



*The World's Largest Open Access Agricultural & Applied Economics Digital Library*

**This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.**

**Help ensure our sustainability.**

Give to AgEcon Search

AgEcon Search

<http://ageconsearch.umn.edu>

[aesearch@umn.edu](mailto:aesearch@umn.edu)

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

*No endorsement of AgEcon Search or its fundraising activities by the author(s) of the following work or their employer(s) is intended or implied.*



GIANNINI FOUNDATION OF  
AGRICULTURAL ECONOMICS  
LIBRARY  
WITHDRAWN

SEP 23 1987

University of Newcastle upon Tyne.



# DISCUSSION PAPER

Department of Agricultural Economics *and*  
Department of Agricultural Marketing

UNIVERSITY OF NEWCASTLE UPON TYNE

Department of Agricultural Economics

Department of Agricultural and Food Marketing

DISCUSSION PAPER

DP 14

October 1985

Forecasting Milk Output in England and Wales

Benedict White  
Department of Agricultural Economics

## FORECASTING MILK OUTPUT IN ENGLAND & WALES

### ABSTRACT

This paper considers forecasting monthly milk output for England and Wales by three extrapolative methods namely linear trend, Holt-Winters and the Box-Jenkins approach to fitting an ARIMA (autogressive intergrated moving average) model. Each technique is used to produce forecasts of milk output for a four-year lead time from April 1980 to March 1984. From the application of the techniques it is found that the ARIMA model's and Holt-Winters' forecasts are of similar accuracy. The ARIMA and Holt-Winters models are updated and used to forecast the April 1984 to March 1985 period as a means of illustrating approximately the effects of the EC imposed quota on output. The difficulty of forecasting the milk output series after the imposition of the quota system is considered, and an extended ARIMA model including a dummy variable to account for the quota period (discontinuity model) is estimated. This latter model forecasts the period from April 1985 to July 1985 substantially better than either the Holt-Winters or the standard ARIMA model, although this result is presented tentatively as insufficient data are available to evaluate fully the model's forecasting ability. The discontinuity model predicts that output in England and Wales up to the year ending March 1986 will be 1.6% under quota.

## 1. Introduction

The variability and uncertainty of agricultural production makes agricultural marketing and investment planning difficult. Furthermore, inelastic demand coupled with variable supply leads to substantial price fluctuations. Within this environment forecasters in government and business have had recourse to statistical methods as a means of estimating point and range forecasts, thereby reducing the uncertainty associated with output and price variability.

Extrapolative methods are often selected in preference to the alternative econometric approach as a means of generating forecasts. Three factors explain this preference. First, extra cost is involved in estimating an econometric model. Second, data are not always available to estimate a complete econometric model. Third, forecasting from an econometric model requires initial forecasts of the exogenous variables, which in effect transforms the forecasting problem from forecasting an endogenous variable to forecasting exogenous variables. Econometric forecasts are therefore conditional upon the values of exogenous variables in the model, whereas extrapolative forecasts can be unconditional and independent of exogenous variables.

Among the extrapolative forecasting methods the autoregressive integrated moving average (ARIMA) model as developed by Box and Jenkins (1970) is of particular importance. The model has become a standard means of representing a time series and is a flexible approach able to cope with

the characteristics shown by a wide range of series. Since 1970 there have been numerous applications of the Box-Jenkins methodology for fitting ARIMA models to economic time series. A number of these have involved agricultural price and supply series, in particular, Brandt and Bessler (1983), Larson (1983) and Leuthold et al (1970). Two types of application emerge: first, in studies where the ARIMA model is used (often incorrectly) as a benchmark against which the forecasting performance of an econometric model is judged; and second, where the model is used as a means of generating short term unconditional forecasts for business purposes.

The aim of this study is to evaluate and discuss the ability of three extrapolative methods - linear trend, Holt-Winters and Box-Jenkins - to forecast monthly milk output for England and Wales. Section 2 considers the application of the three methodologies. It also compares the forecasting performance of the techniques and draws conclusions about their value in terms of both convenience and forecasting performance. Section 3 presents predictions from the ARIMA model to illustrate the effect of the quota, and discusses an extension of the methodology to model a series in which there is a distinct and identifiable discontinuity. Some conclusions are drawn in Section 4.

## 2. Forecasting Milk Output

The extrapolative techniques are applied to a 10-year series (April 1970 to March 1980) of monthly liquid milk output data for England and Wales. Data from the four years April 1980 to March 1984 are held back so that the forecasting ability of the models can be assessed over a reasonably long lead time using the mean absolute percentage error (MAPE)<sup>1</sup>.

Consider the characteristics of the milk output series. Figure 1 shows that monthly milk output has overall an upward trend with a distinct and regular seasonality. Departures from the trend can be related to the 1975 drought and producers' response to the price increase which accompanied EC membership in 1973. Let us now consider each extrapolative technique.

### Linear trend model

One means of representing the series is to fit a trend with dummy variables (to account for seasonality) by OLS regression. The model fitted to the period April 1970 to March 1980 is:

$$\hat{Y}_t = 915.1 + 1.812\text{Trend} + C'D \quad (1)$$

(66.70)      (17.36)

$$R^2 = 0.92$$

(t-statistics in parentheses)

where  $Y_t$  is milk output,  $\hat{Y}_t$  being the estimated values of milk output, Trend takes the value of 1 in first month and 120 in the last month,  $C'$  is a vector of parameters and  $D$  is a vector of dummy variables each taking the value 1 in a given month and 0 in all other months. The

FIGURE 1.

MONTHLY MILK OUTPUT APRIL 1970 TO MARCH 1984

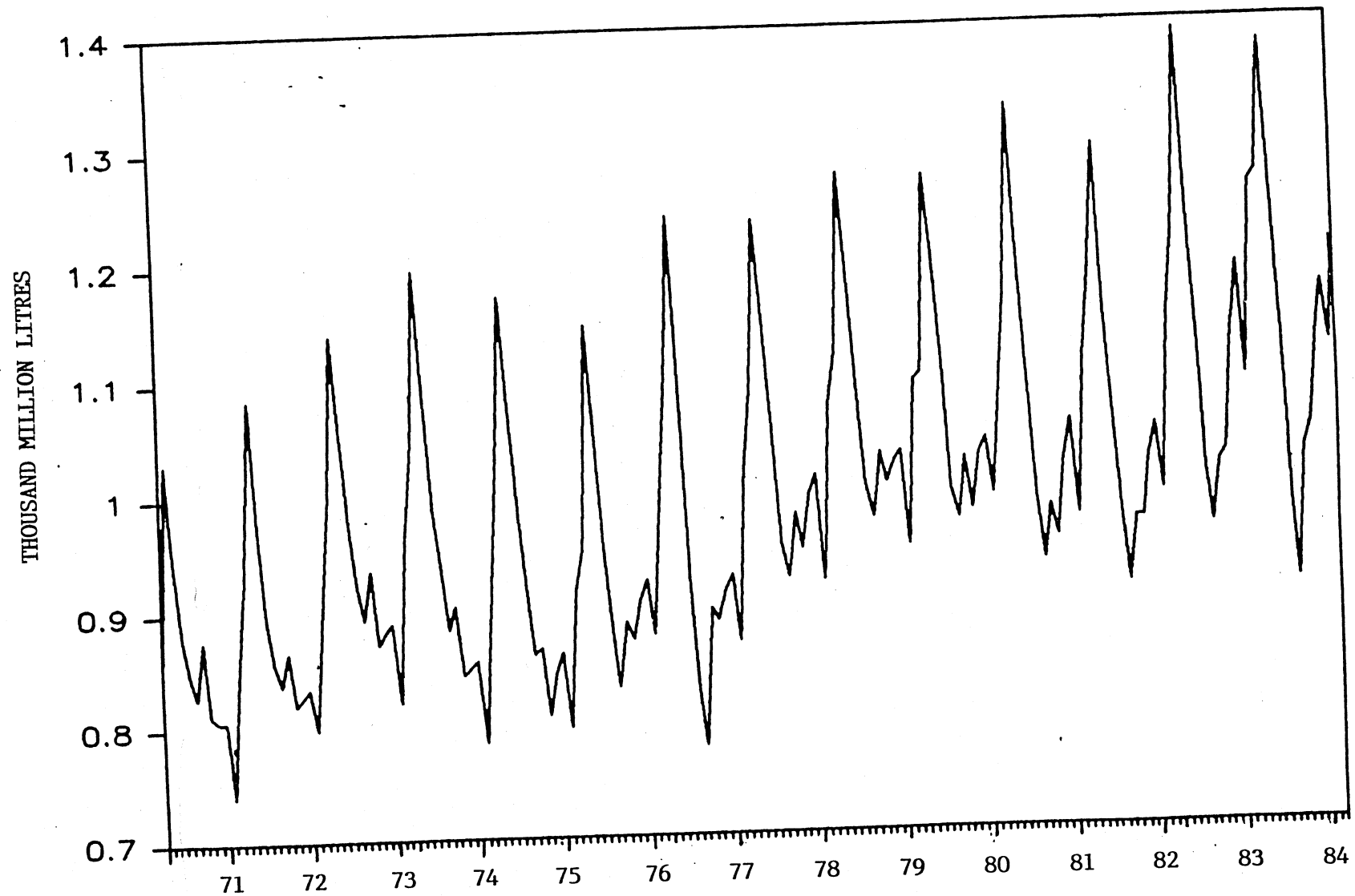
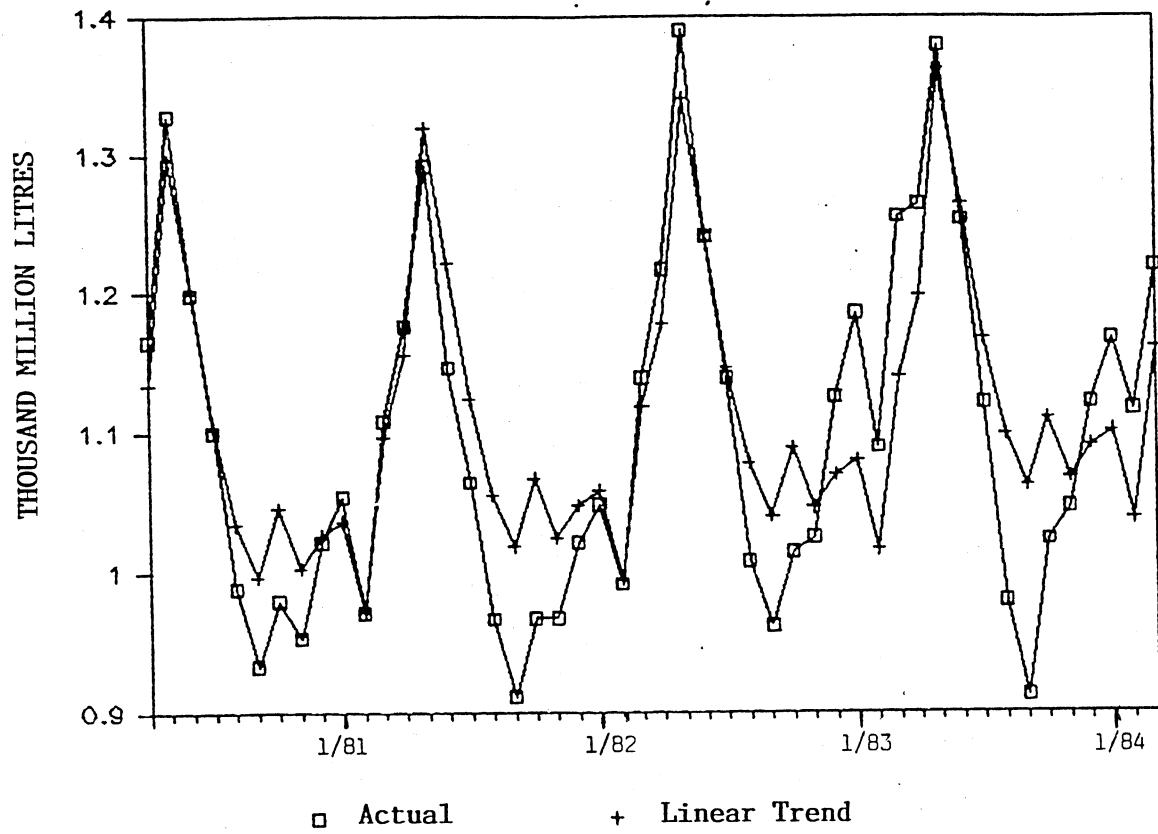




FIGURE 2.

FORECAST AND ACTUAL APRIL 1980 TO MARCH 1984



model implies a fixed and additive seasonality which is constant over the estimation period and a trend which is additive. Thus, in each month milk production is predicted to be 1.812 million litres greater than the previous month before taking into account seasonality. Over the forecast period April 1980 to March 1983, the linear trend equation gives a MAPE of 8.71%. In Figure 2 it is observed that the model overestimates output in the winter months, but provides a more accurate forecast for the summer period. This would tend to suggest that the estimated trend in output is not borne out in the data for the forecast period.

#### Holt-Winters Model

The Holt-Winters method of exponential smoothing has proved to be a particularly reliable means of forecasting seasonal time series (see for example Brandt and Bessler, 1983). The version of the Holt-Winters models described here follows Chatfield (1978), who proposes two Holt-Winters models: additive (HWA) and multiplicative (HWM). The additive model implies that the seasonality is constant. The multiplicative model implies that the magnitude of the seasonal component within the series is in proportion to the local mean. It is usual to estimate both models and to choose between them on the basis of their MAPEs for the forecast period. The additive model is given by:

$$Y_t = (m_t + r_t) + F_t + e_t$$

$$m_t = \alpha (Y_t - F_t) + (1 - \alpha) (m_{t-1} + r_{t-1}) \quad (2)$$

$$F_t = \beta (Y_t - m_t) + (1 - \beta) F_{t-s}$$

$$r_t = \gamma (m_t - m_{t-1}) + (1 - \gamma) r_{t-1}$$

The multiplicative seasonality model is given by:

$$Y_t = (m_t + r_t) \times F_t + e_t$$

$$m_t = \alpha Y_t / F_t + (1 - \alpha) (m_{t-1} + r_{t-1}) \quad (3)$$

$$F_t = \beta Y_t / m_t + (1 - \beta) F_{t-s}$$

$$r_t = \gamma (m_t - m_{t-1}) + (1 - \gamma) r_{t-1}$$

where:  $m_t$  is the estimated deseasonalised mean level at time  $t$ ;

$F_t$  is the estimated seasonal factor for period  $t$ ;

$r_t$  is the estimated trend term for period  $t$ ;

$s$  is the number of observations in seasonal cycle, e.g. 12 monthly;

$\alpha$ ,  $\beta$ ,  $\gamma$  are parameters; and

$e_t$  is an error term.

In order to estimate the parameters of these models the equations are included in an algorithm. The process is initiated by calculating starting values for the mean, trend and seasonal factors and proceeds by trying different values between 0.1 and 0.9 for each of the parameters<sup>2</sup>. The set of parameter values selected are those that give the lowest sum of squared errors. Forecasts are generated by the following equations:

$$\text{HWA: } \hat{Y} = (m_t + jr_t) + F_{t-s+j} \quad (4)$$

$$\text{HWM: } \hat{Y} = (m_t + jr_t) F_{t-s+j} \quad (5)$$

where  $j$  is the lead time.

The coefficients of the Holt-Winters models estimated for milk output are for the period April 1970 to March 1980 :

$$\text{HWA: } \hat{Y}_t = (195.0 + j0.450) + (F_{t-s+j}) \quad (6)$$

$$\text{HWM: } \hat{Y}_t = (1078 + j1.470) \times (F_{t-s+j}) \quad (7)$$

The smoothing coefficients used to estimate the local mean, trend and seasonal factors for milk output are inserted into the multiplicative model:

$$m_t = 0.6 Y_t/F_t + (1-0.6) (m_{t-1} + r_{t-1})$$

$$F_t = 0.9 Y_t/m_t + (1-0.9) F_{t-s}$$

$$r_t = 0.1 (m_t - m_{t-1}) + (1 - 0.1) r_{t-1} \quad (8)$$

The interpretation of each coefficient is that the nearer it is to unity the greater is the weight placed upon the current observation in estimating each factor. Parameters used to estimate the mean and the seasonal factor tend to be greater than that for the trend. A similar interpretation would be placed upon the parameters of the additive model.

Both models give more accurate forecasts than the linear trend. The Holt-Winters additive model with a MAPE of 5.07% is slightly better than the multiplicative model with a MAPE of 5.10%. The trend term in the Holt-Winters additive model is 0.450 which is directly comparable with the trend term in the linear trend model of 1.812. Thus, in each month milk production is predicted to be 0.450 million litres greater than the previous month. As can be observed in Figure 3, the additive model does not greatly overestimate the winter months, whereas the multiplicative model in Figure 4, with a trend term of 1.470, overestimates slightly.

#### Box-Jenkins ARIMA Model

Reconsider the milk output graph in Figure 1. The series shows

FIGURE 3.

FORECAST AND ACTUAL APRIL 1980 TO MARCH 1984

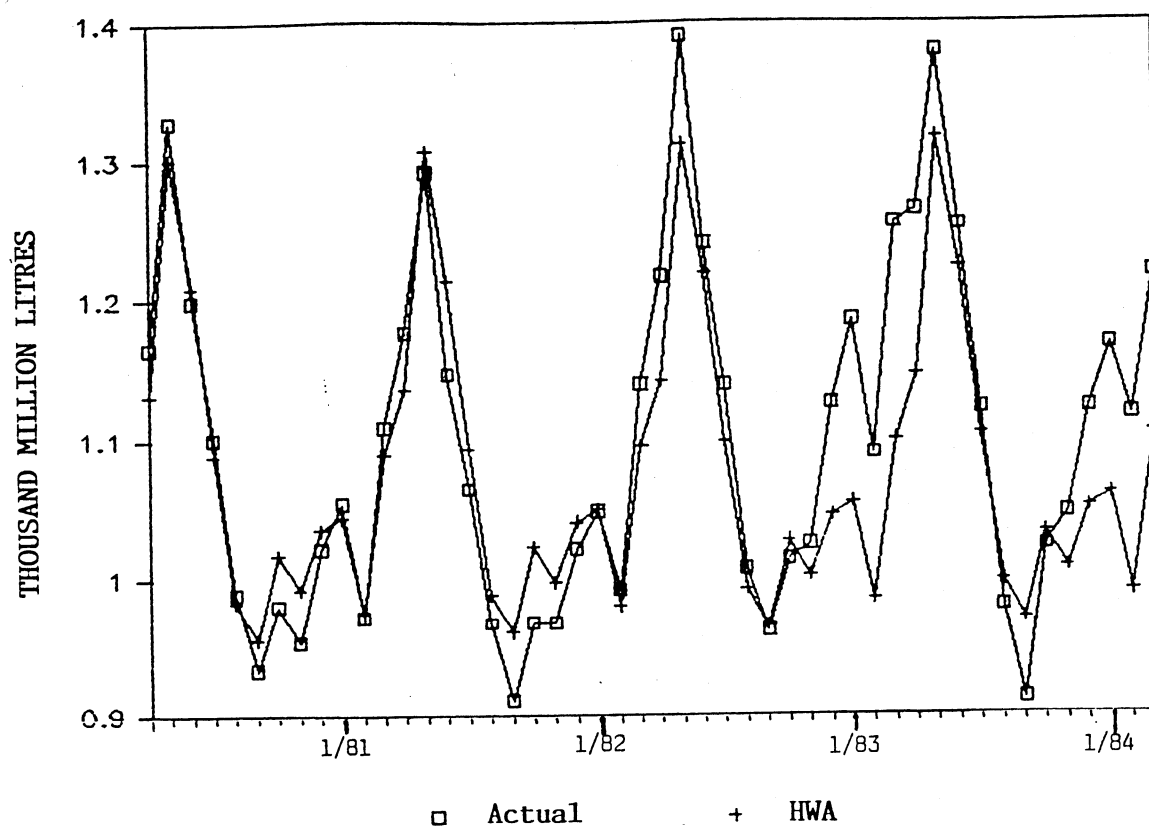
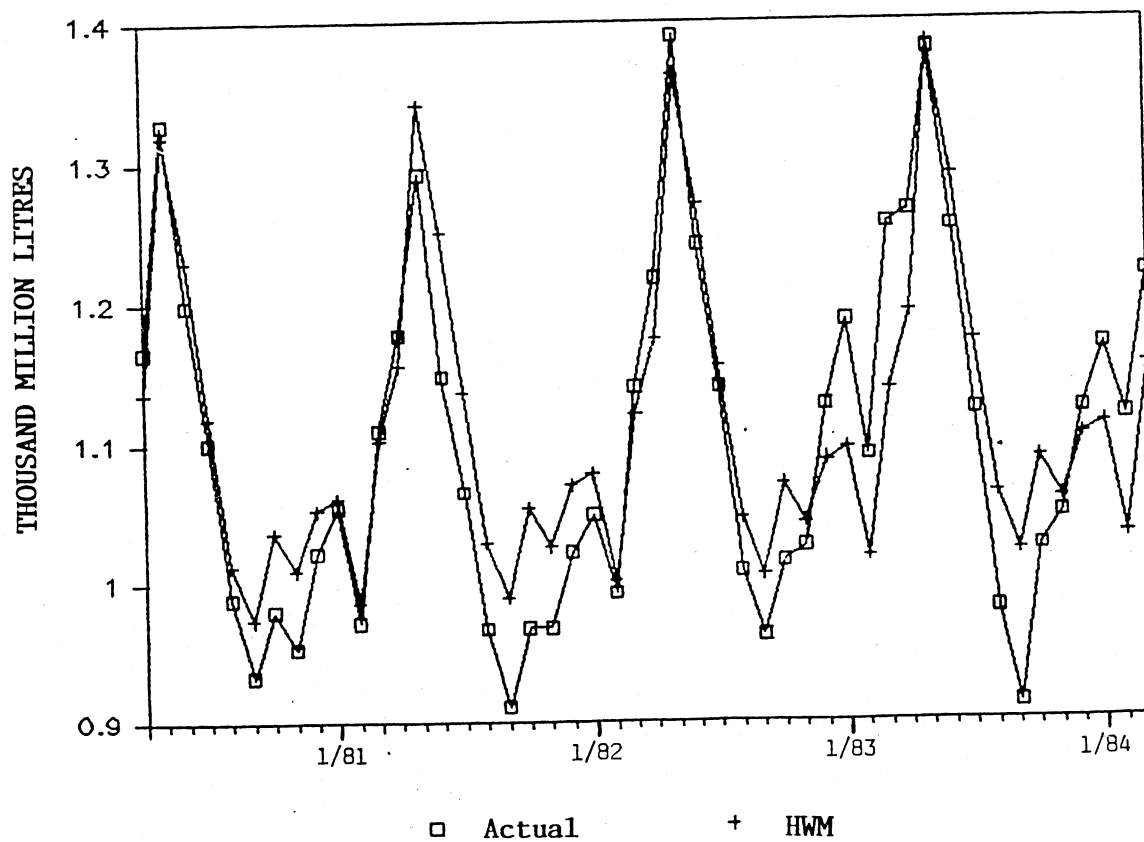


FIGURE 4.

FORECAST AND ACTUAL APRIL 1980 TO MARCH 1984



nonstationary seasonality and trend features. This is confirmed by the autocorrelation function (a.c.f) which remains significant even after 24 lags. Evidence of a trend and seasonality lead to the prescription of first and seasonal differencing to convert milk output into a stationary series. The a.c.f. and partial autocorrelation function (p.a.c.f) given in Figures 5 and 6 suggest that the first differenced seasonally differenced series is stationary, with only one autocorrelation at lag 12 falling outside the estimated two standard errors<sup>3</sup>. This is accepted as sufficient evidence that the differenced series,  $Z_t$ , is stationary.

The model proposed following an inspection of the a.c.f. and trial estimation is (0, 1, 4, 0, 1, 1, 12) which follows the usual convention (see Box and Jenkins 1970). The estimated equation is :

$$Z_t = (1 + \underset{(0.50)}{0.050B^1} - \underset{(0.74)}{0.071B^2} - \underset{(2.61)}{0.240B^3} - \underset{(2.62)}{0.260B^4}) (1 - \underset{(7.75)}{0.698B^{12}}) e_t$$

$$\hat{\sigma}_e = 513.9 \quad Q = 32.49 \quad (9)$$

where:

$Z_t$  is the differenced series  $Z = (Y_t - Y_{t-12}) - (Y_{t-1} - Y_{t-13})$ ;

B is a backshift operator such that:

$$Y_{t-1} = Y_t B^1$$

Q is the Box-Pierce Statistic<sup>4</sup>.

The seasonal moving average parameter was readily identified.

FIGURE 5

A.C.F. OF FIRST DIFFERENCED SEASONALLY  
DIFFERENCED SERIES

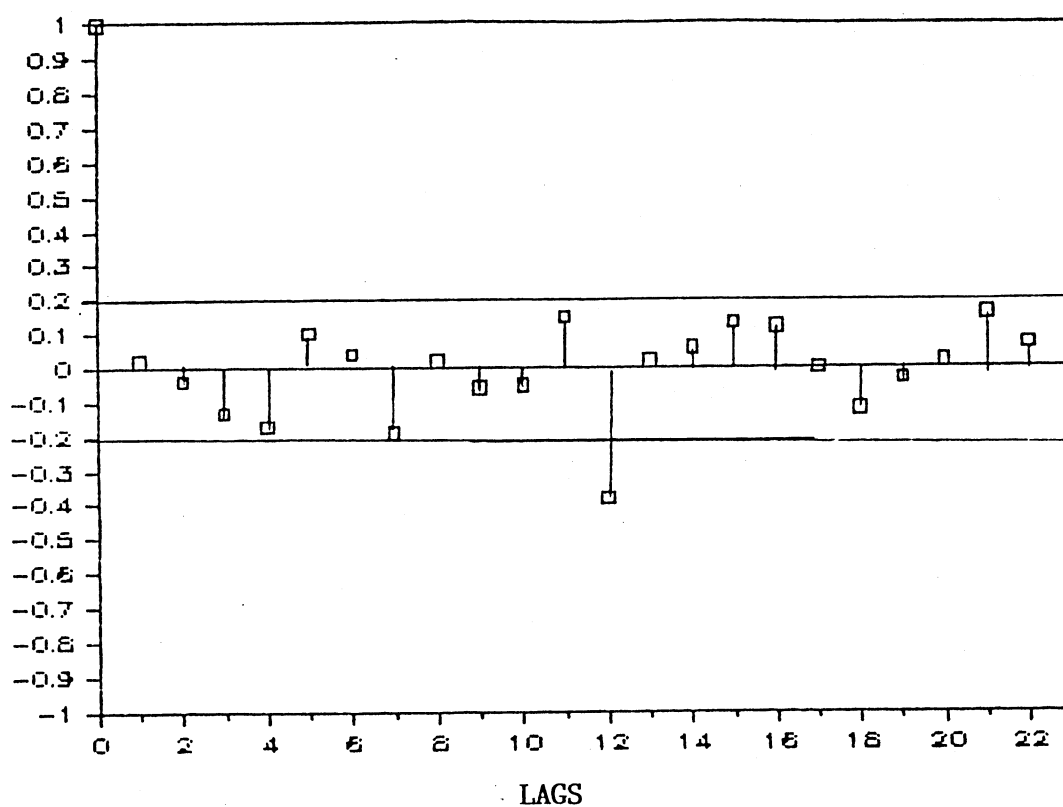
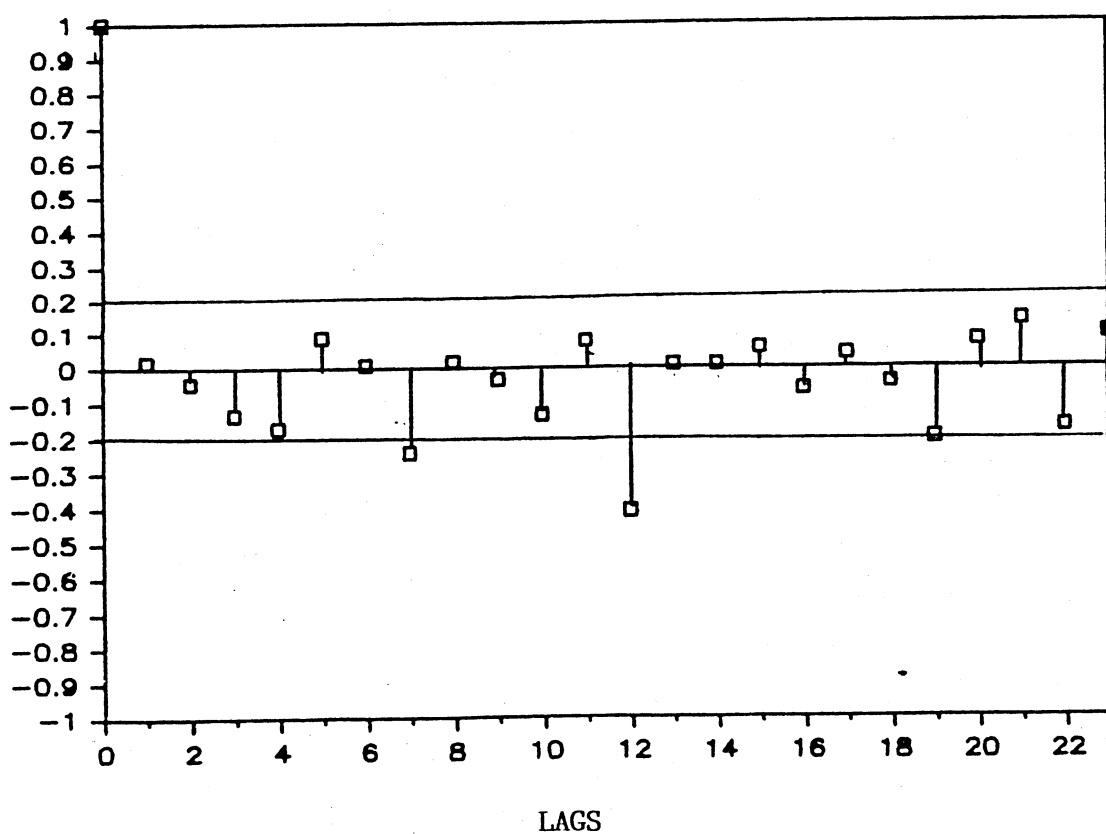


FIGURE 6

P.A.C.F. OF FIRST DIFFERENCED SEASONALLY  
DIFFERENCED SERIES



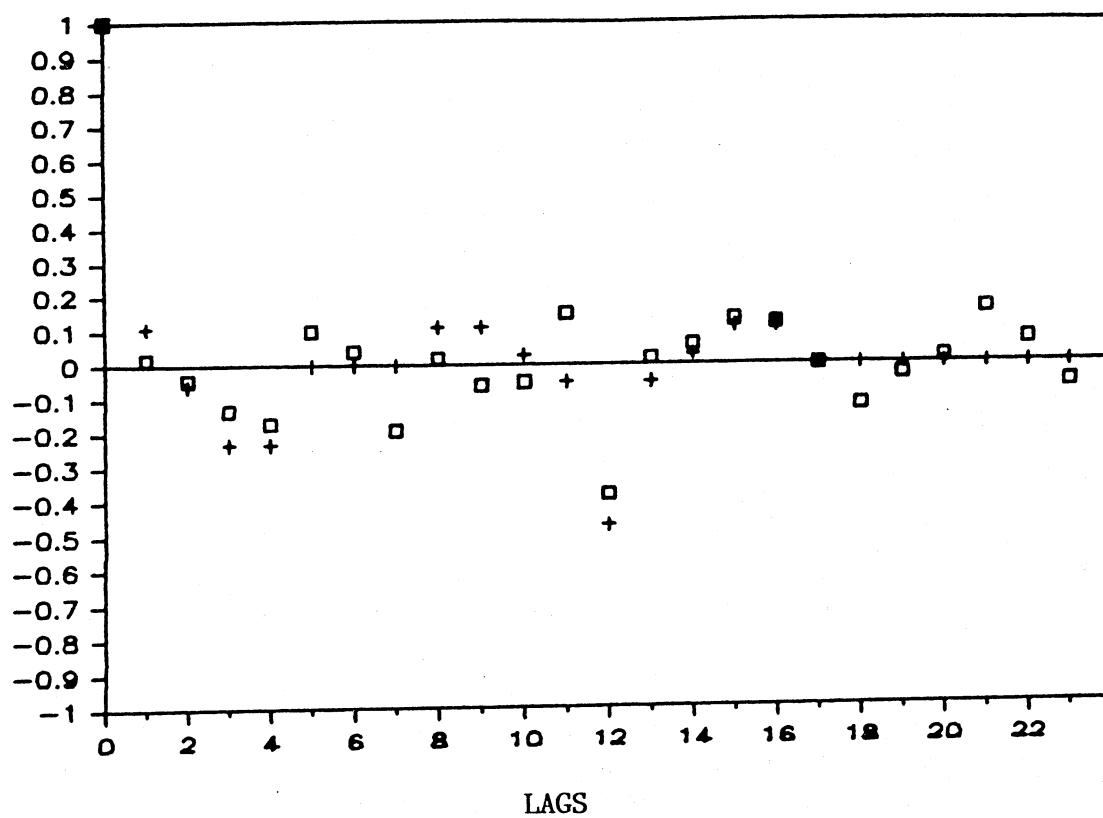


However, the order of the non-seasonal moving average parameters proved more difficult to establish. The final model was determined by repeated estimation, increasing the order of the moving average process until the last parameter was not significantly different from zero at the 95% confidence level (one tailed t-test). The moving average parameters at lags one and two, although insignificant, are left in the model, because the estimation process does not facilitate their removal.

The first stage in checking the model is to examine the residuals to ensure that they are white noise with a constant variance. In fact they exhibit heteroscedasticity towards the end of the series, which suggests that the series remains slightly nonstationary. In the residual a.c.f, there are no values greater than two standard errors. Furthermore, the Box-Pierce Q statistic<sup>4</sup>, designed to pick-up more diffuse characteristics within the residuals, is below the critical value at 95% in a chi-squared test. This implies that the residuals are uncorrelated white noise and the true residual a.c.f is zero. Finally, the theoretical a.c.f. calculated from the model is compared with the sample a.c.f. This test aims to highlight any marked divergences between the a.c.f implied by the estimated model and the sample a.c.f. If there is a significant difference between the two this would lead to a reconsideration of the model as the sample a.c.f is suggesting a different model from the one estimated. In Figure 7 the two series are seen to show a similar pattern. On the basis of the four diagnostic checks applied we accept the model as a reasonable representation of the series. A caveat is the heteroscedasticity observable in the residuals.

FIGURE 7.

THEORETICAL A.C.F. (+) AND SAMPLE A.C.F. (□)  
COMPARED FOR EQUATION 11.



Having accepted the model on the basis of the standard diagnostic checks it is appropriate to proceed to an assessment of forecasting performance. The ARIMA model gives a MAPE of 5.54% over the forecast period. From Figure 8, it is seen that the model tends to overestimate output during the winter months.

The forecasting performance of the ARIMA, Holt-Winters and linear trend models are compared in Table 1. This summarises previous results.

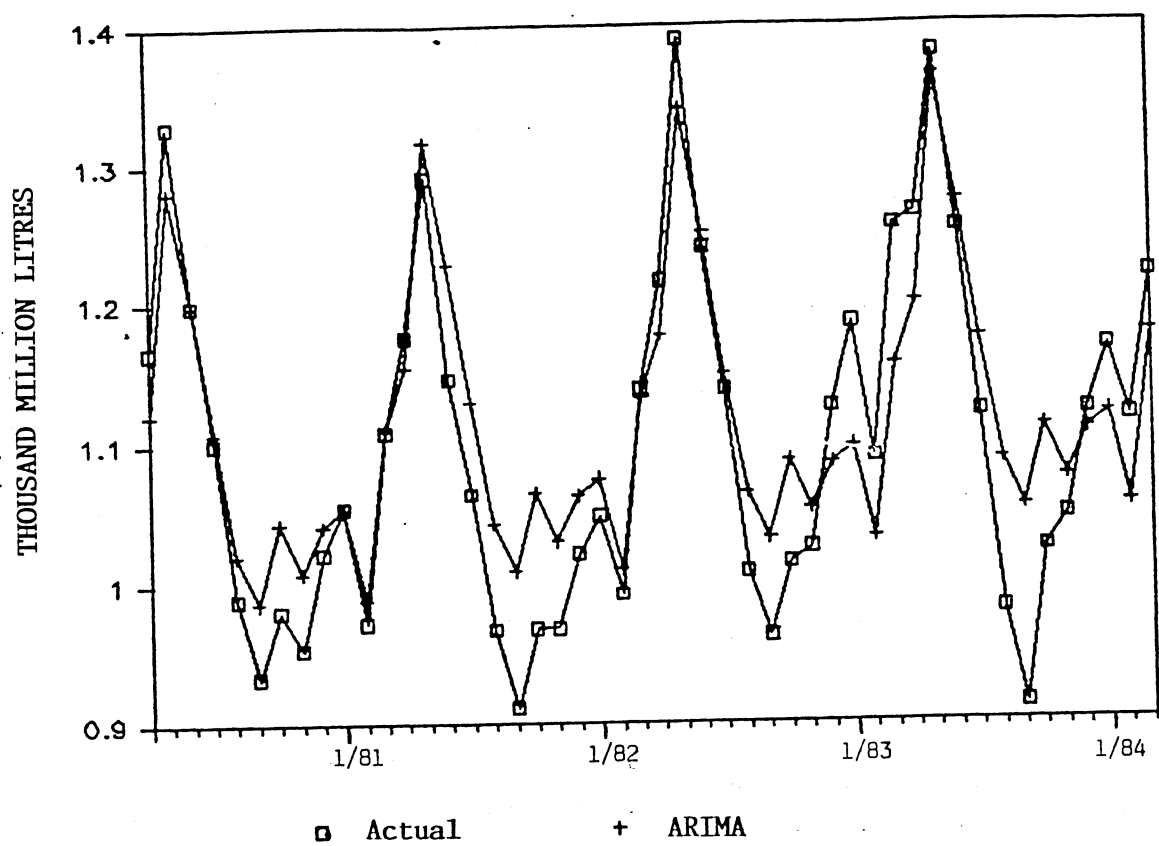
TABLE 1.      Comparison of Forecasting Performance for the Period  
   April 1980 to March 1984

	MAPE %
Holt-Winters Additive	5.07
Holt-Winters Multiplicative	5.10
ARIMA	5.54
Linear trend	8.71

Let us now compare the forecasting performance of each extrapolative technique. Of the forecasting methods, the Holt-Winters models provide the most accurate forecasts, with the additive model being slightly better than the multiplicative model. We can draw two conclusions. First, that the ARIMA and Holt-Winters models give significantly better forecasts than the linear trend model. Second, establishing a completely stationary series using differencing and transformations is not always possible, even for a

FIGURE 8

FORECAST AND ACTUAL APRIL 1980 TO MARCH 1984



comparitively regular series like milk output. It is therefore important to recognise those situations where the application of a single ARIMA model with time-invariant parameters is inappropriate, and to identify at the outset those features within a series likely to give rise to nonstationarity of a form that cannot be eliminated by either differencing or transformation.

The Holt-Winters additive model generates slightly more accurate forecasts than the ARIMA model. It is important to note that the additive model is equivalent to the ARIMA model given in (10)<sup>5</sup>.

$$(1-B^1)(1-B^{12})Y = (1+\theta_1 B^1 + \theta_2 B^2 + \theta_s B^s + \theta_{s+1} B^{s+1} + \theta_{s+2} B^{s+2})e_t \quad (10)$$

Thus, for the Holt-Winters additive model to be an optimal estimator the series must be generated by a process of the form illustrated in (10), where the parameters  $\theta_1$ ,  $\theta_2$ ,  $\theta_s$ ,  $\theta_{s+1}$  and  $\theta_{s+2}$  are all functions of the parameters  $\alpha$ ,  $\beta$  and  $\gamma$ . Since Holt-Winters is a form of ARIMA model, it follows that the Box-Jenkins procedure in principle should produce superior forecasts for any series which does not conform strictly to the model given in (10). However, this is based on the assumption that the Box-Jenkins procedures are used to identify the correct model for the series and that the series is stationary. In the case of milk output, forecasts from the Holt-Winters and ARIMA models are similar. Assuming that the ARIMA model is correctly identified, the slightly inferior forecasts generated from the ARIMA model may be explained in terms of the series being slightly nonstationary even after the application of differencing. It also follows

from (10) that the Holt-Winters approach will tend to produce better forecasts of series that are stationary after the application of first and seasonal differencing than those that remain nonstationary. Moreover, the Holt-Winters additive model generates forecasts at a fraction of the cost in terms of both manpower and computer time.

### 3. The Effect of Quota

A drawback with the Holt-Winters model is that although it copes adequately with regular series it cannot be extended to represent a discontinuity within a series. For the purposes of this paper a discontinuity is defined as a feature, other than trend and seasonality, that is distinguished as either a distinct shift in the level of the local mean or a change in the direction or magnitude of the trend. In the case of milk output such features are related to shocks; like weather effects or policy measures. For instance, the 1975 drought is an example of a weather shock and the introduction of quotas is an illustration of a policy shock. Both of these events disturbed the otherwise regular pattern exhibited by the series. Occurrences of such features brings into question the application of extrapolative forecasting techniques, especially those like the ARIMA model, that depend upon stationarity. Discontinuity features can be looked upon as a source of nonstationarity, and if not accounted for explicitly within the model, could give rise in some instances to model instability or degeneracy. It is in the situation where a series exhibits discontinuities that extended ARIMA models, including terms to account for discontinuities, are to be preferred. These are now discussed as a means of modelling output following the imposition of milk quotas.

The imposition of quotas in April 1984 immediately changed the characteristics of the milk output series. First, the direction of the trend within the series was switched from being positive, to constant, and second, there was a corresponding, although less clearly, identifiable effect upon the seasonal pattern of output. Clearly these changes in the

characteristics of the milk output series must be incorporated into forecasts for the post-quota period. But in attempting to do this the forecaster is faced with the problem that any extrapolative models estimated prior to the quota are unlikely to generate valid forecasts over the quota period. Furthermore, the model adopted must represent a discrete downward shift in a series (the extrapolative models described in Section 2 can only model the trend and seasonal characteristics of the series).

This section illustrates first the effects of quota by updating the ARIMA and Holt-Winters additive model up to March 1984 and then uses these models to forecast 12 months ahead up to March 1985. Second, the ARIMA model is extended to include a dummy variable to represent the quota effect (the discontinuity model). This is then re-estimated up to March 1985. Forecasts from the discontinuity model for the April 1985 to July 1985 period are then compared with those generated from ARIMA and Holt-Winters models which are also re-estimated up to March 1985.

The ARIMA model estimated for the period April 1970 to March 1984 is:

$$\begin{aligned}
 z_t = & (1 + 0.13B^1 - 0.146B^2 - 0.177B^3 - 0.211B^4) \\
 & \quad (0.16) \quad (1.82) \quad (2.21) \quad (2.60) \\
 & (1 - 0.667B^{12}) e_t \\
 & \quad (9.19) \\
 \hat{\sigma}_e = & 600.1 \quad Q = 31.67
 \end{aligned} \tag{11}$$

The Holt-Winters additive model estimated for the same period is:

$$\hat{Y}_t = (303.46 + j5.01) + F_{t-s+j} \tag{12}$$



On the LHS of Figure 9 actual values of milk output and forecast values generated from (11) and (12) are drawn for the period April 1984 to March 1985. It is observed that both models overestimate milk output over this period. The MAPEs for the ARIMA and Holt-Winters models are 15.21% and 18.19% respectively. This represents a marked deterioration in accuracy, compared with the four-year period discussed in Section 2, over which a MAPE of around 5.5% was calculated for both models. The difference between forecast and actual is also accounted for by the drought in the summer of 1984 causing a further reduction in output beyond that explained by the quota. The decline in forecast accuracy is considered unacceptable. Thus, the discontinuity model is proposed as a means of improving forecast accuracy. The model estimated for the period to March 1985 is:

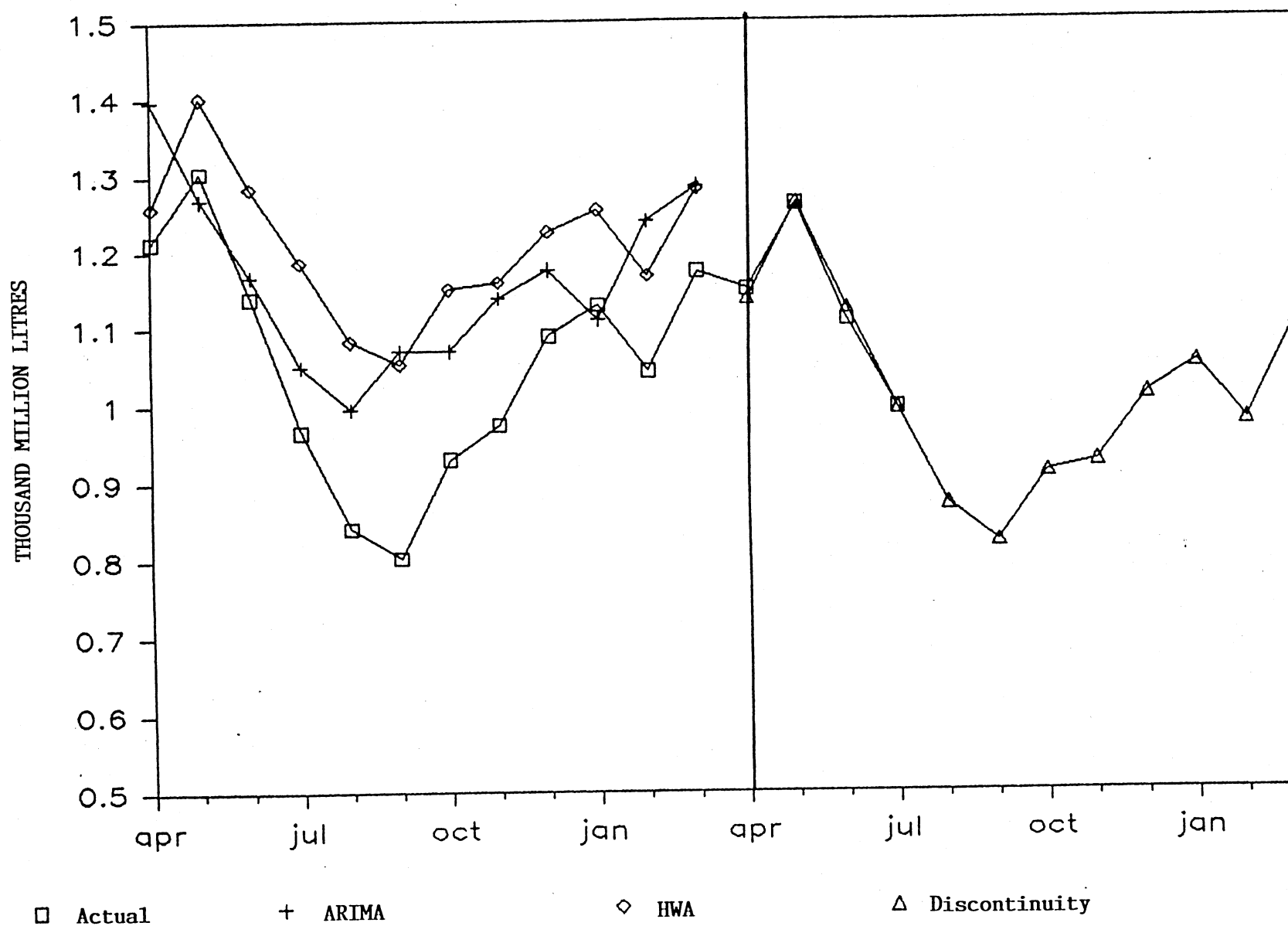
$$\begin{aligned}
 (1-B^1)(1-B^{12})Y_t &= 200 (1-B^1)(1-B^{12})D_t + (1+0.107B^1) \\
 &\quad - 0.08B^2 - 0.153B^3 - 0.182B^4 (1-0.700B^{12})e_t \\
 &\quad (0.53) \quad (1.09) \quad (1.30) \quad (3.68) \quad (13) \\
 \hat{\sigma}_e &= 658.8 \quad Q = 24.56
 \end{aligned}$$

Where:  $D_t$  is a dummy variable taking a value of 0 prior to April 1984 and 1 after April 1984 up to March 1985.

Figure 9 also shows the actual values of milk output for the period April 1985 to July 1985 and forecast values of milk output generated from (13) for the period April 1985 to March 1986. This can be seen on the RHS of the graph.

FIGURE 9

FORECASTS AND ACTUAL APRIL 1984 TO MARCH 1986



In order to assess whether the discontinuity model forecasts more accurately than Holt-Winters and ARIMA models, forecasts are estimated for the period April 1985 to July 1985. The results are given in Table 2.

Table 2      Comparison of Forecasting Performance for  
the period April 1985 to July 1985

	MAPE
Discontinuity model	0.86%
Holt-Winters Additive	6.85%
ARIMA	4.08%

It is clear that the discontinuity model gives the most accurate forecasts by a substantial margin. Thus we conclude that the discontinuity model is potentially the best model for the post-quota period, whereas the Holt-Winters additive model was deemed the best for the pre-quota period.

Following April 1984 producers adjusted gradually to quota, and for the first two months output remained at about the same level as that for the corresponding period in 1983. From June 1984 onwards, through to August, output dipped well below 1983 levels, this was due in part to the quota, and in part, to a drought. The reduction was such that overall it

seemed that output would fall short of the quota for England and Wales. However in the Autumn, output increased and moved back towards 1983 levels. Perhaps producers were responding to the knowledge that the U.K. as a whole was running considerably under quota and that it was probable that there would be no super-levy. Thus by March 1985 output for the year totalled 12601.1 million litres, just 0.7% over the quota for England and Wales of 12506.5 million litres.

Let us now turn to consider predictions for the year March 1985 to April 1986. The discontinuity model predicts a total output of 12181.0 million litres, some 1.6% below the quota level set at 12377.3 million litres. Up to July 1985 the model has predicted very accurately (see Figure 9), however, if producers in England and Wales respond to the knowledge that the U.K. is producing under-quota then output may increase during the Autumn above the levels predicted by the model.

#### 4. Conclusions

For milk output, the pre-quota forecasts generated by the two Holt-Winters methods and the ARIMA model are very similar. The forecasting performance of the ARIMA model would suggest that the time and effort involved in developing an ARIMA model is not justified and that automatic Holt-Winters forecasts are preferable. Moreover, this application exemplifies the problems of establishing stationary series even for comparatively regular and predictable series. The residuals from the ARIMA model still exhibit some nonstationary characteristics in the variance which are not readily removed by either differencing or simple transformations. It is proposed that such slightly nonstationary series are not perfectly simulated by a single ARIMA model with time-invariant parameters.

The extension of the ARIMA model to include a discontinuity term provides an approach to forecasting the milk output series following the imposition of quotas. This does illustrate the flexibility of the extended ARIMA model and the scope for applying it to series which exhibit distinct and identifiable nonstationary features. On this basis, where forecasts are required for a series showing a trend and regular seasonality, it is probable that Holt-Winters will perform adequately. However, where the characteristics of a series are less regular, the discontinuity model offers an approach to forecasting such series not appropriate to the more rigid Holt-Winters formulations. Initial forecast estimates would suggest that the discontinuity model provides more accurate

forecasts than the Holt-Winters or the standard ARIMA models in the post-quota period. It is envisaged that this approach will find applications to other agricultural output series, where the prescence of discontinuities reduces the effectiveness of standard extrapolative models.

Footnotes.

1:

$$MAPE = 100 \times \frac{1}{T} \sqrt{\sum_{t=1}^T \left( \frac{\hat{Y}_t - Y_t}{Y_t} \right)^2}$$

$Y_t$ : actual series in period  $t$ ;  $\hat{Y}_t$ : forecast for period  $t$ ;  $T$ : number of observations.

The MAPE may be interpreted as the average forecast error expressed as a percentage of actual values. Thus, the smaller is the MAPE the better are the forecasts. For instance, a MAPE of 5% states that on average the difference between the forecast and actual values is 5% of the actual value.

2. The parameters are constrained to be greater than zero but less than one to ensure that a positive weight is placed upon both the current estimate of a factor and the previous factor and that the factor estimates are stable and not dependant only upon the most recent estimate. For instance if the parameter was allowed to be one the factor in question would be that determined by the current estimate alone, which leads to unstable factor estimates.

3: This is given by:

$$\pm \sqrt{\frac{2}{T}}$$

4: The Box-Pierce Q statistic is given by:

$$Q = T \sum_{K=1}^K \hat{r}_K^2$$

where  $K$  is the maximum lag of the residual autocorrelations and  $\hat{r}_K^2$  are the residual autocorrelations.

5. See Granger and Newbold, 1977, pp.172.

## References

- BOX, G.E.P. and JENKINS, G.M. (1970) "Time Series Analysis, Forecasting and Control". San Francisco: Holden Day.
- BRANDT, J.A. and BESSLER, D.A. (1983) Price Forecasting and Evaluation: An Application in Agriculture. J.Forecasting, Vol.2. pp.237-248.
- CHATFIELD, C. (1978) The Holt-Winters Forecasting Procedure. Applied Statistics, Vol.27. pp.264-279.
- GENSTAT Manual. REL. 4.03 Part 1. Numerical Algorithms Group Limited: Oxford.
- GRANGER, C.W.J. and NEWBOLD, P. (1977) "Forecasting Economic Time Series." London: Academic Press.
- LARSON, D. (1983) Summary Statistics and Forecasting Performance. Agricultural Economics Research, Vol.35, No.3.
- LEUTHOLD, A.M. and MacCORMICK, A.M.A. et al. (March 1970) Forecasting Daily Hog Prices and Quantities: A Study of Alternative Forecasting Techniques. Journal of American Statistical Association, pp.90-107.
- MELLOR, C.J., RAYNER, A.J. and YOUNG, R.J. (1984) "Using Economic Theory in Identifying Time Series Models - A Case Study of Cereal Area Response in Great Britain." Nottingham University Discussion Paper 41.
- M.M.B. Dairy Facts and Figures (various editions).
- PINDYCK, R.S. and RUBINFELD, D.L. (1976) "Econometric Models and Economic Forecasts." New York: McGraw-Hill.



The Department of Agricultural Economics and the Department of Agricultural and Food Marketing launched the following series of Discussion Papers in the Spring of 1982. The titles available are:

- DP 1      Evaluation of 1982/83 Price Proposals for the CAP  
Kenneth Thomson and Lionel Hubbard
- DP 2      Forecasting EEC Support Prices  
Christopher Ritson
- DP 3      Cereals and the CAP  
Kenneth Thomson
- DP 4      CAP Budget Projections to 1988  
Kenneth Thomson
- DP 5      Herd Size and the Impact of Reducing EEC Dairy Support Prices  
Lionel Hubbard
- DP 6      The CAP for Fruit and Vegetables: Its Impact on Third Countries  
Christopher Ritson and Alan Swinbank
- DP 7      The Urban-Rural Income Gradient and the Pressure of Demand on Labour  
Martin Whitby and Lionel Hubbard
- DP 8      The 1984/85 CAP Price Proposals: An Evaluation and Some Observations  
David Harvey and Kenneth Thomson
- DP 9      Sheep Numbers and Heather Conservation on Common Land in the North of England  
Michael Topham
- DP 10     Agricultural Marketing: Its Relevance to the UK Farming Sector  
Rosalind Warren
- DP 11     Setting Optimal Advertising Budgets in the Northern Ireland Milk Market  
Paul Hayden
- DP 12     An Economic Analysis of the U.K. Early Potato Market  
Benedict White
- DP 13     Economies of Size in the England and Wales Dairy Sector  
P.J. Dawson and L.J. Hubbard
- DP 14     Forecasting Milk Output in England and Wales  
Benedict White

These papers are priced at £3.00 each (including postage and packing in the UK and Eire) and are available from the Department of Agricultural and Food Marketing, The University, Newcastle upon Tyne NE1 7RU, or by telephone on Newcastle (0632) 328511 Extension 2932 (Agricultural and Food Marketing) or 2900 (Agricultural Economics). Please make cheques payable to the University of Newcastle upon Tyne and send to the Department of Agricultural and Food Marketing.

