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Comparing the Box-Jenkins and Econometric Techniques for Forecasting Beef Prices *

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Most published studies which consider the forecasting of agricultural prices have utilized the econometric technique. In many non-agricultural forecasting situations, the Box-Jenkins technique has been found to be of equal accuracy. This paper compares the forecasting accuracy of the Box-Jenkins and econometric techniques for forecasting manufacturing-grade beef prices in the United States of America, and suggests that the Box-Jenkins technique may be the more accurate.

Introduction

Despite the wide interest in forecasting beef prices and the potentially major benefits from accurate forecasts, only limited work dealing with beef price forecasting has been published, and few of the forecasting models have shown any high degree of success. The studies have invariably used econometric models, partly because a prime goal has been to assess the factors influencing supply and demand by developing estimates of coefficients and providing elasticity and flexibility estimates [1] [5]. None of these studies has provided a comparison with other forecasting methods, however, other than where Theil's inequality coefficient has been reported thereby providing an implied comparison with a no-change model. In all cases the conclusion indicated has been that the econometric model(s) performed better than the no-change model—some considerably so, but in many instances only marginally so. The studies do not, however, compare the relative abilities when predicting turning points. This conclusion is, however, in direct opposition to the findings of a study by Teigen [15] which sought to compare the relative performance of different forecasting methods when forecasting cattle prices. Using monthly and quarterly prices for the period 1967–70 a comparison was made of econometric models, trend models, price difference models and the futures market price with the general conclusion that the overall best performing methods consisted of projecting either the current cash price or the corresponding futures price as the price to prevail in the forecast period. This therefore suggested that a simple naive forecasting method provided better results than more sophisticated methods.

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Thus, few techniques have been evaluated in published reports for forecasting beef prices, and little evidence exists to support the most commonly reported technique, the econometric model, as the most accurate technique available. In particular no use has been made of the Box-Jenkins technique, one which has shown considerable potential in non-agricultural forecasting areas. This article therefore seeks to extend the limited number of articles considering the forecasting of beef prices, and in particular to consider the ability of the Box-Jenkins univariate technique to provide accurate forecasts of beef prices.

Application

Beef in the United States may be classified by its major end-use, manufacturing beef referring to beef used for hamburgers, sausages, etc., while non-manufacturing beef is largely used for table-cuts. Within the manufacturing beef category cows of the cutter and canner grade provide a significant proportion of the beef originating from United States sources, with some 30 per cent of manufacturing beef being imported. This article evaluates the accuracy of one period ahead forecasts of the wholesale price of canner and cutter cow beef using both quarterly and monthly price data. Quarterly data are used to provide forecasts one quarter ahead, and monthly data provides forecasts one month ahead.

The extent to which canner and cutter cow beef prices have fluctuated in the past is shown in Figure 1 which indicates quarterly prices over the period 1966–75. Within years, quarterly price fluctuations show a general inverted U shaped pattern, indicating a rise in price in the first part of the year followed by a decline in the second part. In some years the decline commences in the third quarter while in others the fall-off does not occur until the fourth quarter. This pattern was consistently shown until 1974 when the liquidation phase of the long-run cattle cycle masked the seasonal cycle. In 1975 price fell in the first quarter, rose in the second and fell in the third and fourth. Thus a fairly consistent seasonal pattern shows for all years except 1974 and 1975, although minor variations have occurred within the basic pattern.

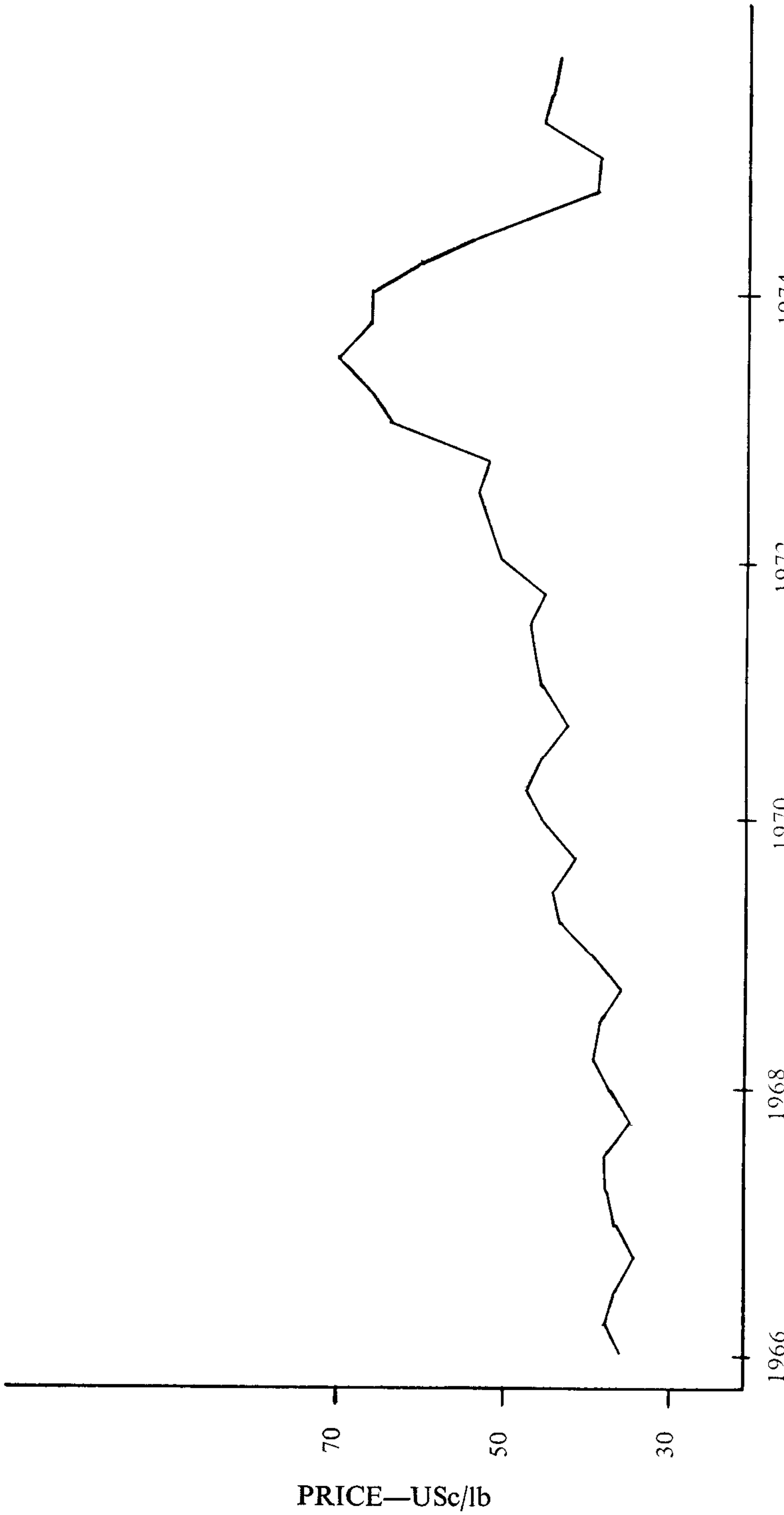
The Box-Jenkins Method

Details of the Box-Jenkins approach may be found in [3] with general discussion found in, for example, the articles by Newbold [13], and that of Geurts and Ibrahim [7]. Helmer and Johansson [8] discussed the application of the Box-Jenkins transfer function analysis as distinct from the more commonly used univariate analysis, the method considered in this study.

General Procedure of the Box-Jenkins Method

The procedure used is one of identification, estimation, and diagnostic checking, a procedure that is repeated until a satisfactory model is obtained. The identification and diagnostic checking stages make use of autocorrelation and/or partial autocorrelation functions to firstly determine whether the data series is a stationary time series, and secondly the most appropriate class of model to use. Stationarity in the time series implies that the expected value of an observation is the same—that is, there is no trend present. If the series is non-stationary it is possible to achieve stationarity by differencing—both

Figure 1: Quarterly Wholesale Price of Canner/Cutter Cow Beef, 1966–76



regular and seasonal. Having achieved a stationary series the autocorrelations and/or partial autocorrelations are employed to select an appropriate class of model which may be tentatively considered. The model is then fitted to the data and its parameters estimated. Diagnostic checks are applied to determine any possible inadequacies in the model, and the process repeated if any are found. This procedure continues until a suitable model is found.

A wide variety of model forms may be developed including forms which take account of seasonal fluctuations in the data, as well as possible trend elements.

Specific Model Forms Used

The broad study of which this reported analysis was part sought to compare a wide variety of forecasting models, and rather than develop "new" models for each forecasting technique sought to use models developed by other research workers whenever possible. In this respect models which had been reported—and which were considered by the authors to be acceptable models of the beef sector in general and manufacturing beef in particular were reviewed and tested.

In the case of econometric models only a relatively few reported models are oriented towards manufacturing beef, while the Box-Jenkins method has had virtually no exposure in the beef sector. As a consequence it became necessary to develop new Box-Jenkins models while modifying existing econometric models.

A number of simultaneous equation models were considered for use, with the models of Langemeir & Thompson [10], Paulsen [14], Graeber [6], Crom [4] and Bain [1] finally being selected for further evaluation.

All models and modifications were tested on quarterly and monthly data and the modified Paulsen model chosen for use. Of the models selected for further evaluation the Paulsen and Crom models do not differentiate between manufacturing and non-manufacturing beef, and it is of considerable interest that a model developed to forecast choice beef prices was found to be more accurate when forecasting manufacturing beef prices than those models which specifically differentiated between the two categories of beef. And of further interest is the fact that the final form of the Paulsen model, as used in this study, shows only minor changes from the original model. In the modified form it was found that neither the inclusion of a separate equation for manufacturing beef additional to the original model form, nor the use of non-manufacturing beef consumption rather than beef consumption in total gave as satisfactory results as the form chosen. In fact, both the inclusion of total manufacturing beef, and its separation into United States manufacturing beef and imports gave considerably poorer results.

Since both the Box-Jenkins method and the simultaneous equation econometric method develop a model specific to the data, four models were developed, a quarterly model for each method and a monthly model for each method.

Quarterly Box-Jenkins Model

Inspection of the autocorrelations of the raw data, first differences, and second differences produced by the identification runs suggested that an initial model could be developed without differencing the data.

The identification of a suitable model for estimation did present some difficulties since a number of possibilities were apparent. Under these circumstances Box and Jenkins suggest that the most appropriate models be estimated and selection based on study of the results. The potential models were therefore estimated and evaluated using firstly, study of the pattern of the autocorrelation of the residuals; secondly, significance of each autocorrelation of the residuals measured by their standard errors; and finally, the level and significance of the Root Mean Square Error (RMSE). Other aids to the evaluation were the confidence limits placed on forecasts, and the general trend of the forecasts.

The form of the model finally selected for fitting was

$$(1 - \theta_1 B)(1 - \theta_s B^4)Z_t = (1 - \varphi_s B^4)u_t$$

where Z_t is the time series of data observations, u_t are random disturbances, θ and φ are weights, and B is a "backshift operator" such that $B^j Z_t = Z_{t-j}$. which when fitted yielded the following estimates (with estimated standard errors in brackets):

$$\hat{\theta}_1 = 0.938\ (0.081)$$

$$\hat{\theta}_s = 0.960\ (0.035) \quad \text{S.E.} = 3.300$$

$$\hat{\varphi}_s = 1.021\ (0.094)$$

This model involves a regular autoregressive element, a seasonal, autoregressive element, and a seasonal moving average element.

The forecasting form of this model was

$$(1) \quad Z_{t+1} = 0.93812Z_t + 0.95955Z_{t-3} - 0.90017Z_{t-4} + u_{t+1} - 1.021u_{t-3}$$

The forecast price, therefore, involves the current price (Z_t) and those 3 and 4 periods previous, together with the forecast error for time $t + 1$ (taken as zero since it is unknown at this stage) and $t - 3$.

Monthly Box-Jenkins Model

For the monthly data it was apparent that a first difference was necessary to achieve stationarity. The seasonal pattern shown by the data suggested that first seasonal differences might be appropriate, that is, $\nabla_{12}Z_t$ became the basic data, where $\nabla_{12}Z_t = Z_t - Z_{t-12}$. Autocorrelations for the first seasonal differences appeared to give better results while having the general sinusoidal shape which suggested a second-order autoregressive formulation

$$(1 - \varphi_1 B - \varphi_2 B^2)\nabla_{12}Z_t = u_t$$

Estimation of this tentative model and its subsequent revision resulted in the form

$$(1 - \varphi_1 B - \varphi_2 B^2)\nabla_{12}Z_t = (1 - \theta_1 B^{12})u_t$$

which when fitted yielded the following estimates (with estimated standard errors in brackets:

$$\hat{\varphi}_1 = 1.3175 \quad (0.0803)$$
$$\hat{\varphi}_2 = -0.3423 \quad (0.0792)$$
$$\hat{\theta}_1 = 1.0137 \quad (0.0440) \qquad SE = 3.253$$

This model involves a second-order autoregressive element and a seasonal moving average element.

The forecasting form of this model was

(2) $$Z_{t+n} = 1.3175Z_{t+n-1} - 0.3423Z_{t+n-2} + Z_{t+n-12} - 1.2175Z_{t+n-13} + 0.3423Z_{t+n-14} + u_{t+n} - 1.0137u_{t+n-12} \text{ for } n < 13$$

Quarterly Econometric Model

The Paulsen et al. [14] simultaneous equation model was modified to accommodate manufacturing grade beef, and the unrestricted reduced form equation used to forecast price.[1] A reduced form equation expresses a single endogenous variable (price in this case) as a function of all predetermined variables in the model.

Such reduced form equations may be (a) algebraically derived from the structural coefficients estimated by one of the simultaneous equation estimation methods (derived reduced form), or (b) fitted directly by ordinary least squares (unrestricted reduced form). Unless all structural equations are just identified the coefficients estimated by these two methods will not coincide, with the unrestricted estimates being asymptotically less efficient. In theoretical terms therefore in certain situations derived estimates should be preferred. There has been disagreement on this conclusion however, with a recent study [12] concluding there is little practical difference between the results obtained by the two methods.

Fitting the reduced form equation using ordinary least squares gave the result

(3) $$\underset{}{PCBW} = 13.504 - \underset{(3.47)}{2.052\,BCN} - \underset{(0.72)}{0.547\,PCN} + \underset{(3.43)}{9.496\,BRCN}$$
$$+ \underset{(0.78)}{3.730\,TRCN} - \underset{(0.17)}{1.655\,LCN} - \underset{(4.38)}{3.682\,UNEMP} + \underset{(0.38)}{1.084\,TIME}$$
$$+ \underset{(0.57)}{0.0227\,DLAG} + \underset{(1.56)}{9.473\,D1} - \underset{(0.03)}{0.139\,D2} - \underset{(1.51)}{2.799\,D3}$$
$$R^2 = 0.872 \quad F = 19.16^{**} \quad DW = 1.3974 \quad SE = 4.291$$

where: *BCN, LCN, PCN, BRCN, TRCN* = consumption respectively beef, lamb, pork, broiler and turkey meat (lbs/capita)
PCBW = undeflated wholesale price cow beef, US cents/lb.
DLAG = undeflated disposable income in period $t - 1$ (\$/capita)
UNEMP = per cent unemployment
TIME = coded value (1 = 1965, 2 = 1966, etc.)
*D*1 = dummy for quarter 1
*D*2 = dummy for quarter 2
*D*3 = dummy for quarter 3

[1] The original model considered choice beef, not manufacturing beef.

The model generally provides a suitable representation, although only four of the coefficients are significant at the 95 per cent level. Economically the model meets *a priori* expectations.

Monthly Econometric Model

For the monthly forecasting model the Paulsen simultaneous equation model was again modified, and the reduced form equation expressing price as a function of all pre-determined variables estimated by ordinary least squares. The forecasting model is

$$\begin{aligned}(4)\quad PCBW = {} & 47.44 - \underset{(1.276)}{0.604}\,BCN + \underset{(1.375)}{1.493}\,BRCN - \underset{(0.52)}{0.258}\,UNEMP \\ & - \underset{(0.031)}{0.017}\,PCN + \underset{(0.33)}{0.0049}\,DLAG - \underset{(1.98)}{1.08}\,Jan + \underset{(2.86)}{1.586}\,Feb + \underset{(3.74)}{1.902}\,Mar \\ & + \underset{(3.15)}{1.576}\,Ap + \underset{(3.00)}{1.577}\,May + \underset{(2.08)}{1.267}\,June + \underset{(1.38)}{0.783}\,July + \underset{(0.040)}{0.221}\,Aug \\ & + \underset{(0.025)}{0.118}\,Sep - \underset{(3.49)}{1.842}\,Oct - \underset{(5.77)}{3.535}\,Nov\end{aligned}$$

$$R^2 = 0.981 \quad F = 367.957^{**} \quad DW = 1.34 \quad SE = 1.52$$

The model is similar to the quarterly model with the exclusion of *LCN* and *TIME* which were deleted since they contributed little to the equation, and the substitution of monthly dummy variables (*January*, *February*, etc.) for the quarterly dummy variables.

The Cochrane-Orcutt iterative procedure was used to adjust for autocorrelation between the independent variables.

This procedure is necessary where autocorrelation is present since this condition, while providing unbiased estimates of the coefficients, will give biased estimates of the variances and will result in inefficient predictions. By using the Cochrane-Orcutt procedure alternative estimates which do not suffer from these shortcomings are produced.[2]

The model is acceptable on economic grounds since most signs conform to expectations. It does have low t values for three of the coefficients on the economic variables while having most monthly dummy coefficients with high t values.

Forecasting Comparison

Evaluation of the forecasts is based on:

(a) *Root Mean Squared Error* (*RMSE*)

$$RMSE = \sqrt{\Sigma(P_t - A_t)^2/N}$$

where P_t is the forecast value, A_t the actual value and N the number of time periods;

[2] See Kmenta, J. [9, p. 287] for a discussion of the procedure.

(b) *Theil's Inequality coefficient*[3]

$$U_2 = \sqrt{\Sigma(P_t - A_t)^2/N} \Big/ \sqrt{\Sigma(A_t - A_{t-1})^2/N}$$

(c) *Turning Points*

In addition to absolute accuracy it is essential in most instances that a forecasting model correctly anticipate turning points, particularly in short term forecasting. The test can be carried out in various ways and in general more than one measure needs to be reported to give a balanced picture of accuracy. Turning point evaluations may be separated into these which consider a turning point in the statistical sense, where an error relates to any forecast direction of change that does not agree with the actual direction of movement, and those which consider a turning point in the economic sense of a reversal of current trend. In this study the two are called "statistical turning points", and "cyclical turning points" respectively, although the latter are in many instances seasonal rather than cyclical turning points.

In evaluating cyclical turning points two types of errors are involved: (i) a turning point may be incorrectly predicted (Type I error) or (ii) none predicted when one actually occurs (Type II error).

Table 1: *Types of Turning Point Errors*

		Prediction	
		Turn	No Turn
Actual	Turn No Turn	*a* *b*	*c* *d*

Quantitative measures of these errors can be developed as:

$$f_1 = b/(a + b); \quad f_2 = c/(c + d).$$

Generally, the lower f_1 the better, but both must be considered in association since Type I errors may be avoided by never predicting a turning point, and similarly for Type II errors.

No definite statement can be made on which of these two types of errors will be most serious in a practical sense since this will depend on the situation in the market at the time of the forecast, and the activity of the user of the forecast.

For example it will be related to whether the market is rising or falling prior to the forecast, and whether or not the user is a buyer or seller of beef. If a seller, the impact will also be affected by whether the beef involved has

[3] Considerable variation exists in the form of this coefficient with many reported values being incorrectly estimated. Additionally an earlier coefficient (U_1) is reported by Theil [16] although he considers the U_2 coefficient more appropriate. Leuthold [7] has commented on the problem of incorrect usage while Bliemel [2] indicates that U_1 should not be used at all for ranking alternative forecasting methods.

already been bought or is about to be bought. Either type of error may have significant implications for those involved in the beef trade depending on the specific situation.

Evaluation of cyclical turning points in this study is based on both these types of errors using f_1 and f_2 as a basis of comparison. Entries involving the prediction of a turning point but in the wrong direction are classified in position *b* since they represent an incorrectly predicted turning point.

Results

Ideally, when evaluating forecasting accuracy the evaluation should be carried out on data outside the period of model development, since only then is the forecasting ability rather than explanatory ability of the model being assessed. In practice, this either requires the researcher to hold back any evaluation for some time, or to estimate the model on less current data. As a compromise situation the evaluation of forecasting models is commonly carried out firstly on sample period data and subsequently on a short period of data outside the sample period.

The models being evaluated in this study were assessed on the period 1966–75, the period the models were developed on, and then on one year (1976) outside this period. This represented a compromise between holding back more data to enable a longer true forecasting period, and developing the models on more current data. In both instances, however, the econometric model is offered the benefit of perfect knowledge of the independent variables, ensuring it performs better than would be the case in a true forecasting situation.

One final point that should be borne in mind is that the forecasts of both models represent mechanical estimates—in a practical situation the forecasts would almost certainly be modified by the forecasters judgement.

Comparison of the accuracy of the two forecasting methods indicates that during the period 1966–75 (sample period) the Box-Jenkins method gave more accurate forecasts than the econometric method when forecasting both quarterly and monthly prices. The RMSE's (Table 2) indicate however, that the differences were small. Both forecasting methods were considerably more accurate than a no-change simple model, as indicated by the level of the U coefficients.

In terms of forecasting turning points both methods gave closely similar results with the Box-Jenkins model slightly more accurate than the econometric model for quarterly forecasts while the reverse was the case for monthly forecasts.

Essentially, therefore, the two forecasting methods showed closely similar results for the period 1966–75, with the Box-Jenkins method marginally superior overall.

Table 2: *Forecast Evaluation*, 1966–75

	RMSE	U_2	Turning Point		
			Cyclical Errors		Statistical
			f_1 (per cent)	f_2 (per cent)	Correct (per cent)
Quarterly—					
Box-Jenkins	3.198	.791	60.0	50.0	62.2
Econometric	3.325	.823	62.5	53.8	62.2
Monthly—					
Box-Jenkins	1.469	.723	54.6	26.9	66.1
Econometric	1.482	.731	53.1	30.4	70.3

When forecasting outside the period of model development (1976) the Box-Jenkins models were again more accurate than the econometric models for both quarterly and monthly forecasts, when RMSE and the U coefficient are considered. Again, the extent of this superiority was not great, particularly for the monthly forecasts. The results do show that for monthly forecasts a simple no-change model would have given slightly more accurate forecasts. The econometric models show a lower degree of error in forecasting monthly turning points, however. No conclusions can be drawn concerning quarterly turning points as too few occurred.

Table 3: *Forecast Evaluation*, 1976

	RMSE	U_2	Turning Point		
			Cyclical Errors		Statistical
			f_1 (per cent)	f_2 (per cent)	Correct (per cent)
Quarterly—					
Box-Jenkins..	5.15	.759	NA	NA	NA
Econometric	5.52	.814	NA	NA	NA
Monthly—					
Box-Jenkins	3.471	1.064	75.0	14.3	81.8
Econometric	3.523	1.080	50.0	11.1	90.9

NA = Too few turning points occurred for valid comparison.

The greater inaccuracy of all models when forecasting outside the model development period is clearly indicated by the substantial increase in the values of the RMSE's.

Discussion

Two issues are involved in the interpretation of these results, (a) comparison of the two forecasting methods, and (b) conclusions on the adequacy of the forecasts produced by these methods for practical price forecasts.

In the case of a comparison of the two methods, the Box-Jenkins models were in general marginally superior to the econometric method. It may be considered, however, that the Box-Jenkins models are clearly superior since the econometric forecasts were produced under optimal conditions, in that the values of the independent variables used for all the forecasts were the known *ex-post* values of these variables.[4] In a practical forecasting situation these variable values would have to be forecast first, introducing considerably more error into the econometric forecasts. In the case of the Box-Jenkins models only past prices are required for the forecasts.

Conclusions on the adequacy of the forecasts produced by the two methods are more difficult since to a large extent this will depend on the use to which the forecast is to be put. And it is necessary to consider not only the two types of turning points, but also the two types of forecast errors that can occur when predicting statistical turning points.

Subjectively, however, the two methods performed adequately but not spectacularly. On average, forecast errors were less than 3 cents per lb for monthly forecasts while being up to 5 cents per lb for quarterly forecasts. In some isolated periods however, errors of up to 6.5 cents occurred.

It appears from the results that the Box-Jenkins method is superior to the econometric method for forecasting manufacturing beef prices, and therefore, that more use should be made of this method than has in fact occurred in agricultural forecasting situations.

Whether or not the methods considered are accurate enough for practical forecasting situations will depend on the accuracy of currently used methods. It should be noted however, that in practice the forecasts produced by these methods would be modified by the knowledge and experience of the user, to arrive at a final forecast. This will always be necessary since the findings of this study indicate that a high degree of accuracy cannot be expected from the methods evaluated.

[4] However, little is known about the form of the distribution of the Box-Jenkins forecasts unlike the econometric method for which the forecasts may have confidence limits specified

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