MINNESOTA-WISCONSIN MILK PRICE DRIVES CHEESE PRICE: SOME EMPIRICAL EVIDENCE

AFPC Policy Research Report 96-2

August 1996

AFPC
AGRICULTURAL & FOOD POLICY CENTER

Agricultural and Food Policy Center
Department of Agricultural Economics
Texas Agricultural Experiment Station
Texas Agricultural Extension Service
Texas A&M University

A policy research report represents the final results of a research project undertaken by AFPC faculty. At least a portion of the contents of this report may have been published previously as an AFPC issue paper or working paper. Since issue and working papers are preliminary reports, the final results contained in a research report may differ -- but, hopefully, in only marginal terms. Research reports are reviewed by faculty of AFPC and the Department of Agricultural Economics, Texas A&M University. AFPC welcomes comments and discussions of these results and their implications. Address such comments to the author(s) at:

Agricultural and Food Policy Center
Department of Agricultural Economics
Texas A&M University
College Station, Texas 77843-2124

or call 409-845-5913.

MINNESOTA-WISCONSIN MILK PRICE DRIVES CHEESE PRICE: SOME EMPIRICAL EVIDENCE

AFPC Policy Research Report 96-2

Jayantha R. Perera
Joe L. Outlaw
Ronald D. Knutson

Agricultural and Food Policy Center
Department of Agricultural Economics
Texas Agricultural Experiment Station
Texas Agricultural Extension Service
Texas A&M University

August 1996

College Station, Texas 77843-2124
Telephone: (409) 845-5913
Web: AFPC1.TAMU.EDU

Minnesota-Wisconsin Milk Price Drives Cheese Price: Some Empirical Evidence

Jayantha R. Perera
Joe L. Outlaw
Ronald D. Knutson

Abstract

There is a strong belief in the dairy industry that the Minnesota-Wisconsin (M-W) milk price series has become an unreliable indicator and/or mover of classified milk prices under federal milk marketing orders. Some believe that the M-W milk price is driven primarily by the cheese price. This paper investigates the criticism of M-W milk price series using monthly time series data from January 1970 to March 1996.

An error correction model was formulated to capture short run and long run relationships. The estimated model revealed the existence of a cointegration vector. In the short run, both the cheese and nonfat dry milk prices indicated positive and significant impacts on the M-W milk price. The cointegration vector revealed the M-W milk price drives the cheese price in the long run.

Jayantha R. Perera is a research associate. Joe L. Outlaw is an assistant professor and Ronald D. Knutson is a professor. All are, respectively, at the Agricultural and Food Policy Center, Department of Agricultural Economics at Texas A&M University, College Station, Texas.

Introduction

The Minnesota-Wisconsin Manufacturing Milk Price Series (M-W price) is directly tied to the minimum prices of all Federal Milk Marketing Orders (FMMOs). The M-W price is described by the United States Department of Agriculture (USDA) as follows: "The M-W price estimate is the average price for all milk manufacturing grade delivered in bulk tanks and in cans f.o.b plant or receiving station, before hauling costs and producer assessments under the various dairy collection (assessment) programs and national Advertising and Promotion Programs are deducted. It includes bulk-tank, quantity, component, or other premiums paid to producers, but excludes hauling subsidies. The estimates relate only to manufacturing (Grade B) milk purchased from farmers and do not include Grade A milk diverted to manufacturing uses." Each month, the Wisconsin Agricultural Statistics Service surveys 49 plants in Wisconsin and the Minnesota Agricultural Statistics Service surveys 21 plants in Minnesota. Their state price estimates are independently forwarded to the National Agricultural Statistics Service (NASS), which determines the announced M-W price (Agricultural Statistics Board, USDA).

The M-W price series has been used to set minimum producer prices under FMMOs since 1961. The M-W price of the current month establishes the minimum class III price, milk used for hard manufacturing products. The minimum class II price, milk used for soft manufacturing products, is the current month M-W price plus a differential that is constant across all orders. In all orders the price for Class I, the milk used in fluid form, is the M-W price lagged two months plus a differential that varies across orders.

The M-W price is believed to be the best measure of manufacturing milk values (USDA, 1973; GAO, 1989). Industry confidence in the price series has generally existed. But recently, industry members and analysts are saying that the time has come to replace the M-W as the way to establish milk prices. The ever declining (over the last two decades) amount of grade B or manufactured grade milk in Wisconsin and Minnesota and the extremely wide swings of the M-W price in 1988 and 1989 are considered as major reasons for the need to replace it. Some of the other reasons are; 1) the M-W price reflects regional conditions, 2) the M-W price overstates the price actually paid because of butterfat testing practices at dairy plants, 3) the M-W price understates the price actually paid by plants because it does not include patronage refunds or hauling subsidies.

The National Agricultural Statistics Service reported the M-W price on the fifth day of each month until April 1995. However, NASS discontinued reporting the M-W price series in April 1995 and adopted Basic Formula Price (BFP) in May 1995. The BFP price is calculated by using a "base month" competitive pay price for Grade B milk in Minnesota and Wisconsin adjusted by the most recent month-to-month changes in market prices for butter, powder and cheese. The "base month" milk price is a part of the two-step process used to determine the M-W price. In it's decision, USDA recognizes that the adoption of new base month M-W, or any Grade B milk series, is only a short term solution since the amount of Grade B milk is expected to continue to decline. Therefore, it is imperative that the dairy industry develop and evaluate alternatives to the M-W price.

Many economists have described alternatives to the M-W price. Among the various alternatives the most likely options, discussed by Knutson and Jesse are: 1) a regulated grade A manufacturing price; and 2) a product formula price.

Even though, the M-W price was replaced by the basic formula price (BFP) in May 1995 this study provides a closer look at the M-W price by determining the short-run and long-run impacts of cheese, butter, and nonfat dry milk prices along with stocks to use ratios of butter, cheese and nonfat dry milk on the M-W price. Additionally, this study investigate the criticism of the M-W price series in a rigorous time series analytical framework.

Much of the literature dealing with M-W price has used regression-based methods on historical time series data. This study uses recent innovations in the analysis of economic time series in an attempt to give additional insights into the dynamics of the M-W price and its relationship with product prices and stocks to use ratios of dairy products. In particular, cointegration analysis allows researchers to study dynamic properties of multiple series and partition influences into short run and long run effects. This type of model appears, at first glance, to offer interesting possibilities to study the M-W price criticism.

The paper is presented in four sections. First we review past studies on the M-W price. Second, we describe the data used in our study and offer results of transformations to induce stationarity. Third, we consider cointegration properties presented in the data. Error correction models are built to capture cointegration relationships. Finally, a discussion of the results is offered.

Past Studies

Most of the literature addressing the use of product formulas in the pricing of milk and the adoption of the M-W price as the link between the federal order system and the manufacturing milk market was written prior to 1960. More recent literature addresses the reliability of the M-W price series and develops and analyses alternative pricing procedures for milk.

Harris and Hedges state that in the early years of the federal milk order program (1937-

1945) the objective of manufacturing milk pricing policy was to price reserve supplies at a level which would provide an outlet for all milk not needed for fluid use. In 1948, 23 order markets based prices of milk used in manufacturing classes, at least in part, on the formula price paid by specified manufacturing plants, either the Midwestern condensery price series or local plant averages. A butter-nonfat dry milk product formula was used in 24 markets, and a butter-cheese formula was in used in 12 markets. Other formulas were based on cheese alone, cream-nonfat dry milk, and butter-casein.

In the late 1950s, a disenchantment with the product price formula emerged. This was due to the tendency for product price formulas to remain in effect for long periods of time without a change in the make allowance. New technology and other factors affecting plant operating costs brought about significant changes in costs, and the make allowance became obsolete (USDA 1962).

In 1961 the Secretary of Agriculture appointed a committee to address the problem connected with the pricing of fluid milk under the federal milk marketing order in light of technology and commercial developments. The committee reported that in general, technological and commercial developments would lead to an expansion of the milk supply at least as fast and probably faster than any foreseeable expansion in demand. Therefore the committee concluded that the problem of price-depressing surpluses would not go away but must be dealt with sooner or later in a decisive manner (USDA, 1962).

Historically, changes in the price for grade B milk (M-W series) have been used as the most convenient indicator available of changes in the overall supply and demand conditions in the dairy economy. However, as early as 1972, it was recognized that the reservoir of grade B milk available to processors was disappearing as milk producers went out of business or shifted to production of grade A milk. Therefore it was predicted in 1973 that the open-market indicator of the overall supply and demand situation for raw milk would disappear in the next decade (USDA, 1973).

In 1973 Graf wrote: "The M-W Series has done a good job in the past. Nevertheless, it's inevitable that its days are numbered. In the not-too-distance future, enough manufacturing grade milk will have converted to Grade A, so the M-W price will no longer will be a good measure of a competitive pay price, and hence, not a good "mover" for Federal order Class I and II prices." He suggested that an alternative pricing system should be developed and it must be responsive to changed conditions of supply relative to demand can signa adjustments in marketing and prices.

A study by Jacobson et al., in 1978 stated that if competitive pay prices are not available, product price formulas represent an effective alternative for pricing reserve milk. The U.S. General Accounting Office (GAO) was requested by Senators Leahy, Boschwitz and Kasten to: 1) determine whether the M-W price series is a reliable and appropriate adjuster of milk prices, 2) determine whether the M-W price series needs to be improved, and 3) develop recommendations for improving the pricing system for milk used in manufacturing, if warranted.

Cropp and Jesse in 1987 studied M-W milk price series and suggested that subsidization of hauling by plants, inaccurate reporting of various premiums paid, lack of accounting for patronage refunds and any errors in reporting weights and tests may cause less precise M-W price. Additionally, they suggested four alternatives to the M-W price: 1) changing the M-W price to correct for deficiencies; 2) Replace with some type of product formula; 3) Federal order hearing; or 4) Use some other competitive pay price series (Cropp and Jesse, 1987).

The GAO evaluation of the M-W system determined that the current M-W series has gradually become a less reliable indicator of national supply and demand conditions. The GAO highlighted several reasons for less reliability of M-W milk price: 1) the M-W milk price series is affected by local conditions in Minnesota and Wisconsin; 2) there is a significant decline in Grade B milk production and corresponding decline in Grade B milk purchasing plants in Minnesota and Wisconsin; 3) The hauling subsidy paid by the plants in Minnesota and Wisconsin is not included in the M-W price; 4) the M-W price is not adjusted for extra protein or solids-non-fat value. They concluded that M-W milk price does not provide a valid mechanism for setting prices over the long term. Furthermore, the analysis concluded that the regulated grade A price and the product formula price would best incorporate most of the characteristics necessary for a pricing mechanism to generate a representative milk price within the regulatory system; however, no preference between the two alternatives was indicated (Cropp and Jesse, 1990a).

Novakovic in 1990 suggested competitive grade A milk pay price to replace M-W milk price. As with the M-W price, plants would be asked to itemize all payments made for Grade A milk, including any deductions and/or premiums from a basic price quote. The argument in favor of this approach is that it establishes a price based on competition for farm milk and the criticism stems from doubts that plants associated with a federal order would actually provide a competitive price. Jesse in 1990(b) also suggested that regulated Grade A manufacturing milk price will be a better alternative than product price formula to replace the M-W price series. However, Knutson (1990) indicated the political infeasibility of regulated Grade A manufacturing milk price to replace the M-W price series. He argued that the de-pooling of Grade A manufacturing milk price from the federal order to reflect competitive pay price would create lower price for Grade A manufacturing milk because it was de-pooled.

The Agricultural Marketing Service of USDA conducted comprehensive study on alternatives to the M-W price series. They developed and tested: 1) Grade A/B manufacturing price; 2) Ag. Prices M-W price; and 3) several dairy product price formulas. The milk values developed by these alternatives were compared with the current M-W price.

Chite in 1992 suggested agricultural prices M-W price, Grade A/B manufacturing price, Product price formula, cost of production and support price as alternatives to the M-W price. The agriculture price M-W price calculated using "competitive pay price" for Grade B milk and the main drawback to this system would be that price estimate require one month lag, since processors pay producers in the middle of the month for the previous month's purchase. Some are concern of the use of Grade A/B manufacturing prices as a alternative to replace M-W price series, because Grade A milk price is regulated by Federal orders and would not reflect true competitive price for milk. Some suggest that the use of product price formula when used as an updating mechanism rather than on its own, tends to do a better of averaging out these wide monthly swings. Opponents to the cost of production measure as a replacement to the M-W price indicated that it only reflect supply side of the equation in establishing minimum farm milk prices. Some suggested that the last alternative suggested by Chite (support price) would result in a significant reduction in farm milk prices.

Debate over the merits of the two prominent alternatives (product formula pricing and competitive Grade A milk price) has been provided by Knutson and Jesse. Jesse's position was that the regulated Grade A price represents what plants in region where manufacturing is important must pay to obtain milk. Jesse *et al.* contended that a product formula would disadvantage cheese plants in regions where manufacturing is important because cheese plants would frequently pay more than the minimum formula plants. Knutson's position was that the regulated grade A price would probably not be any more competitive than the current M-W price because that price would be influenced by the two major federal orders in the Minnesota-Wisconsin region. In addition, he contended that changes in the Minnesota-Wisconsin dairy industry were making prices in the region more reflective of local competitive conditions. Alternatively, Knutson asserted that a product formula holds potential for leading competitive pay prices in reflecting national forces of supply and demand.

The data

Monthly data (January 1970 through March 1996) on M-W Price (MWP), Butter Price (BUP), Cheese Price(CHP), Non-fat Dry Milk Price (NDMP), total stocks/ use ratio of butter(BUS), total stocks/use ratio of cheese(CHS), and total stocks/use ratio of nonfat dry milk(NDMS) were obtained from the Economic Research Service, USDA.

The reasons for studying these variables stem from the factors considered in developing the M-W milk price and also from the findings reviewed in the previous section. First, Jacobson *et al.*, suggested that alternative pricing methods to the M-W price should be investigated, given that the open market indicator of the overall supply and demand situation for raw milk will disappear in the future. Later GAO further supported this by claiming that their evaluation of the M-W price system shows gradual decrease in reliability and does not provide a valid mechanism for setting price over the long run. The recent developments in the time series analysis provide us an exciting opportunity to analyze short-run as well as long-run equilibrium (cointegrating) relationships between the M-W price and other dairy product prices. First, we will develop the model and the hypothesis tests that characterize the cointegrating relationship. Then, we will explore the short-run and long-run relationships.

Stationarity

The search for nonstationarity relies both on graphical plots and Dickey-Fuller (DF), Augmented Dickey-Fuller (ADF) and Phillips-Perron tests. The observations on levels, first differences of levels, log of level and first differences of log levels are plotted. The plots of levels, first differences of levels, log levels and first differences of log levels are presented in Figures 1 to 4. DF test statistics -1.9328, -0.8085, -2.3242, and -2.2034 for MWP, BUP, CHP and CHS respectively, offer no evidence to reject a null hypothesis of nonstationarity in levels. ADF tests statistics also failed to reject the null hypothesis of nonstationary in levels for MWP, BUP, CHP and CHS (Table 1). DF and ADF test statistics for NDMP, BUS and NDMS reject the null hypothesis of nonstationarity in levels.

The plots of levels (Figure 1 and 2) reveal strong evidence of mean nonstationarity for MWP, BUP, CHP and CHS series and indicated mean stationarity in NDMP, BUS and NDMS. The first differences of levels and log levels appear to be stationary in the plots for all (nonstationary variables in levels) variables, these results were consistent with the DF, ADF and Phillips-Perron test statistics. In this paper we used first differences of log levels as we are more interested in percentage changes and also the magnitude of the variances are smaller in first differences of log levels. The estimated autocorrelation and partial autocorrelation of levels are given in Table 2. The autocorrelations gradually decline while partial autocorrelation show a sudden drop after one lag. This indicates that there is no evidence supporting any moving average behavior in the levels of these series. The first differencing brings the autocorrelated variables to be variables with white noise. Table 2 also provided information about autocorrelation and partial autocorrelation of first differences of all variables.

Cointegration

We do not expect the M-W price to move aimlessly away from manufactured milk prices and stocks to use ratios in the long-run. It may diverge in the short run but we expect it to converge to some neighborhood of milk products in the long run. Cointegration refers to common long-run trends that hold economic time series together. A common trend refers to the order of integration of time-indexed observations of a variable. The order of integration, refers to the stationary condition of the time series. A stochastic process Y(t) is said to be stationary (or covariance stationary, or weakly stationary) if neither the mean μ_t nor the autocovariance γ_{jt}, depends on t. Here t is the date of the observation and j is the length of time separating the observations.

That is:

$$E(Y_t) = \mu \qquad \text{for all t, and}$$

$$E((Y_t - \mu)(Y_{t-j} - \mu)) = \gamma_j \qquad \text{for all t and any j}$$

(Hamilton).

A stationary series is important, as it guarantees that there are no fundamental changes in the structure of the process that would render prediction difficult or impossible (Judge, Hill, Griffiths, Lutkepohl, and Lee). The concept of cointegration is fundamental to the understanding of long run relationships among economic time series. The cointegration vectors can be interpreted as a partial adjustment of one variable on another (or group of others).

Our analysis follows the methods of Johansen (1988) and Johansen and Juselius (1990).

The procedure is based on error-correction representation. Consider $X_{(t)}$ a (px1) vector of series under investigation.

$$\Delta X_{(t)} = \mu + \tau_{(1)}\Delta X_{(t-1)} + \ldots + \tau_{(k-1)}\Delta X_{(t-k+1)} + \pi X_{(t-k)} + \epsilon_{(t)} \text{ ---------- } (1)$$

Where

$$\tau_{(I)} = -[I - \pi_{(1)} - \ldots - \pi_{(I)}] \qquad \text{for } I = 1, \ldots, k-1;$$

and

$$\pi = -[I - \pi_{(1)} - \ldots - \pi_{(k)}].$$

Here the $\pi_{(I)}$ are (pxp) matrices of autoregressive parameters from a VAR in level of $X_{(t)}$ of lags order k (Δ is the difference operator, $\Delta X_t = X_t - X_{t-1}$), μ is a constant, $\epsilon_{(t)}$ is a white noise innovation term. Label the model given by equation (1) H_1. Equation 1 resembles a vector autoregression (VAR) model in first differences, except for the presence of the lagged level of $X_{(t-k)}$. Π, the error correction term, will contain information about long-run (cointegrating) relationships among the variables in X. There are three possible cases: (1) Rank(π) = p, i.e. the matrix π has full rank, indicating that the vector process X_t is stationary and a VAR in levels is an appropriate model; (b) Rank(π) = 0, i.e. the matrix π is the null matrix and (1) corresponds to a traditional difference vector time series model; (3) $0 < \text{Rank}(\pi) = r < p$ implying that there are p x r matrices α and β such that $\pi = \alpha\beta'$. In the latter case, $\beta' X_{(t)}$ is stationary, even through $X_{(t)}$ is not. The hypothesis that there are at most r cointegrating vectors is labeled $H_2(r)$; that is π is of reduced rank $r < p$(see Johansen and Juselius for details).

The treatment of the constant μ is interesting, as under (3) the constant term can be decomposed into two parts, that in the intercept of the cointegration relation ($\beta' X_{(t)}$) and that representing a linear trend (see Johansen). These alternatives lead to sequential hypothesis testing with respect to the rank (r) of (π). If there is a linear trend in the model, label this hypothesis

$H_2(r)$ which is not restricted. If there is no linear trend in the model, label the hypothesis $H_2(r)^*$ which is restricted. Johansen (1993) provides the rational for sequential hypothesis testing to decide jointly for the rank of cointegrating vector (r) and whether there is linear trend in the model. He suggests testing the hypothesis in the following sequence: $H_2(0)^*$, $H_2(0)$, $H_2(1)^*$, $H_2(1)$, ... Stop testing the first time we do not reject.

These tests are carried out using the ordered eigenvalues λ_i or λ_i^*, I=1,...,p (use an asterisk to indicate that the eigenvalues have been calculated without linear trend in the model). The trace test considers the hypothesis that the rank of π is less than or equal to r. Under the linear time trend hypothesis (no restriction) the trace test is given by:

$$-2 \ln(Q; H_2 \mid H_1) \quad = T\Sigma^{p}_{i=r+1} \ln(1-\lambda_i)$$

A similar test statistic is defined under the no time trend hypothesis (restriction) by replacing λ_i by λ_i^*. Johansen and Juselius (1990) provide the asymptotic critical values (Appendix table A1 for linear time trend and A3 without a time trend).

Table 3 gives the trace test for both restricted and unrestricted models. For these models we used the lag order k+1=2 for the first differences of log level models. At the 5 percent level we reject r = 0 under the * hypothesis as well as no * hypothesis and we fail to reject $r \leq 1$ under the no * hypothesis. The evidence does support the presence of no linear trend in the model.

Error Correction Specification

The following error correction representation (ECM) on first differences of log levels of MWP, BUP, CHP, CHS and levels of NDMP, BUS and NDMS was estimated using CATS in RATS software (see Juselius 1991). Constants were not included in the unrestricted models as suggested by the trace test (Table 3) in the difference of log level representation (using a constant is to include a time trend). Autocorrelation and partial autocorrelation on each series suggested very short lags on the differences of these series (Table 2). We selected a lag of two on the first differences of log levels. We also introduced 12 seasonal binary variables to model the seasonal variations in the data.

The general form of ECM estimated is:

$$\begin{vmatrix} \Delta \ln MWP_{(t)} \\ \Delta \ln BUP_{(t)} \\ \Delta \ln CHP_{(t)} \\ \Delta \ln NDMP_{(t)} \\ \Delta \ln BUS_{(t)} \\ \Delta \ln CHS_{(t)} \\ \Delta \ln NDMS_{(t)} \end{vmatrix} = |\tau| \begin{vmatrix} \Delta \ln MWP_{(t-1)} \\ \Delta \ln BUP_{(t-1)} \\ \Delta \ln CHP_{(t-1)} \\ \Delta \ln NDMP_{(t-1)} \\ \Delta \ln BUS_{(t-1)} \\ \Delta \ln CHS_{(t-1)} \\ \Delta \ln NDMS_{(t-1)} \end{vmatrix} + |\psi| \begin{vmatrix} D1 \\ D2 \\ .. \\ .. \\ .. \\ .. \\ D11 \end{vmatrix} + |\pi| \begin{vmatrix} \ln MWP_{(t-1)} \\ \ln BUP_{(t-1)} \\ \ln CHP_{(t-1)} \\ \ln NDMP_{(t-1)} \\ \ln BUS_{(t-1)} \\ \ln CHS_{(t-1)} \\ \ln NDMS_{(t-1)} \end{vmatrix}$$

Estimated ECM for January 1970 to March 1996

$$
\begin{vmatrix}
\Delta \ln MWP_{(t)} \\ \\
\Delta \ln BUP_{(t)} \\ \\
\Delta \ln CHP_{(t)} \\ \\
\Delta \ln NDMP_{(t)} \\ \\
\Delta \ln BUS_{(t)} \\ \\
\Delta \ln CHS_{(t)} \\ \\
\Delta \ln NDMS_{(t)} \\ \\
\end{vmatrix}
=
\begin{vmatrix}
0.122 & 0.043 & 0.201 & 0.193 & -0.010 & -0.020 & 0.001 \\
(1.14) & (1.24) & (2.26)^{*} & (5.59)^{*} & (1.68) & (1.19) & (0.17) \\
0.004 & 0.079 & 0.033 & -0.078 & -0.001 & -0.028 & -0.008 \\
(0.02) & (1.34) & (0.21) & (1.31) & (0.06) & (0.99) & (1.15) \\
0.084 & 0.088 & 0.298 & 0.205 & -0.009 & -0.033 & -0.004 \\
(0.62) & (2.02)^{*} & (2.61)^{*} & (4.69)^{*} & (1.17) & (1.59) & (0.81) \\
-0.482 & 0.080 & 0.409 & 0.530 & -0.006 & -0.044 & -0.007 \\
(1.03) & (0.56) & (0.68) & (0.84) & (2.60)^{*} & (0.55) & (0.65) \\
-1.050 & 0.183 & 0.584 & -0.279 & -0.151 & 0.086 & -0.025 \\
(1.03) & (0.56) & (0.68) & (0.85) & (2.60)^{*} & (0.54) & (0.65) \\
0.603 & 0.104 & -0.736 & -0.009 & 0.011 & -0.207 & 0.014 \\
(1.61) & (0.86) & (2.32)^{*} & (0.07) & (0.51) & (3.58)^{*} & (1.02) \\
1.448 & 0.083 & -2.893 & -0.061 & -0.059 & -0.165 & -0.308 \\
(0.98) & (0.18) & (2.34)^{*} & (0.13) & (0.71) & (0.73) & (5.56)^{*}
\end{vmatrix}
\begin{vmatrix}
\Delta \ln MWP_{(t-1)} \\ \\
\Delta \ln BUP_{(t-1)} \\ \\
\Delta \ln CHP_{(t-1)} \\ \\
\Delta \ln NDMP_{(t-1)} \\ \\
\Delta \ln BUS_{(t-1)} \\ \\
\Delta \ln CHS_{(t-1)} \\ \\
\Delta \ln NDMS_{(t-1)} \\ \\
\end{vmatrix}
$$

$$
+
\begin{vmatrix}
-0.019 & -0.001 & 0.005 & 0.010 & 0.008 & 0.000 & -0.003 & -0.013 & -0.008 & -0.009 & 0.013 \\
(2.79)^{*} & (0.13) & (0.74) & (1.57) & (1.24) & (0.06) & (0.45) & (1.90) & (1.13) & (1.37) & (1.96)^{*} \\
-0.022 & 0.001 & 0.008 & 0.017 & -0.011 & -0.012 & -0.011 & -0.041 & -0.038 & -0.020 & -0.002 \\
(1.88) & (0.07) & (0.75) & (1.53) & (0.99) & (0.99) & (0.91) & (3.43)^{*} & (3.28)^{*} & (1.79) & (0.16) \\
-0.029 & -0.005 & 0.004 & 0.012 & 0.003 & -0.010 & -0.016 & -0.028 & -0.018 & -0.020 & 0.009 \\
(3.36)^{*} & (0.57) & (0.52) & (1.41) & (0.38) & (1.14) & (1.87) & (3.23)^{*} & (2.12)^{*} & (2.39)^{*} & (1.12) \\
-0.022 & -0.013 & -0.009 & -0.010 & -0.020 & 0.001 & -0.019 & -0.024 & -0.027 & -0.014 & -0.003 \\
((1.94)^{*} & (1.20) & (0.86) & (0.91) & (1.84) & (0.06) & (1.67) & (2.13)^{*} & (2.48)^{*} & (1.32) & (0.29) \\
0.353 & 0.371 & 0.143 & 0.068 & -0.038 & -0.015 & -0.018 & -0.039 & 0.156 & 0.487 & 0.353 \\
(5.44)^{*} & (6.09)^{*} & (2.37)^{*} & (1.11) & (0.60) & (0.23) & (0.27) & (0.59) & (2.42)^{*} & (7.83)^{*} & (5.64)^{*} \\
0.172 & 0.113 & 0.142 & 0.096 & 0.013 & 0.012 & -0.011 & 0.080 & 0.058 & 0.173 & 0.140 \\
(7.19)^{*} & (5.04)^{*} & (6.39)^{*} & (4.23)^{*} & (0.54) & (0.49) & (0.44) & (3.32)^{*} & (2.45)^{*} & (7.58)^{*} & (6.07)^{*} \\
0.325 & 0.184 & 0.053 & -0.113 & -0.064 & -0.114 & 0.060 & 0.099 & 0.081 & -0.144 & 0.183 \\
(3.47)^{*} & (2.09)^{*} & (0.61) & (1.27) & (0.69) & (1.19) & (0.64) & (1.05) & (0.87) & (1.60) & (2.03)^{*}
\end{vmatrix}
\begin{vmatrix}
D1 \\ D2 \\ D3 \\ D4 \\ D5 \\ D6 \\ D7 \\ D8 \\ D9 \\ D10 \\ D11
\end{vmatrix}
$$

$$+\begin{vmatrix} -0.219 & 0.076 & 0.070 & 0.162 & -0.003 & 0.004 & -0.049 & -1.368 \\ (0.19) & (4.38)^{*} & (1.41) & (4.17)^{*} & (1.17) & (4.23)^{*} & (4.44)^{*} & (0.27) \\ -0.032 & -0.081 & -0.004 & -0.088 & -0.038 & 0.009 & 0.083 & 0.769 \\ (0.67) & (1.08) & (0.28) & (1.14) & (0.87) & (0.73) & (0.91) & (0.57) \\ 0.225 & 0.086 & -0.410 & 0.192 & -0.017 & 0.008 & -0.058 & -0.297 \\ (3.92)^{*} & (4.39)^{*} & (5.61)^{*} & (3.44)^{*} & (2.63)^{*} & (6.31)^{*} & (5.67)^{*} & (4.47)^{*} \\ -0.001 & 0.000 & 0.001 & 0.001 & 0.000 & 0.000 & -0.001 & -0.007 \\ (1.39) & (4.42)^{*} & (0.22) & (4.42)^{*} & (2.28)^{*} & (3.68)^{*} & (4.13)^{*} & (0.94) \\ -0.026 & 0.002 & 0.019 & 0.049 & -0.031 & 0.006 & 0.000 & -0.312 \\ (1.58) & (0.14) & (1.66) & (0.15) & (0.14) & (0.93) & (0.61) & (1.63) \\ -0.214 & -0.045 & 0.456 & -0.253 & 0.079 & -0.051 & 0.028 & 0.240 \\ (1.18) & (1.57) & (1.78) & (1.27) & (0.74) & (2.15)^{*} & (1.97)^{*} & (1.38) \\ -0.008 & 0.008 & -0.001 & 0.035 & -0.007 & 0.006 & -0.011 & -0.220 \\ (2.77)^{*} & (0.81) & (2.52) & (1.26) & (2.74)^{*} & (0.59) & (0.01) & (5.56)^{*} \end{vmatrix} \begin{vmatrix} \ln MWP_{(t-1)} \\ \\ \ln BUP_{(t-1)} \\ \\ \ln CHP_{(t-1)} \\ \\ \ln NDMP_{(t-1)} \\ \\ \ln BUS_{(t-1)} \\ \\ \ln CHS_{(t-1)} \\ \\ \ln NDMS_{(t-1)} \\ \\ \end{vmatrix}$$

*** = significant at 5% level of significance Δ = first difference**

All variable in the short run matrix are in first differences. In the short run (first matrix of equation (3)) lagged cheese price and nonfat dry milk price indicated a significant and positive relationship with the M-W milk price. The butter price showed no significant impact from any of the variables in the short-run. The lagged butter, cheese and nonfat dry milk prices exhibited significant positive impact on cheese price. Increase in the lagged butter stock/use ratio showed decreasing impact on the nonfat dry milk price. The lagged butter stock/use ratio is significantly effected by the of butter stock/use ratio. Additionally, cheese stock/use ratio negatively influenced by the lagged cheese price and cheese stock/use ratio. Furthermore, the lagged nonfat dry milk price and stock/use ratio indicated negative relationship with the nonfat dry milk price. The estimated R^2 values for each equation are given in Table 4.

The second matrix of the equation (3) revealed the behavior of seasonal binary variables and considered December as the base period. It showed that January and November M-W prices are significantly higher, August and September butter prices are higher and January, August, September and October cheese prices are higher than that of December. January, August and September nonfat dry milk prices are higher than that of December. Furthermore, it also revealed that January, February, March, September, October and November butter stock are higher than December. January, February, March, April, August, September, October and November cheese stock/use ratio are larger than December. Additionally, January, February and November nonfat dry milk stock/use ratio is significantly higher than December nonfat dry milk stock/use ratio.

The third matrix in the equation (3) contains the long-run information. The interpretation of long run relationship is not as straight as that of short run. The third matrix is further partitioned into matrices and investigated for true long run cointegration relationships. Additionally, the coefficients of the variable which were introduced in levels to the error correction representation are restricted to be equal to zero. This investigation followed Johanson and Juselius procedures (Described in details in Johanson and Juselius (1990)) and discussed in the fourth section.

Analysis of Long-run Components

The error correction formulation given in equation 3 has MWP, BUP, CHP and CHS in first differences while NDMP, BUS and NDMS are in levels. The variables in the third matrix of Equation (3) do not represent the actual long-run equilibrium relationship because of the levels of the NDMP, BUS and NDMS variables. The long-run analysis is conducted restricting NDMP, BUS and NDMS variables to be zero. First, a reduced rank of the π matrix (matrix 3 of the equation 2 or 3) is calculated. The analysis indicated that there is one cointegration vector in the model. As suggested by the tests offered in table 3, matrix π is of reduced rank $\alpha\beta'$, which is presented as:

$$\alpha\beta' = \left|\begin{array}{c} 0.038 \\ 0.001 \\ 0.473 \\ -0.001 \\ -0.028 \\ -0.750 \\ 0.000 \end{array}\right| \left|\begin{array}{cccccccc} 1.000 & 0.009 & -1.080 & 0.000 & 0.000 & 0.006 & 0.000 & 2.772 \end{array}\right|$$

Two hypothesis are of interest with respect to α and β. First do any of the elements in the cointegrating vectors (β_{ij}) equal to zero?, for I =1,...8. This is accomplished by testing the hypothesis:

$$\mathbf{H_3 : \ \beta = H\varphi,}$$

where H is a known design matrix of dimension (pxs) with rank s, and φ (sxr) is a matrix of unknown parameters. It is assumed that $r \leq s \leq p$. If s=p, then there are no restrictions no the cointegration vector, and if s=r, then the cointegration space is fully specified. To test the hypothesis $H_3 : \beta_{ij}=0$, Johansen (1988), and Johansen and Juselius (1990), demonstrated the appropriate likelihood ratio test is:

$$-2 \ln(Q;H_3 | H_2) = T\Sigma^{r}_{i=1}\ln[(1-\lambda_{3i})/(1-\lambda_i)].$$

The test statistic is asymptotically distributed as χ^2 with r(p-s) degrees of freedom. The appropriate decision rule is to reject the null H_3 if the likelihood ratio exceeds the critical chi-square value. Rejecting H_3: $\beta_{ij}=0$ for some I indicates that the ith series is not relevant in the long run equilibrium. The tests of the hypothesis H_3: $\beta=H\varphi$ is summarized in Table 5. Our analysis indicated MWP, CHP and constant term enters to the long run equilibrium relationship. It is interesting to note BUP and BUS does not enters to the long run relationship. The estimated long run equilibrium relationship can be noted as;

$$\ln MWP - 1.056 \ln CHP + 2.684 = Z(t) \text{-----}(4)$$

Z(t) is the stationary process over time.

A second case of interest is whether the any element of α_{ij} equal to zero? for I=1,..7.

$$H_3: \alpha = A\psi$$

are tested, where A is a (pxm) matrix. In this tests also we kept NDMP, BUS and NDMS equal to zero. A matrix of dimension (px(p-m)) is introduced. This matrix is expressed as B. B is designed to be orthogonal to A, i.e., $B'A=0$. The test of linear restriction on α can be expressed as $B'\alpha=0$. Interpretation of this result is that some of the rows of α are zero. Furthermore, if $\alpha_i=0$, this implies that the cointegration relation $\beta_j'X_t$ does not enter the ith equation. In essence, this is a test of weak exogeneity of X_{it} for the long run parameter β. Johansen (1988), and Johansen and Juselius (1990), demonstrated the appropriate likelihood test statistics of this hypothesis test is:

$$-2 \ln Q = T\Sigma^{r}_{i=1}[\ln[(1-\lambda_1^{*})/(1-\lambda_i)].$$

where λ_1^{*} are the eigenvectors of the restricted model, and λ_i are the eigenvectors from the unrestricted model. This test statistic is asymptotically distributed as χ^2 with r(p-m) degrees of freedom. Tests of the linear restrictions of α are also summarized in Table 5. The α's can be interpreted as the weight with which each variable enters the cointegration relation. For instance, a low coefficient indicates a slow adjustment and a high coefficient indicates rapid or quick adjustment. In other words, they can be interpreted as the average speed of adjustment towards the estimated steady state relationship or a test for weak exogeneity.

The analyses revealed that M-W milk price and butter price are weakly exogeneous in the model. In fact it tells us that any perturbation in the long run cointegration relationship does not affect M-W price and butter price (Table 5). This indicates, though cheese price is in the long run equilibrium relationship M-W milk price ignores it (α for M-W milk price fails to reject the null hypothesis). The M-W is in the long run relationship and cheese price does not ignore it (α for cheese price reject the null hypothesis). Taken together the weak exogeneity indicate that M-W milk price drives cheese price in the long run. Therefore, long run equilibrium relationship can be written as:

$\ln CHP = 2.541 + 0.947 \ln MWP$-----(5)

Discussion

Multiple cointegration is applied to a seven-variable system. Stationarity tests indicated MWP, BUP, CHP and CHS are stationary in first difference. NDMS, BUS and NDMS are stationery in levels. The variables are introduced to an error correction model according to their demonstrated stationarity properties. In other words, MWP, BUP, CHP and CHS were introduced in first differences and NDMP, BUS and NDMS were introduced in levels.

Analyses of the short run indicate significant positive impact from cheese and nonfat dry milk on MW milk prices and cheese price is influenced by lagged butter, cheese and nonfat dry milk prices (Table 6).

The third matrix in the (3) contains the long run cointegration information. The true cointegration relationship need variables to be integrated of degree one or higher. Therefore, the variables which are not integrated were removed from the long run analysis. The long run analysis was conducted using four variables (MWP, BUP, CHP and CHS) which are integrated of degree one and restricted other variables to be zero. The long run equilibrium relationship showed that there is one cointagration vector. The π matrix partitioned in to α and β matrices. Each elements of the α and β metrics were tested to find whether they are higher than zero. If an element of β vector does not significantly deviate from zero it does not come into long run equilibrium relationship. If an element of α vector does not significantly deviate from zero it means the variable corresponding to that element is weakly exogeneous to the model. In other words, perturbation in the long run equilibrium relationship does not effect that particular variable. The variation in that variable is explained by the factor outside model. The long run cointegration relationship was investigated keeping coefficients for NDMP, BUS and NDMS to be zero. When entire data set is considered one cointegration vector holds the model together.

The estimated cointegration vector (normalized with MWP) is given as:

$$\ln MWP + 0.015 \ln BUP - 1.067 \ln CHP - 0.005\ CHS + 2.667 = Z(t) \text{-----} (6)$$

where,
Z(t) is a stationary process over time.

This result has an interesting interpretation in terms of market information control. That is, this vector can be viewed as long-run relations or steady states. Understanding the pricing of one product, allows us to formulate expectations about prices in the other products. For instance, the fact that we have one cointegration vectors in a four variable model means that we need only to model four series to determine the whole set of information about the other series. Thus, the long run relationship can be understood as the canonical form which allows us to reduce the space we need to concern ourselves with (relation basis and market information control). Further investigation of this cointegration vector resulted in final long run equilibrium relationship (Equation (5)). It indicated that cheese price is a function of M-W milk price in the long run.

One step ahead forecast of the cheese price using this relationship is given in Figure 5. Results indicated M-W milk price forecast cheese price fairly well.

Conclusion

There are four major results of the this analysis. First, the lagged cheese and nonfat dry milk price indicated positive significant impact on M-W milk prices in the short run. The butter price does not effected by all the variables in the model. The cheese price indicated positive significant impact from lagged butter, cheese and nonfat dry milk prices. Non fat dry milk price showed negative significant influence from lagged M-W milk price and Positive significant influence from lagged cheese and butter prices.

Second, the existence of I(0) and I(1) variable provided considerable difficulty in finding the true cointegration relationship. The estimation of the variables and restricting I(0) coefficients to be zero provide novel idea to introduce I(0) and I(1) data in an error correction model. The model indicated that their is one cointegration vector which hold the model together (Equation (6)).

Third, closer examination of the cointegration vector revealed butter price and nonfat dry milk stock/use ratio does not come to the long run equilibrium relationship. In other words, the true cointegration relationship exists with M-W milk price and cheese price (functional relationship is given in Equation (5)).

Fourth, further testing on cointegration relationship revealed M-W milk price and butter price are weakly exogeneneous to the long run equilibrium relationship. It suggests that any perturbation in the equilibrium long run does not reflect in the M-W milk and butter prices. In other words M-W milk price drives cheese price in the long run.

Taken together, the four major findings and the short-run impacts imply that the Minnesota-Wisconsin price response to cheese and nonfat dry milk prices in the short run. The cheese price respond to M-W milk price in the long run. In light of these findings we conclude that cheese price is a function of M-W milk price and Figure 5 showed actual and forecasted relationship (using Equation (5)) of cheese price. Forecasted values of cheese prices followed actual cheese price fairly well.

Table 1: **Dickey-Fuller, Augmented Dickey-Fuller and Phillips-Perron Tests on Levels, and First Differences of Minnesota-Wisconsin Price(MWP), Butter Price(BUP), Cheese Price(CHP), Nonfat Dry Milk Price(NDMP), Butter stock/Use ratio(BUS), Cheese Stock/Use ratio, and Nonfat Dry Milk Stock/Use ratio(NDMS)**

Variables	Dickey-Fuller Test	Augmented Dickey-Fuller Test	Phillips-Perron Test	Phillips-Perron Test with covariance lags
$MWP_{(t)}$	-1.9328	-3.1579 (1)	-1.9423	-2.2922(1)
$BUP_{(t)}$	-0.8085	-0.9565 (1)	-0.8124	-0.9159 (1)
$CHP_{(t)}$	-2.3242	-3.3507 (1)	-2.3355	-2.6755 (1)
$NDMP_{(t)}$	-3.5181	-5.7072 (1)	-3.5353	-4.2900 (2)
$BUS_{(t)}$	-4.4766	-4.4766(0)	-4.4985	-4.4985 (0)
$CHS_{(t)}$	-2.2034	-2.2034 (0)	-2.2141	-2.2141 (0)
$NDMS_{(t)}$	-4.5934	-4.5934(0)	-4.6158	-4.6158 (0)
$\Delta MWP_{(t)}$	-10.2000	-11.6768(1)	-10.2499	-10.5942 (1)
$\Delta BUP_{(t)}$	-12.9998	-12.9163 (1)	-13.0634	-13.1769 (1)
$\Delta CHP_{(t)}$	-11.9163	-12.6212 (1)	-11.9746	-12.1748 (1)
$\Delta NDMP_{(t)}$	-10.8432	-13.4468 (1)	-10.8963	-11.2915 (1)
$\Delta BUS_{(t)}$	-21.2400	-21.2400 (0)	-21.3439	-21.9530 (3)
$\Delta CHS_{(t)}$	-19.1319	-19.1319 (0)	-19.2255	-20.4102 (11)
$\Delta NDMS_{(t)}$	-31.0951	-31.0951 (0)	-31.2472	-46.8067 (10)
$\Delta \ln MWP_{(t)}$	-10.2623	-10.9810 (1)	-10.3125	-10.5784 (1)
$\Delta \ln BUP_{(t)}$	-12.3875	-13.0577 (1)	-12.4481	-12.6199 (1)
$\Delta \ln CHP_{(t)}$	-12.0499	-12.5191 (1)	-12.1088	-12.2891 (1)
$\Delta \ln NDMP_{(t)}$	-10.6511	-12.7349 (1)	-10.7032	-11.0690 (1)
$\Delta \ln BUS_{(t)}$	-16.3315	-16.3315 (0)	-16.4113	-17.9168 (10)
$\Delta \ln CHS_{(t)}$	-20.0922	-20.0922 (0)	-20.1904	-22.0513 (11)
$\Delta \ln NDMS_{(t)}$	-23.9394	-23.9394 (0)	-24.0565	-25.9257 (10)

Δ^* first differences. The test is on the estimated coefficient β_1 from the following prototype regression:

$$\Delta X_{(t)} = \beta_0 + \gamma_1 t + \rho_1 X_{(t-1)} + \sum_{I=1}^{K^*} \lambda \Delta X_{(t-1)}$$

The entries in the column labeled Dickey-Fuller have all coefficients on lags of the dependent variable set equal to zero. The entries in the column labeled Augmented Dickey-Fuller have K^* lags on the dependent variable (Phillips-Perron tests set-up are also similar this). The value of K^* was found by applying an AIC search to consecutive regressions; the number in parenthesis indicates the minimum AIC lag for each regression.

Table 2: Autocorrelation (a) and Partial Autocorelation (p) on Levels of MWP, BUP, CHP, NDMP, BUS, CHS and NDMS

Lags	Levels of Variables													
	MWP		BUP		CHP		NDMP		BUS		CHS		NDMS	
	auto	par. auto	auto	par. auto	auto	par. auto	auto	par. auto	auto	par. auto	auto	par. auto	auto	par. auto
1	0.98	0.98	0.98	0.98	0.97	0.97	0.97	0.97	0.88	0.88	0.96	0.96	0.86	0.86
2	0.96	-0.23	0.97	0.02	0.95	-0.23	0.93	-0.26	0.81	0.13	0.94	0.06	0.87	0.47
3	0.93	0.03	0.96	0.05	0.92	0.08	0.89	0.13	0.76	0.13	0.91	0.04	0.82	0.05
4	0.91	0.09	0.95	-0.06	0.90	0.07	0.86	0.15	0.70	-0.03	0.89	0.03	0.82	0.18
5	0.90	0.07	0.94	-0.00	0.88	0.08	0.85	0.17	0.64	-0.04	0.88	0.16	0.80	0.11

Table 3: Trace Test on Alternative Cointegration Specifications, with and without Linear Trend.

Data from January 1970 to March 1996							
p-r	r	T^*	C^* (10%)	Decision	T	C (10%)	Decision
7	0	209.99	126.58	R	207.51	118.50	R
6	1	93.46	97.18	F	87.00	89.48	-
5	2	66.21	71.86	-	63.75	64.84	-
4	3	35.68	49.65	-	33.22	43.95	-
3	4	18.21	32.00	-	15.92	26.79	-
2	5	8.76	17.85	-	6.79	13.33	-
1	6	1.66	7.52	-	0.16	2.69	-

C^* : taken from table A.3 of Johansen and Juselius
C : Taken from table A.1 of Johansen and Juselius
T^* : trace test calculated under the hypothesis of no linear trend
T : trace test calculated under the hypothesis of a linear trend
p : the number of series
r : the number of cointegrating vectors
Dec : Hypothesis testing Decision

Table 4: R^2 Values for Each Equation

Variable	R^2 Values
MWP	0.327
BUP	0.203
CHP	0.303
NDMP	0.990
BUS	0.952
CHS	0.436
NDMS	0.863

Table 5. Test of Hypothesis H_3: $\beta = H\varphi$ and $H_4 : \alpha = A\psi$

	Hypothesis	Jun. 1970 to Mar. 1996		
Variable	$\beta_{1j} = 0$	Chi-square	Significance (p value)	Decision
MWP	$\beta_{1j} = 0$	76.74	0.00	R
BUP	$\beta_{2j} = 0$	2.03	0.00	F
CHP	$\beta_{3j} = 0$	76.72	0.00	R
CHS	$\beta_{6j} = 0$	0.75	0.39	F
Constant	$\beta_{8j} = 0$	76.76	0.00	R
MWP	$\alpha_{1j} = 0$	0.02	0.88	F
BUP	$\alpha_{2j} = 0$	0.01	0.94	F
CHP	$\alpha_{3j} = 0$	16.80	0.00	R
CHS	$\alpha_{6j} = 0$	3.84	0.05	R

R : Reject the null hypothesis (5% level of significance)
F : Fail to reject the null hypothesis

Figure 1: Levels of MWP. BUP, CHP, NDMP, BUS, CHS, and NDMS

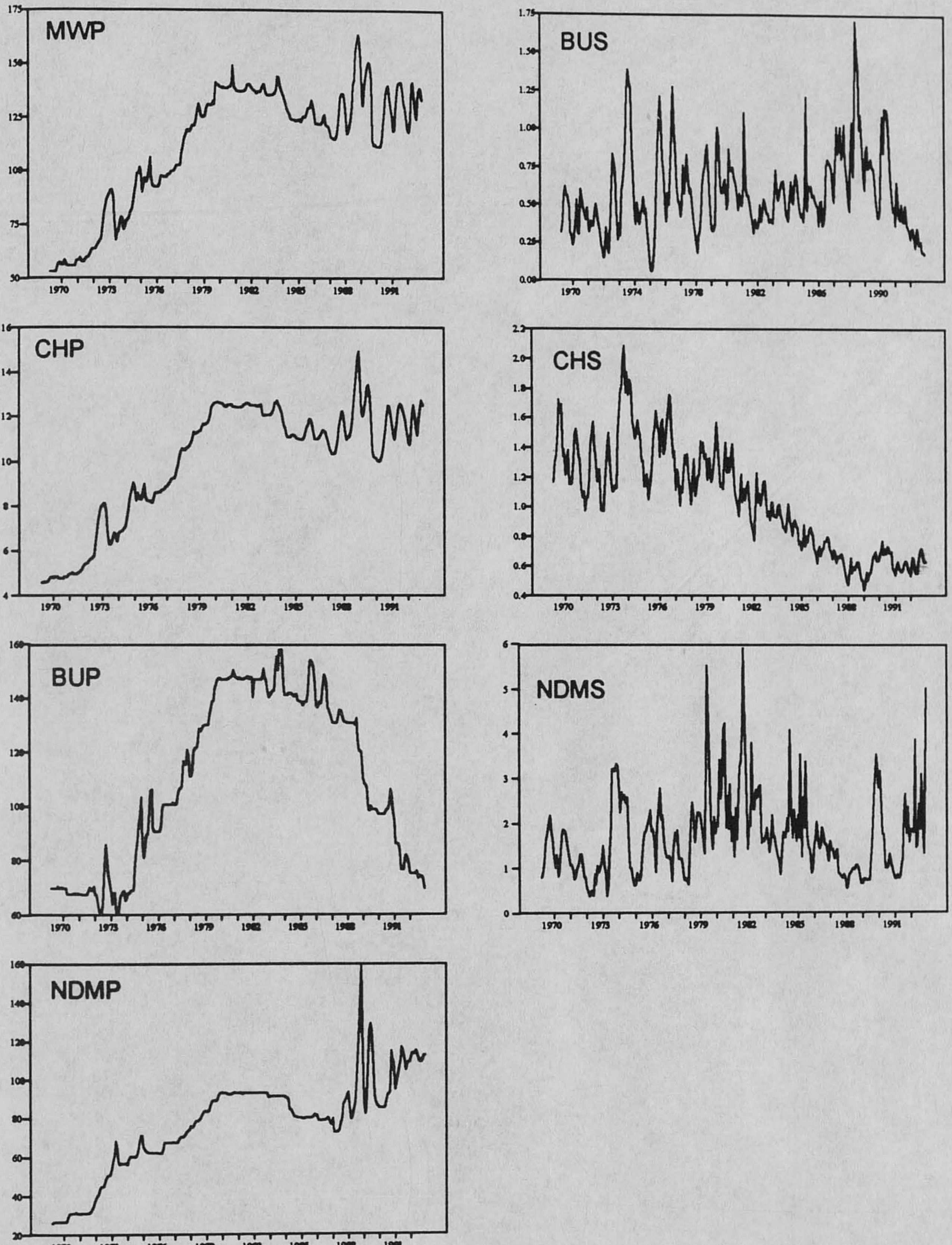


Figure 2: First Differences of MWP, BUP, CHP, BUS, CHS, and NDMS

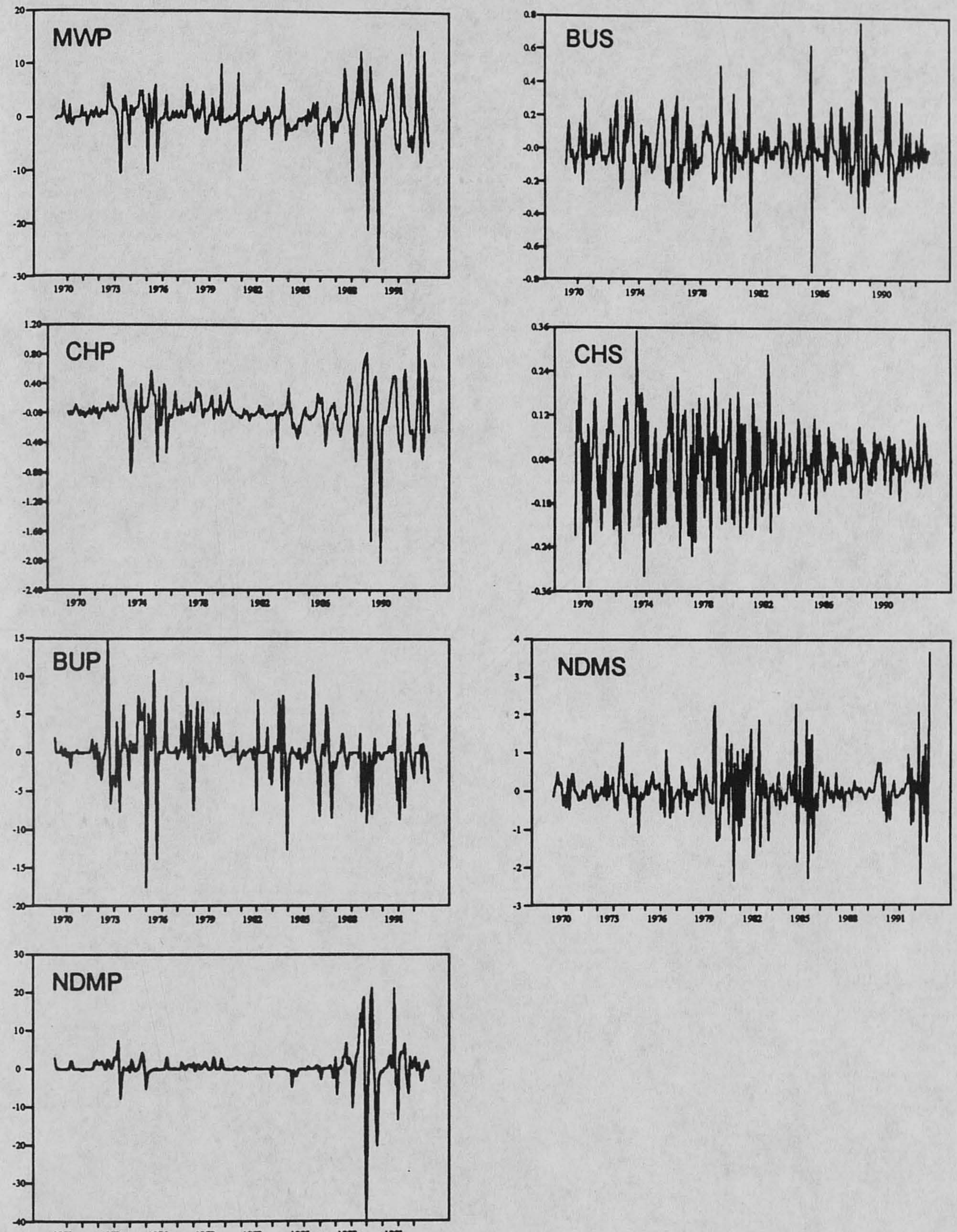


Figure 3: Log Levels of MWP, BUP, CHP, NDMP, BUS, CHS, and NDMS

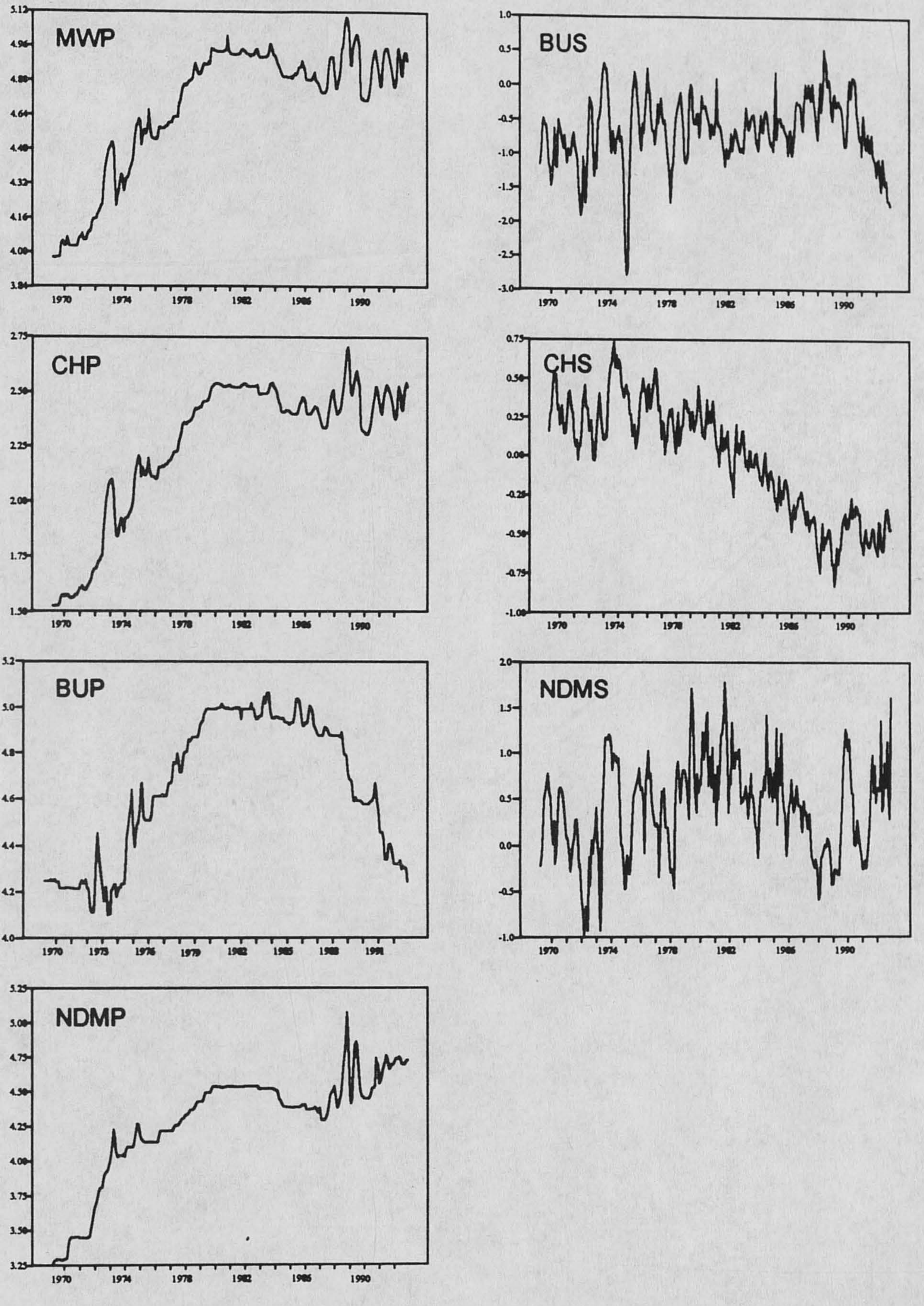


Figure 4: First Differences of Log Levels of MWP, BUP, CHP, NDMP, BUS, CHS, and NDMS

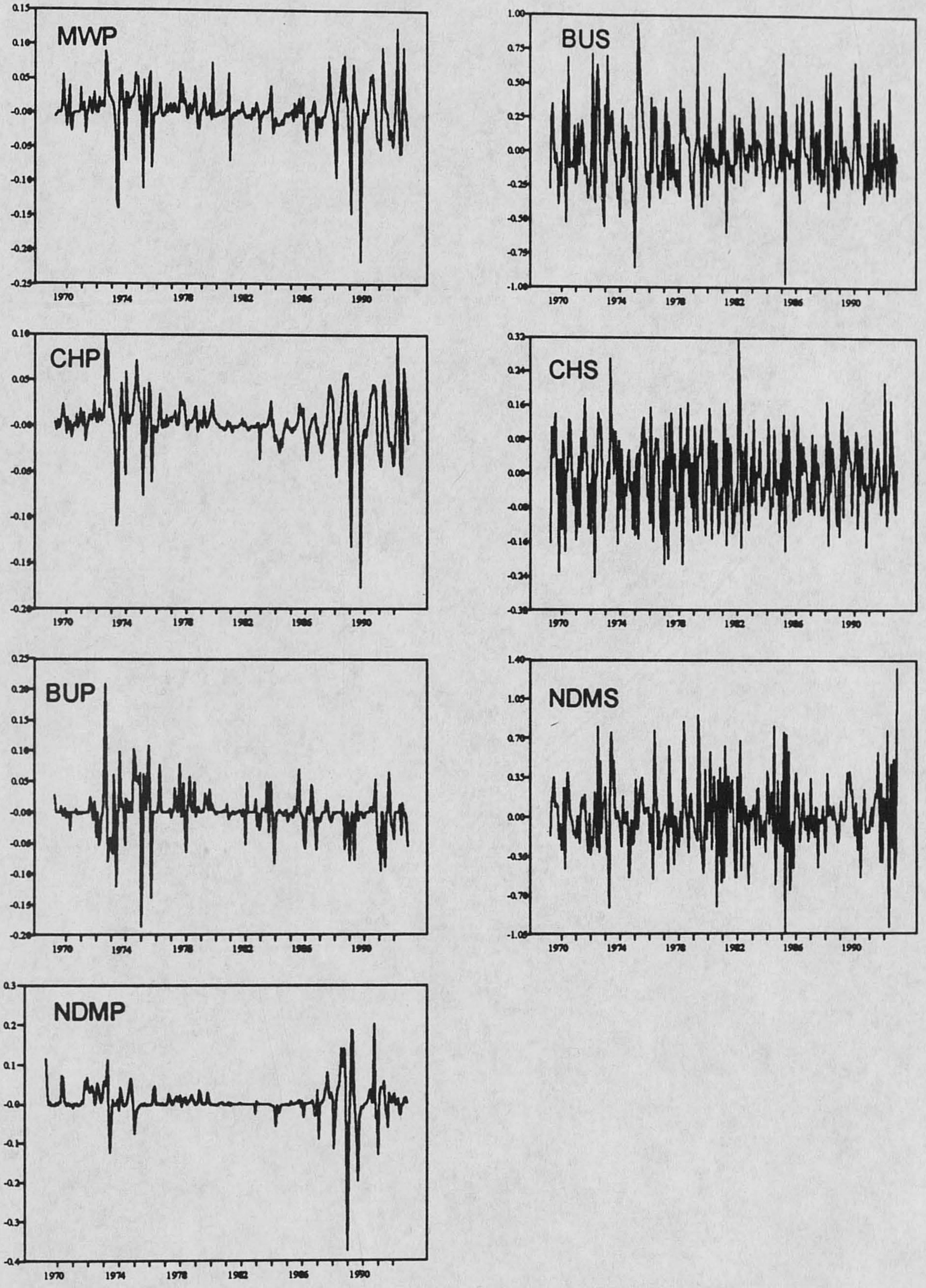
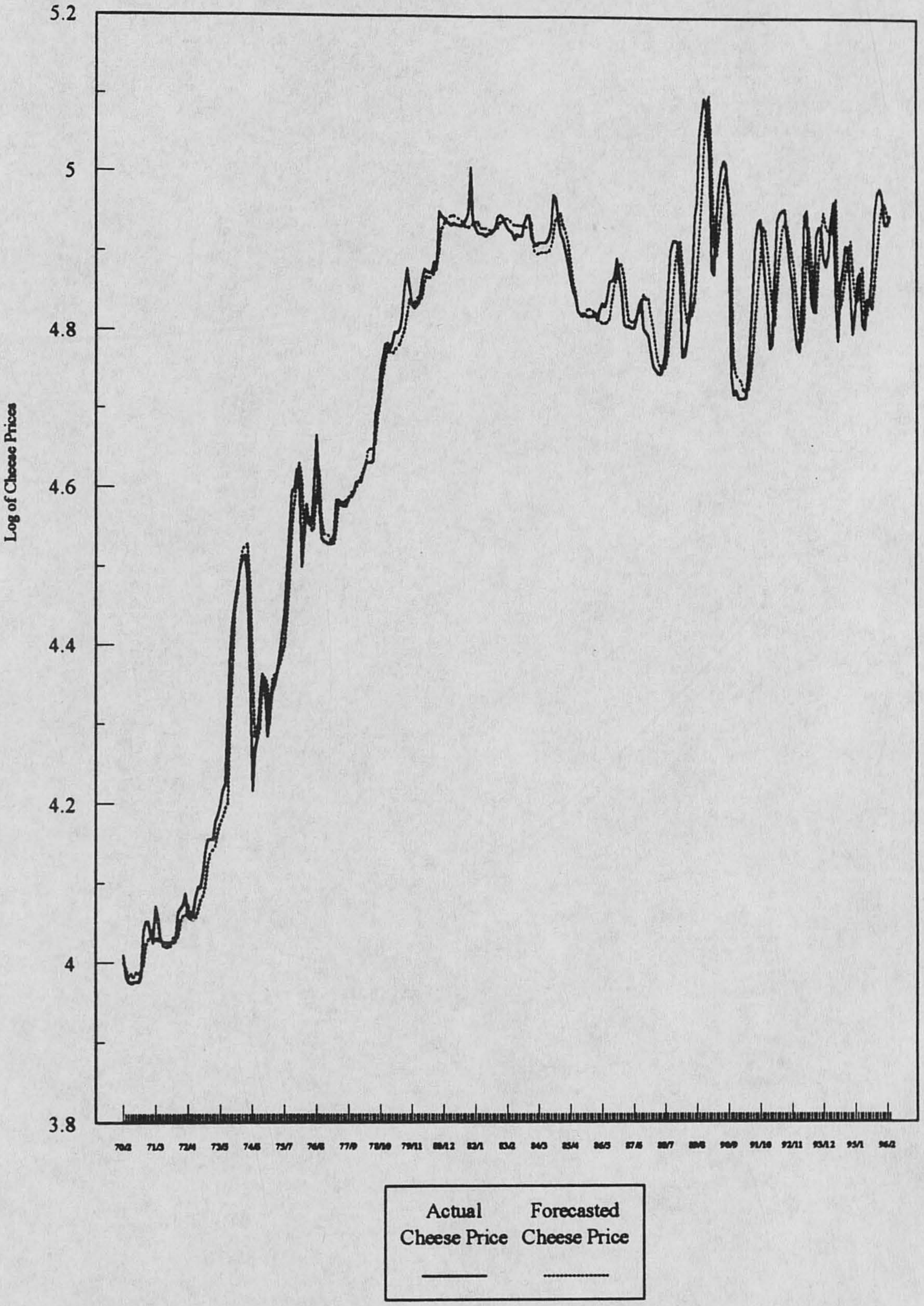


Figure 5: Actual and Forecasted Values of Cheese Prices



References

Alston, Julian M. "An Analysis of growth of U.S. Farmland Prices, 1963-82." *Amer. J. Agr. Econ.* 68(February 1986).

Bessler, D.A. and Hui-Kuang Yu. "Official and Black Market Exchange Rates in Brazil: A Case of the Iterated Logarithm." Unpublished manuscript, Department of Agricultural Economics, Texas A&M University, USA, 1993.

Burt, Oscar R. "Econometric Modeling of the Capitalization Formula for Farmland Prices." *Amer. J. Agr. Econ.* 68(February 1986).

Chambers, Robert G. and Tim T. Phipps. "Accumulation and Rental Behavior in the Market for Farmland." *W. J. Agr. Econ.* 13(December 1988).

Chavas, Jean-Paul and Bruce Jones. "An Analysis of Land Pricing Under Risk." *Rev. Agr. Econ.* 15(May 1993).

Chite R. M., "The Minnesota-Wisconsin (M-W) Milk Price Series: Basic Issues and Proposals for Change". CRS Report for Congress, Congressional Research Service, The Library of Congress, 92-641 ENR, August 1992.

Cropp B. and Ed Jesse. "The Minnesota - Wisconsin Price Series: Its Validity and Alternatives". Marketing and Policy Briefing Paper, Department of Agricultural Economics, College of Agriculture and Life Sciences, University of Wisconsin-Madison Cooperative Extension Service, Paper No. 18, September 1987.

Cropp B. and Ed Jesse. "The General Accounting Office (GAO) Report on The M-W Price Series' What Does It Mean".Marketing and Policy Briefing Paper, Department of Agricultural Economics, College of Agriculture and Life Sciences, University of Wisconsin-Madison Cooperative Extension Service, Paper No. 30, January 1990.

Dickey, D. and W. Fuller. "Distribution of the Estimates for Autoregressive Time Series with a Unit Root." *J. Amer. Stat. Asso.* 74(1979):427-31.

Doan, T. and R. Litterman. Rats User's Manual. Evanston: VAR-Econometrics, 1990.

Falk, Barry. "Formally Testing the Present Value Model of Farmland Prices." *Amer. J. Agr. Econ.* 73(February 1991).

Featherstone, A.M and Timothy G. Baker. "Effect of Reduced Price and Income Supports on Farmland Rent and Value." *N. C. J. Agr. Econ.* 10(July 1988).

General Accounting Office. (GAO/RECD-90-8) Milk Pricing: New Method for Setting Farm Milk Prices Needs to be Developed. November 1989.

George, Iden. "Farmland Values Re-explored." *Agricultural Economic Research,* Vol. XVI, No. 2, April 1964.

Granger. C.W.J. "Some Properties of Time Series Data and Their Use in Econometric Model Specification." *J. Econometrics* 16(1981):121-30.

Granger, C.W.J. and R.F. Engle. "Dynamic Model Specification with Equilibrium Constraints: Co-Integration and Error-Correction." Mimeo, Department of Economics. University of California, San Diego, 1985.

Graf, T.F., "Is the Minnesota-Wisconsin Series Price Doomed?" Staff Paper Series, Department of Agricultural Economics, University of Wisconsin, Madison, No. 66. November 1973.

Hammill, Anne E. "Variables related to Farm Real Estate Values in Minnesota Counties." *Agricultural Economic Research*, 21(April 1969):

Harris, Duane G. and Richard F. Nehring. "Impact of Farm Size on the Bidding Potential for Agricultural Land." *Amer. J. Agr. Econ.* 58(May 1976):

Harris, E. and I. Hedges. Formula Pricing of Milk for Fluid Use. Farm Credit Administration, USDA, Washington, D.C., 1948.

Herdt, R.W. and W.W. Cochrane. "Farm Land Prices and Farm Technological Advance." *J. Farm Econ.* 48(May 1966):

Jacobson, R., J. Hammond, and T. Graf. "Pricing Grade A Milk Used in Manufacturing Dairy Products." Ohio Agricultural Research and Development Center. Research Bulletin 1105. December 1978.

Jesse, E. V., "Alternative to The M-W Price: The Case for a Regulated Grade A Manufacturing Milk Price". Dairy Marketing Notes, Department of Agricultural Economics, Cornell University, No. 3, 1990.

Jesse, E., R. Cropp and P. Christ. "Federal Order Testimony." Presented at the 1990 Federal Order Hearing. Dallas, Texas. October 1990.

Johansen, S. "Statistical Analysis of Cointegration Vectors." *J. Econ. Dyn. Cont.* 12(1988):231-54.

Johanson, S. "Determination of Cointegration Rank in the Presence of a Linear Trend." Unpublished manuscript, University of Copenhagen, Institute of Mathematical Statistics, 1993.

Johansen, S. and K. Juselious. "Maximum Likelihood and Inference on Cointegration -- With Applications to the Demand for Money." *Oxford Bulletin of Economics and Statistics* 52(1990):169-210.

Knutson, R.D., “Alternative to The M-W Price: The Case for Manufacturing Dairy Product Formulas”. Dairy Marketing Notes, Department of Agricultural Economics, Cornell University, No. 3, 1990.

Keough, M. J., "An Evaluation of Product Formulas as an Alternative to the Minnesota-Wisconsin Price Series". M.S. thesis, Texas A&M University, December 1990.

Leistritz, F. L., Garland D. Wiedrich and Harvey G. Vreugdenhil. "Effect of Energy Development on Agricultural Land Values." *W. J. Agr. Econ.* 10(December 1985):

Montgomery, A.A. and J.R. Tarbet. "Land Returns and Farm Real Estate Values." *Agr. Econ. Research,* 20(January 1968):

Novakovic, A. “Alternative to The M-W Price as The Basis for Setting Prices Under Federal Milk Marketing Orders”. Issues and Options 25, Dairy Policy for the Farm Bill, Part II: The 1990 Hearing on the Federal Milk Marketing Order Program, Cornell Program on Dairy Marketing and Policy, Cornell University.

Navakovik A., “Alternatives to The M-W Price: An Overview”. Dairy Marketing Notes, Department of Agricultural Economics, Cornell University, No. 3, 1990.

Phipps, Tim T. "Land Prices and Farm-Based Returns." *Amer. J. Agr. Econ.* 66(November 1984):

Pope, Arden C. "Agricultural Productive and Consumptive Use Components of Rural Land values in Texas." *Amer. J. Agr. Econ.* 67(February 1985).

Pope R.D., R.A. Kramer, R.D. Green and B.D. Gardner. "An Evaluation of Econometric Model of U.S. Farmland Prices." *W. J. Agr. Econ.* 4(July 1979):

Posour Jr, E.C., "Real Property Taxes and Farm Real Estate Values: Incidence and Implications." *Amer. J. Agr. Econ.* 55(November 1973):

Sandrey R.A., L.M Arthur, R.A. Olivera and W.R. Wilson. "Determinants of Oregon Farmland Values: a Pooled Cross-Sectional, Time Series Analysis." *W. J. Agr. Econ.* 7(December 1982):

White, Fread C., M. N. Wesley and A.R. Sheffield. "Some evidence on the Declining Effect of Farm Consolidation on Farm Real Estate Prices." *S. J. Agr. Econ.* 9(December 1977):

U.S. Department of Agriculture. "Study of Alternatives to Minnesota-Wisconsin Price." Agricultural Marketing Service, Dairy Division, September 1991.

U.S. Department of Agriculture. Milk Pricing Policy and Procedures, Part II: Alternative Pricing Procedures. USDA, Washington, D.C., 1973.

U.S. Department of Agriculture. Report to the Secretary of Agriculture by the Federal Milk Order Study Committee. December 1962.