Max E
a-ratio	1:3			11.11	2.67	Trace

a-ratio: The ratio of the adjustment coefficient on the cash price to the futures price. Indicates the relative speed with which the cash vs. Futures price returns to equilibrium after being driven from equilibrium.

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Endnotes

[1] The dairy title provisions of the 1996 Agricultural Act will, effective in 1999, eliminate the enabling legislation dating back to 1949 which authorized the use of price supports and public stockholding for price stabilization. Currently the mandated federal minimum price level is substantially below the market clearing equilibrium price and would be effective only under unlikely circumstances.

[2] For the purposes of this study we have specified the basis as the current cash price minus the nearby futures contract price since the nearby contract price is the one which market participants will be most likely offsetting their positions and which they have to accurately predict.

[3] Fortenberry and Zapata (1997) consider the existence of cointegration futures and cash markets for cheese over the time period of June 1993 - July 1995. Fortenberry and Zapata consider both a bivariate relationship between cheese futures prices and cash prices and a trivariate relationship which introduces a

short-term interest rate series as a measure of the cost-of-carry. For both the bivariate and trivariate models they conclude that a long-term equilibrium relationship is not present between the spot and futures markets and that a stable long-run pricing relationship between cash and futures markets for cheddar cheese had not yet been established. Their conclusion was that the cheese cash and futures markets had not yet established an efficient pricing relationship and hedging opportunities using the cheese futures market were limited.

[4] For those not familiar with the concepts required for the analysis of cointegration we recommend the introduction to the literature by Dickey, Jansen, and Thornton.

[5] The field of time series analysis is vast and complex. While there are many excellent texts on the subject the reader is referred to Time Series Analysis by James D. Hamilton for a complete reference on the subject. Standard advanced references for non-stationary time-series econometrics are Hamilton's textbook and the advanced and exhaustive monograph by Banerjee, et. al..

[6] Following Hamilton, section 19.2, one performs an auxiliary OLS regression of I(0) variables Δyt on a constant and Δyt-1, Δyt-2, ...,Δyt-p+1 with ut denoting the residuals. A second auxiliary regression of the levels yt-1 is run on a constant and Δyt-1, Δyt-2, ...,Δyt-p+1 with vt denoting the residuals. Then the sample variance-covariance matrices of the OLS residuals ut and vt are used to compute the ordered eigenvalues denoted as $\lambda 1 > \lambda 2 > \ldots > \lambda n$, where n is the number of components of the vector yt. Then the trace test is constructed as $T= - N * \Sigma_{k+1,n} \ln (1-\lambda i)$ with the null H_0: there are k or less cointegrating vectors, and the maximum eigenvalue test $\Lambda= - N * \ln(1-\lambda_{k+1})$ with the null H_0: there are exactly k cointegrating relations and the alternative H_1: the number of cointegrating relations is k+1. In general, we require that both tests indicate the same number of cointegrating relationships.

[7] The derivative formulae used and the actual calculations are available from the authors on request.

[8] However with only 59 weeks of data it is difficult to reach a definitive conclusion as to the presence or absence of trend.

[9] We also performed the same tests for the logarithms of the data. This conclusions did not change. The unit root tests and cointegration tests were constructed using the COINT© by Ouliaris and Phillips and run with the GAUSS Programming Software by Aptech Systems, Inc.

[10] This is not as mechanical as it may appear. There are a number of empirical issues in the application of cointegration testing using the JJ-MLE method which require substantial investigator insight. First, the method assumes that the error structure can be specified as Gaussian. Violation of this assumption can have serious consequences for hypotheses tests. Second, the ECM representation of the DGP requires an appropriate specification of the number of lag terms in the vector autoregression so that the estimated residual series are white noise processes. Third, the research analyst must decide as to whether or not there exists a drift in the original price series and whether or not this should be modeled as part of the price series alone or as part of the DGP. Resolution of the last two questions is subject to a degree of individual interpretation and can be instrumental in the conclusions reached from the analysis.

[11] The reader should keep in mind that the results reported here reflect these assumptions and, in the realm of cointegration analysis, assumptions such as these definitely influence the conclusions of the analysis.