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EVALUATION OF TIME SERIES MODEL FORECASTS FOR THE MINNESOTA-WISCONSIN MILK PRICE

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ABSTRACT

The National Agricultural Statistics Service (NASS) publishes the Minnesota-Wisconsin milk price (M-W). The M-W is a preliminary estimate of the Final two-State (Minnesota-Wisconsin) average price farmers received for manufacturing grade milk produced during the previous month. This price is used to price fluid and surplus Grade A milk in Federal milk marketing orders. The Final two-State price is published in June of the following year. Since the M-W is a preliminary estimate, or forecast, it is subject to error. This report compares procedures that use Box-Jenkins transfer functions models against the current M-W procedure.

Single model procedures model the 3.5 percent milkfat M-W price. Double model procedures separately model the unadjusted price and milkfat test then combine the two forecasts to a 3.5 percent milkfat price. Both single model and double model procedures reduced the bias from 5 cents for the current model to 1 cent over 5 years of monthly forecasts used in this analysis. However, the single model procedure uses Commodity Statistician input, making it somewhat subjective and sensitive to personnel changes. Therefore, it is recommended that forecasts from the double model procedure be available for Commodity Statistician review when estimating the M-W price.

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SUMMARY

Each month, the National Agricultural Statistics Service (NASS) publishes the Minnesota-Wisconsin milk price (M-W). The M-W is a preliminary estimate of the Final two-State (Minnesota-Wisconsin) average price farmers received for manufacturing grade milk produced during the previous month. This price is used to price fluid and surplus Grade A Milk in Federal milk marketing orders. The Final two-State price is published in June of the following year.

This research was done at NASS Estimates Division's request. The current procedure combines panel survey data, administrative data, and chart readings by Commodity Statisticians. The panel survey sample size has steadily decreased over the past several years. There was concern that this panel sample was becoming too small to measure adequately the manufacturing grade milk price in the two-State region. Previous work by Klugh and Markham[5], followed by Eldridge[3], showed that Box-Jenkins transfer function models could predict entire month milk prices.

Several different procedures using Box-Jenkins transfer function models (TFM) were compared to the current procedure. TFM input variables examined included panel survey data, administrative data, and published preliminary data. Autobox Plus 2.0 software generated the TFMs and forecasts.

Procedures simulated real time monthly preliminary estimates from January 1984 through December 1988. Final two-State estimates were considered truth for this analysis. Statistical measures of bias, accuracy, and forecast error size were used to compare procedure performance. Practical measures, such as ease of implementation and computing, time were also considered.

Single model procedures model the 3.5 percent milkfat M-W price. Double model procedures separately model the unadjusted price and milkfat test, then combine the two forecasts to a 3.5 percent milkfat price. A single model and double model procedure each reduced the bias from 5 cents for the current model to 1 cent over 5 years of monthly forecasts used in this analysis. However, the single model procedure uses Commodity Statistician input. This makes it somewhat subjective and sensitive to personnel changes. Therefore, it is recommended that forecasts from the double model procedure be available for Commodity Statistician review when estimating the M-W price.

Evaluation of Time Series Model Forecasts for the Minnesota-Wisconsin Milk Price

Gary Keough

INTRODUCTION

The National Agricultural Statistics Service (NASS) publishes the Minnesota-Wisconsin Milk (M-W) Price on or before the fifth of each month. The M-W is a preliminary estimate of the average price farmers received for manufacturing grade (Grade B) milk in the two-State (Minnesota-Wisconsin) region for the previous month. This price is used to price fluid and surplus Grade A Milk in Federal milk marketing orders. NASS publishes monthly Final two-State price estimates in June of the following year. These final prices are based on a nearly complete census of operations that purchase Grade B milk in the two States.

The difference between the M-W and the Final two-State price is watched closely by the milk industry. A consistently low M-W means that milk priced through Federal milk marketing orders was underpriced and farmers were underpaid. A consistently high M-W means that milk priced through Federal milk marketing orders was overpriced and farmers were overpaid. If the difference between the M-W and the Final two-State price is highly variable, the M-W price is not adequately measuring the Grade B milk price.

This research was done at NASS Estimates Division's request. NASS uses panel survey data, administrative data, and chart reading by Commodity Statisticians to estimate the M-W. The original panel survey sample was drawn in 1971. It is made up of milk manufacturing plants that make bi-monthly payments to farmers. Over the years, several plants changed from bi-monthly payments to only one payment per month. As plants dropped out of the sample they were replaced by similar plants. The current sample is essentially all remaining plants that make bi-monthly payments. For the last quarter of 1988, the current procedure's errors was twice the previous year's errors. This caused concern that the panel sample was getting too small to measure adequately the Grade B milk price in the two-State region.

This report evaluates procedures using different input variables (leading indicators) with Box-Jenkins transfer function models to estimate the M-W. Previous work by Klugh and Markham[5], followed by Eldridge[3], showed Box-Jenkins transfer function models could predict entire month milk prices. Input variables examined included statistician estimates, panel survey data, Market News Service data, and the support price. Market News Service data included a cheese price, butter price, and non-fat dry milk price. Autobox Plus 2.0 software generated the Box-Jenkins transfer function models and forecasts.

Procedures were evaluated using statistical measures of bias, accuracy and forecast error size, along with practical measures such as ease of implementation and computing time. Practical measures included being able to run an IBM PC-AT. An evaluation period of 5 years or 60 monthly forecasts was used. All procedures simulated real time forecasts for January 1984 through December 1988.

METHODOLOGY

This analysis focuses on the feasibility of implementing procedures using Autobox Plus 2.0 generated Box-Jenkins transfer function models for setting the M-W price. A description of time series methodology will not be given. Instead a description of procedures tested will be presented. Donaldson and Klugh[2], and Keough and Miles[4], document other uses of Autobox Plus 2.0. Box and Jenkins[1] describe the time series methodology.

A procedure will be defined as a group of steps or operations that takes the data and develops a M-W estimate. NASS publishes preliminary and Final two-State estimates of three series; the price adjusted to 3.5 percent milkfat (the M-W), the unadjusted price, and the percent milkfat (test). Therefore, procedures could fall into two major groups:

1) Single model procedures that develop models for the only the 3.5 percent milkfat price, and

2) Double model procedures that develop separate models for the unadjusted price and test, then adjust the price to 3.5 percent milkfat using the same steps as in the current procedure.

CURRENT PROCEDURE

The current procedure uses a ratio estimator to estimate the percent change from the base (previous) month to current month for price and test. This percent change is then applied to base month indications.

During the last half of each month, the Minnesota and Wisconsin State Statistical Offices (SSO's) collect data from milk manufacturing plants that purchase Grade B milk from farmers. The SSOs collect data for base month and current month estimates of the average Grade B milk price and test.

The original sample was drawn in 1971. The universe consisted of 278 Wisconsin plants and 98 Minnesota plants. The universe was stratified by type of production and pounds of milk received. The number of plants has decreased to 133 in Wisconsin and 82 in Minnesota.

In 1983, base month price and test averages were based on data from 175 Wisconsin plants and 100 Minnesota plants[9]. By 1988, the number of plants had dropped to 110 in Wisconsin and 80 in Minnesota[8]. These plants were well distributed geographically over both States and represented all major types of processing plants using Grade B milk. They purchased approximately 60 percent of all Grade B milk.

In 1983, current month price and test averages were obtained from a panel of 70 Wisconsin plants and 40 Minnesota plants[9]. By 1988, these numbers had dropped to 50 Wisconsin plants and 25 Minnesota plants. Originally, plants were randomly selected from the base month sample plants that make payments for the first 15 days of the current month purchases. Now, all plants that make bi-monthly payments are in the current month sample. These plants account for about 30 percent of the Grade B milk in the two states.

For each State, a percent change in price and test is estimated from the current month panel survey data. These percents are then applied to the base month estimates to forecast the average price and test for the current month.

State Commodity Statisticians review their State's base survey, panel survey, and check data. Check data includes weekly cheddar cheese, butter, non fat dry milk, and whey powder prices published by AMS[7]. After review, State Commodity Statisticians recommend a price and test estimate for their State. These recommendations along with base survey, panel survey, and check data indications are forwarded to Headquarters. Headquarters Commodity Statisticians plot and review the data and adopt preliminary estimates for each State. These official preliminary estimates are weighted to a two-State average price. Weights are based on the proportion of the two-State total Grade B milk production for the corresponding month of the previous year. This average price is then adjusted to 3.5 percent milkfat.

Adjusting to 3.5 percent milkfat is done in the following manner:

1) Multiply the Chicago Grade A butter price (published weekly by AMS, USDA in "Dairy Market News") by 0.120. This product is the milkfat differential.

2) Subtract the milkfat test from 3.5 and divide by 0.001 to get the number of "points".

3) Multiply milkfat differential by the points to get a price adjustment.

4) Add the price adjustment to current milk price.

Notice that, if the test is greater than 3.5, the points will be negative and the adjusted price will be less than the actual price. The reason for that is because milk with a higher test is more valuable.

Preliminary estimates published are:

1) Price and test for each State.

2) Weighted price and test for the two-State region.

3) Weighted price adjusted to 3.5 percent milkfat (M-W).

In June of the following year, official monthly Final two-State estimates are published. These estimates are based on a nearly complete census of Grade B milk plants in the two-State region. Revisions to items listed in 2 and 3 above are published with the differences between preliminary and final prices and the proportion of Grade B milk produced in each State.

VARIABLES

The Box-Jenkins transfer function model provides an estimate of a dependent or output variable based on previous dependent variable values and the values of independent or input variables. The dependent variables are the official Final two-State estimates of the price adjusted to 3.5 percent milkfat, the unadjusted price, and the test. Several independent variables were examined. Tables 1a-d describe the dependent and independent variables examined and give abbreviations used throughout this report.

Survey variables in Table 1a are from the monthly panel surveys of Grade B milk buyers. These variables can pertain to Wisconsin, Minnesota, or a weighted combination. Weights are the same as those used in the current procedure. A "W" in front of an abbreviation means that it pertains to Wisconsin. A "M" means Minnesota and a "MW" means a weighted combination of the Minnesota and Wisconsin variable. Survey variables values are available from January 1980 to present.

Table 1a -- Survey variables

Variables	Abbreviation
Current survey price Average price paid for manufacturing grade milk from current month data.	CSP
Current survey test Average milkfat test of manufacturing grade milk purchased from current month data.	CST
Base survey price Average price paid for manufacturing grade milk from base month data.	BSP
Base survey test Average milkfat test of manufacturing grade milk purchased from base month data.	BST

Administrative data series based weekly data are published by Agricultural Marketing Service in the Dairy Market News publication. Monthly values were generated by averaging the weekly values published in the same month.

Table 1b -- Administrative variables

Variables	Abbreviation
Green Bay Cheese Exchange Simple average of the weekly bids for cheddar cheese.	CHEESE
Chicago Butter Price Price for 92-score butter on Chicago Mercantile Spot market.	BUTTER
Non-Fat Dry Milk Price for Central States nonfat dry milk, average of extra grade high and low heat	NFDM
Support price, adjusted for 3.5 percent milkfat Price for 3.5 percent milkfat milk supported by the U.S. Government.	SUPADJ
Support price, unadjusted Price for milk at actual test supported by the U.S. Government.	SUPUNADJ

Statistician estimates are the preliminary estimates. They are the subjective combination of survey and administrative data. Data for these series are available from 1961 to present.

Table 1c -- Statistician estimates

Variables	Abbreviation
Minnesota-Wisconsin Milk Price The published preliminary estimate of 3.5 percent milkfat manufacturing grade milk purchased in the two-State region.	MWADJ
Minnesota-Wisconsin Milk Price, unadjusted The published preliminary estimate of manufacturing grade milk purchased in the two-State region.	MWUNADJ
Minnesota-Wisconsin Milk Test The published preliminary estimate of milkfat test of manufacturing grade milk purchased in the two-State region.	MWTEST

Monthly Final two-State values are published in June of the following year (1988 values were not published until June 1989). Therefore, a minimum of the previous six Final two-State estimates are not available at the time an estimate must be made. To overcome this, "revised" MW values were substituted when Final two-States values were not available. Revised MW values use the corresponding base survey values. For example, when estimating the May M-W, the current survey data covers the first 15 days of May and the base survey data covers the entire month of April. The April entire month data are used to calculate revised April M-W values. These revised MW values have historically deviated very little from the final estimates. Price differences averaged less than 2 cents between 1980-1988. Test differences averaged just over 0.006 percent during the same period.

Table 1d -- Dependent variables

Variables	Abbreviation
Final two-State Milk Price The published estimate of 3.5 percent milkfat manufacturing grade milk purchased in the two-State region.	FNADJ
Final two-State Milk Price, unadjusted The published estimate of manufacturing grade milk purchased in the two-State region.	FNUNADJ
Final two-State Milk Test The published estimate of milkfat test of manufacturing grade milk purchased in the two-State region.	FNTEST

TFM FORECASTS

Overview

Several procedures using the different groups of data series were examined. However, because of the declining current survey sample size, it was hoped that a procedure that does not use current survey data would perform as well or better than the current procedure. This type of procedure could use some combination of base survey and administrative data. Single State procedures were examined to see if modeling the current survey data for one State with administrative data could perform as well as modeling the current survey data for both States. Univariate models (models using only the dependent variable) for the official estimates were also examined.

Time Series Modeling

Autobox Plus 2.0 uses Box-Jenkins methodology for determining time series models. This is a three-step iterative approach[1]. Details of the methodology will not be presented here. However, a general description of times series models will be given. Examples of models will be given.

Time series models differ from regression models in that time series models depend on the order of the observations. In regression, the order of the observations does not effect on the model. Time series models use historic values of a series to predict future values. Some time series models try to use seasonal and cyclic patterns.

Transfer functions are a subdivision of time series models. Transfer functions use leading indicators, or input variables, to forecast values of an output series[1]. In this sense they transfer changes of an input variable to the output variable. Transfer functions can also incorporate information about just the output series. The Autobox Plus software can measure the relationship between the input and output series, as well as the historic relationship of the output series with itself. If an input series is not providing sufficient information, the software will exclude it from the model.

EXAMPLES OF MODELS

The following is a simple example of a Box-Jenkins model.

$$(\hat{Y}_{TFMt})^{1/2} = 1.829 + [0.978\ (X_t)^{1/2} - 1.825]$$

This example looks very similar to a regression model where the variables have been transformed by taking the square roots. The equation uses an input variable, X, for which we have a value at time t, to forecast an output variable, Y. The value 1.829, which looks like an intercept, is the mean of the transformed output series. The term $(X_t)^{1/2} - 1.825$ is the square root of the current input value $(X_t)^{1/2}$ minus the mean (1.825) of the transformed input series. This term is then multiplied by the coefficient 0.978. In this example, a forecast is made by transferring to the output series's mean, a portion of the difference between the input series's current value and its mean.

A more complicated model that accounts for 12 month seasonality is:

$$\hat{Y}_t = Y_{t-1} + (Y_{t-12} - Y_{t-13}) + (0.526)[X_t - X_{t-1} - (X_{t-12} - X_{t-13})].$$

Here, the terms $(Y_{t-12} - Y_{t-13})$ and $(X_{t-12} - X_{t-13})$ bring the output and input series changes from a year ago into the model.

TFM's examined ranged from models using variables from only one State to ones using administrative and survey data from both States. When two or more independent variables are modeled, the series can be filtered using the common filter or cross correlation filter. Filtering is similar to univariate modeling of the independent variable. If significant cross correlation exists between independent series, then the common filter method should be used[6]. Both filtering methods were used in this analysis.

AUTOBOX PLUS 2.0 SOFTWARE

Autobox Plus 2.0 by AFS generated the TFM forecasts. This software package performs automated time domain time series analysis. The user tells the program the data and options to use. The package then identifies the model form, estimates the coefficients, and generates the forecast. Coefficients are estimated using a nonlinear least squares estimation procedure based on the Marquardt algorithm[1 6].

Autobox Plus is designed primarily for interactive use. Because of the large number of forecasts required, a non-interactive approach was developed. Autobox Plus has an interactive front-end program to create set-up files used by the execution file ABXMAIN.EXE. These files contain the input and output series data, input series data for forecasting, file names, and options settings. Documentation for creating these files for batch processing was obtained from AFS. SAS macros have been written to create the necessary set-up files. These macros can be easily modified to do a similar analysis on other series.

The version of Autobox Plus has a limit of 300 observations per series. This would be 25 years of monthly data. However, some series cover the period from 1961 to 1988, 27 years of data. In those cases, models were developed using the most current 25 years of data.

ANALYSIS OF FORECASTS

Evaluation Statistics

Evaluation statistics used are the mean error, mean absolute percent error (MAPE), root mean square error (RMSE), and maximum absolute error (MAE). The mean error measures a procedure's bias. The RMSE, which reflects both bias and variability of the estimate, measures a procedure's accuracy. RMSE is the square root of the averaged squared deviations of a forecast from truth. The MAPE is a relative measure of the absolute size of the forecast errors. Forecast errors are transformed to percentages of the truth. The absolute value of these percentages is averaged over the number of time periods. The MAPE does not penalize large deviations as severely as the RMSE does when the truth is also large. Also, the MAE will be used because an alternative procedure must have a smaller maximum error than the current procedure. Recall that larger than expected errors in the last quarter of 1988 prompted this analysis. The official Final two-State estimate is considered truth for computing evaluation statistics.

For the equations describing the statistics, i indexes the procedures and k indexes time periods which, for this study are months. Mean error for the ith procedure is defined as:

$$ME_i = [(1/t) \sum_{k=1}^{t} (f_{ik} - Y_k)].$$

The RMSE for the ith procedure is defined as:

$$RMSE_i = [(1/t) \sum_{k=1}^{t} (f_{ik} - Y_k)^2]^{1/2}.$$

The MAPE for the ith procedure is defined as:

$$MAPE_i = (1/t) \sum_{k=1}^{t} |(f_{ik} - Y_k) / Y_k| \cdot 100.$$

The MAE for the ith procedure is defined as:

$$MAE_i = MAX(|(f_{ik} - Y_k)|)$$

where:

f_{ik} = the forecast from procedure i for the kth time period,

and

Y_k = the truth for the kth time period.

Practical Measures

Procedures were limited operationally by time and computer hardware constraints. The M-W has to be ready for release to the public by 12:00 noon EST on the 5th of the month (or previous Friday if the 5th falls during a weekend). SSO's submit their recommendations that morning. This limits the amount of time needed to complete a procedure. Within this limited time, the procedure must run on a PC-AT. Ease of implementing and repeatability were also considered.

RESULTS

In this section, software problems and evaluation statistics are reported. Several variable combinations did not perform well enough to be considered suitable for use. Evaluation statistics for only the most promising procedures are presented.

Software Problems

Batch programs were created to model and make 60 monthly forecasts from a group of variables in one run. However, sometimes Autobox Plus could not provide forecasts for all months. This was especially true when multiple input variables were highly correlated. When that happened, preliminary evaluation statistics where calculated using the forecasts that Autobox Plus had generated. These preliminary statistics were compared with the current procedure's evaluation statistics. If the evaluation statistics were close, Autobox Plus options were modified so that forecasts for the remaining months could be generated. Software documentation contains suggestions for what to do when the software cannot estimate the model. Usually, lowering the number of autocorrelations and partial correlations to be calculated solved the problem. However, in most multiple input variable cases the evaluation statistics were not close enough to justify modifying the options.

Single Model Procedures

Single model procedures provide estimates of the Final 3.5 percent milkfat price at the two-State level (FNADJ). Only two single model procedures produced smaller mean errors, RMSE's, and MAPE's than the current procedure. Both procedures used the MWADJ as the only independent variable. One procedure identifies and estimates a model for the first month and then uses this model to make forecasts for three months. This procedure, called P1, is then repeated every fourth month. The other procedure, called P2, identifies and estimates the model every month.

Double Model Procedures

Double model procedures provide separate estimates of the two-State unadjusted price (FNUNADJ) and test (FNTEST). The unadjusted price is then adjusted to a 3.5 percent price. No double model procedure performed as well statistically as did P1 and P2. However, two double model procedures that closely mimic the current procedure were found to perform as well or better than the current procedure. One procedure, known as MWCS, has the following steps:

1) Weight together WCSP and MCSP, the current survey prices for each State, using the same weights currently used to calculate the M-W unadjusted price,

2) Model this weighted survey data series with FNUADJ and generate a forecast of the unadjusted price,

3) Repeats steps 1 and 2 using WCST and MCST to forecast the test, then

4) Adjust the forecast to 3.5 percent milkfat.

The other procedure, known as MWCS_CH, is identical except that the CHEESE data series is included in step 2 as a deterministic variable for modeling the unadjusted price.

Analysis Statistics

Table 2 shows single model and double model procedures reduced the bias from about 5 cents to 2 cents or less. These procedures also produced smaller MAE's than the current procedure with the single model procedures producing the smallest MAE. Single model MAPE's and RMSE's are slightly smaller than those for the other procedures.

Figures 1 through 5 show the reasons for differences in the evaluation statistics. Figure 1 shows the current procedure's error distribution is skewed right. However, Figures 2 through 5 show the other procedures' error distributions are more bell shaped and centered closer to zero. This explains the difference in bias. Figures 2 and 3 show that P1 and P2 have narrower error distributions. This explains their smaller RMSE's and MAPE's.

Figures 4 and 5 show the double model procedures' error distributions have wider ranges (28 cents and 35 cents) than the current procedure's, yet their MAE's, 16 cents and 18 cents, are smaller than the current procedure's MAE (22 cents).

Table 2 evaluation statistics and Figures 1 through 5 support using any of the single model or double model procedures over the current procedure. However, comparing MWCS's and MWCS_CH's evaluation statistics do not justify using MWCH_CH.

When comparing MWCS with the single model procedures, note that P1 and P2 simply model the published M-W price preliminary estimate (MWADJ) against the official Final two-State adjusted price (FNADJ). Headquarters Commodity Statisticians would still have to read charts subjectively, then use their chart reading as input for the model. Also, if a personnel change occurred, the new person would be unlikely to read the chart the same as the predecessor. If NASS adopted this procedure, the Commodity Statistician might find it difficult to continue reading the chart consistently. Though these procedures may be statistically superior, they are not more practical.

Table 2 -- Evaluation statistics by procedure

Procedure	Evaluation Statistics			
	Mean Error (dollars)	Mean Absolute Percent Error	Root Mean Square Error (dollars)	Max. Absolute Error (dollars)
Current	0.05	0.42	0.07	0.22
Single model				
P1	0.02	0.31	0.05	0.11
P2	0.01	0.31	0.05	0.11
Double model				
MWCS	0.01	0.42	0.06	0.16
MWCS_CH	0.02	0.44	0.07	0.18

COMPUTER TIME

MWCS takes about 30 minutes total computer time with a PC-AT. Computer times for other procedures were not measured because they were considered not suitable for operational use, either because of inferior evaluation statistics or for practical measures.

Figure 1. MW Error Distribution
1984-88

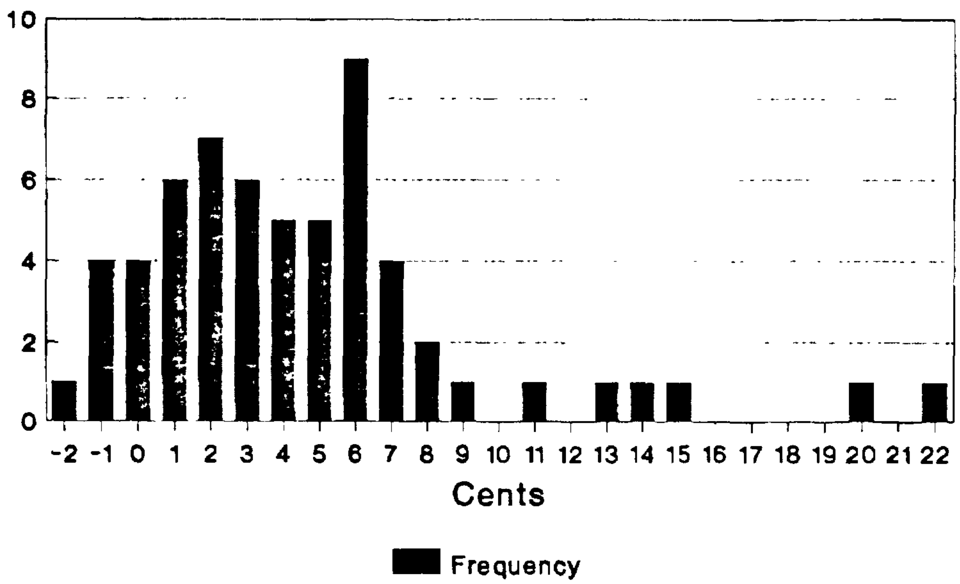


Figure 2. P1 Error Distribution 1984-88

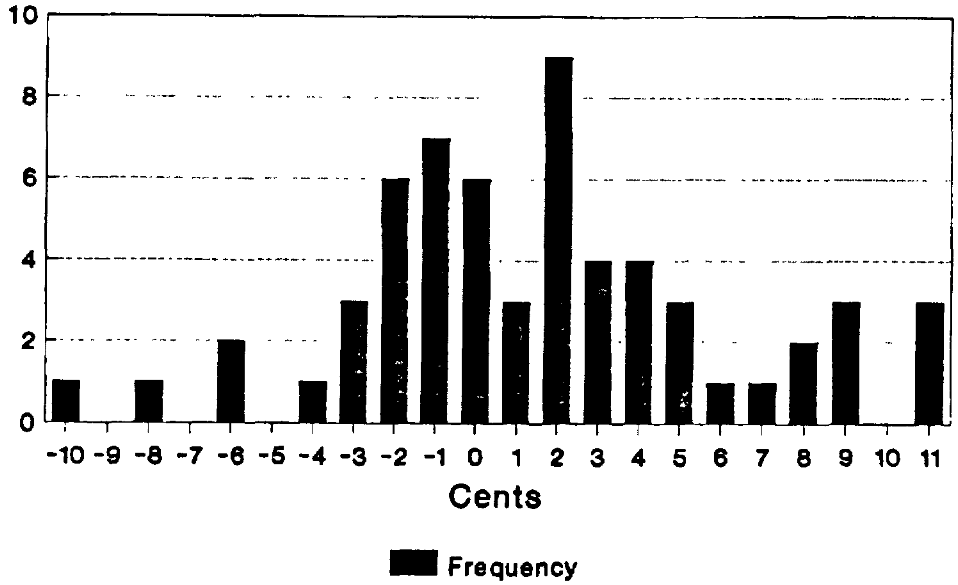


Figure 3. P2 Error Distribution 1984-88

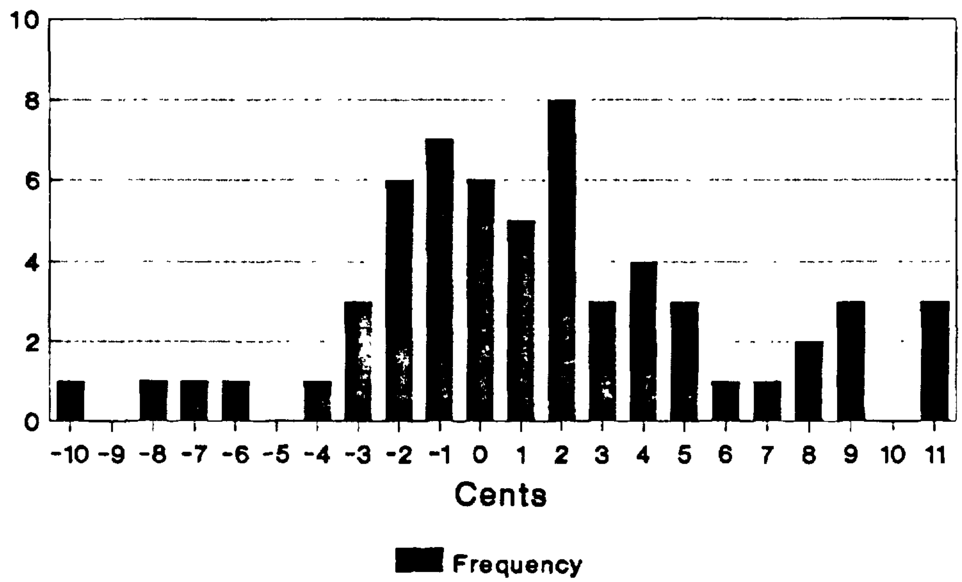


Figure 4. MWCS Error Distribution 1984-88

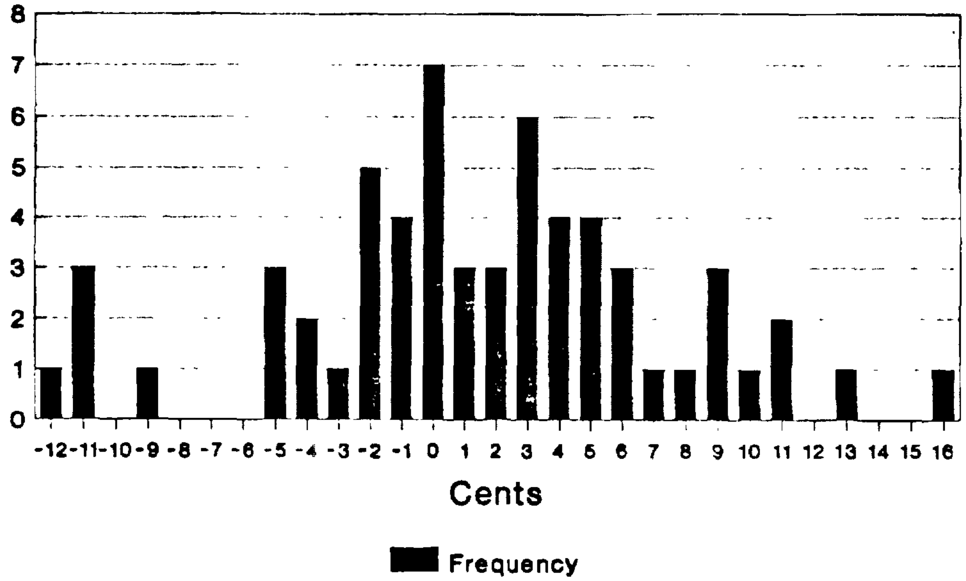
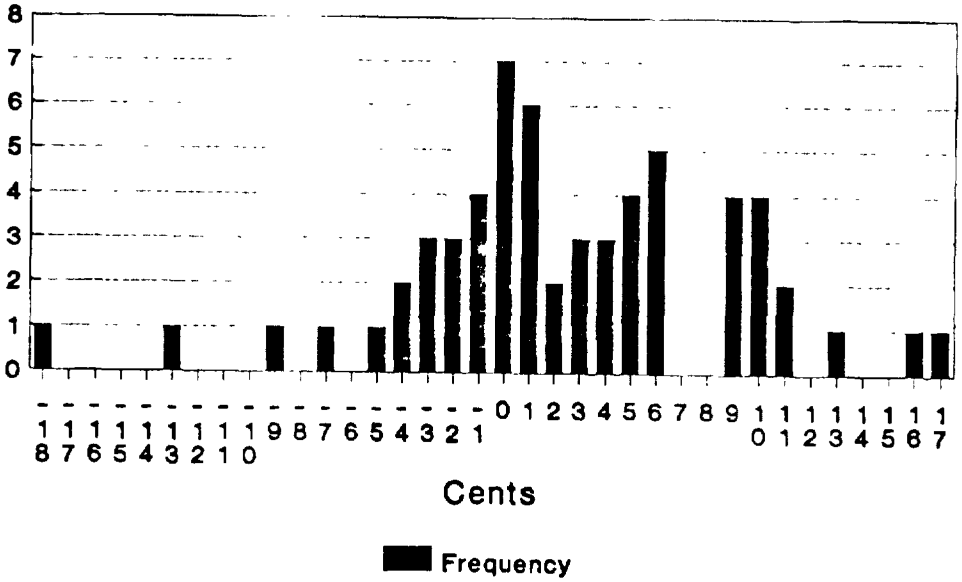


Figure 5. MWCS_CH Error Distribution 1984-88



CONCLUSIONS

This report compares the performance of procedures using Box-Jenkins transfer function models against the current procedure to estimate the monthly M-W price for 1984-88. Single model procedures that develop models for the 3.5 percent milkfat M-W price directly, and double model procedures that develop separate models for the unadjusted price and milkfat test, were evaluated.

Several combinations of input variable series were examined, but, most did not perform well enough to be considered suitable for use. Only the results for two single model and two double model procedures that outperformed the current procedure were presented.

The two double model procedures, MWCS and MWCS_CH, differ only in that MWCS_CH allows for an input variable based on the Green Bay Cheese Exchange price in the TFM. However, evaluation statistics did not improve with the addition of this variable.

Single model procedures produced the best evaluation statistics of any procedure. However, they require the Headquarters Commodity Statisticians to read time series charts subjectively, then use their chart reading as input for the TFM model. If this procedure was adopted, the Commodity Statistician might find it difficult to continue reading the chart consistently. Also, if a personnel change occurred, the new person would be unlikely to read the chart the same as the predecessor. Though single model procedures may be statistically superior, double model procedures are more practical, and still out perform the current procedure.

RECOMMENDATIONS

Forecasts from the MWCS procedure should be available for Commodity Statistician review when setting the M-W price, though two single model procedures may be statistically superior. Single model procedures require the Headquarters Commodity Statisticians to read time series charts subjectively, then use their chart reading as input for the TFM model. This makes the procedure sensitive to personnel changes. The MWCS procedure does not have this problem.

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