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PRICE RELATIONSHIPS FOR FROZEN APPLES AND TART CHERRIES*

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Extremely volatile price behavior is characteristic of the markets for apples and cherries. Unstable price behavior makes it particularly difficult for the industry to accurately anticipate future prices. Accordingly, uncertainty regarding the nature of the price determination forces can lead to serious marketing inefficiencies. To enable more effective production and marketing decisions, improved price forecasting methods are needed. Thus, the purpose of this paper is to examine the nature of the price structure within the apple and cherry industries by suggesting an appropriate analytical model and empirically evaluating its performance.

An Inventory Model

Since carryover levels of apples and cherries are hypothesized to be a major determinant of prices, a model is postulated that introduces inventory as a separate structural equation. This model is essentially an extension of that applied by McCallum [2] and Haley [1] and assumes the following mechanisms:

$$P_{t+1}^* - P_t = f(I_t), \text{ and} \tag{1}$$

$$f(I_t) = \beta_0 + \beta_1 I_t. \tag{2}$$

The equilibrium level of inventories is determined by equating the difference between anticipated prices (P_{t+1}^*) and current prices (P_t) with the supply of inventories $[f(I_t)]$ as a linear function of current

inventories (I_t) where $\beta_1 > 0$ and $\beta_0 \lesseqgtr 0$. The following adaptive expectations model is used,

$$P^*_{t+1} - P^*_t = \lambda(P_t - P^*_t), \tag{3}$$

where prices are defined as above and λ is the adjustment coefficient. Using the Koyck transformation and substituting equation (1) into equation (2), the equilibrium inventory (I_t) can be solved as:

$$I_t = -\frac{\lambda\beta_0}{\beta_1} + (1-\lambda)I_{t-1} - (\frac{1-\lambda}{\beta_1})(P_t - P_{t-1}). \tag{4}$$

When inventory enters the model as in equation (4), the market clearing condition is given by:

$$Q^d = I_{t-1} + Q^s - I_t, \tag{5}$$

where Q^d is quantity demanded, I_{t-1} is the carryover inventory, I_t is the inventory at the end of current period and Q^s is quantity supplied.

The demand specification is hypothesized to be,

$$Q^d_t = \alpha_0 + \alpha_1 P_t + \alpha_2 P^s_t + \alpha_3 P^I_t + \alpha_4 Y_t, \tag{6}$$

where P^s_t is the current price of a substitute for Q^d_t, P^I_t is the consumer price index, and Y_t is disposable personal income. It is expected that α_1, $\alpha_3 < 0$ and α_2, $\alpha_4 > 0$.

Current production (supply) is assumed to be exogenous, given as:

$$Q^s_t = Q_t + U_t, \tag{7}$$

where U_t is an independent normally distributed random error term.

Substitution of (4), (6), and (7) into (5) and solving for current price (P_t) yields:

$$P_t = \gamma_0 + \gamma_1 P^s_t + \gamma_2 P^I_t + \gamma_3 Y_t + \gamma_4 Q^s_t + \gamma_5 I_{t-1} + \gamma_6 P_{t-1} + V_t \tag{8}$$

where V_t is an independent normally distributed random error term, and γ_1, γ_3, $\gamma_6 > 0$ and γ_2, γ_4, $\gamma_5 < 0$. The sign of γ_0 is indeterminate.

There are three important points to notice with respect to the model in general and equation (8) in particular. First, the model is structurally underidentified so that estimation of equation (8) does not allow the derivation of unbiased estimates of the underlying structural parameters. Second, the model is structurally unstable, in the sense that analysis of the time path of equation (8) does not permit $0 < \lambda < 1$ for large values of α_1, the price coefficient of demand for frozen cherries. The range of values of α_1 and β_1 is extremely limited if $0 < \lambda < 1$, and unless unique values of α_1, β_1 are found within this small range, then $\lambda > 1$, in which case overadjustment results in an unstable and relatively volatile market. Finally, it should also be noted that serial correlation is introduced when lagged endogenous variables are used.[1]

Empirical Results

The data and estimation

The demand relationships can be estimated without the knowledge of the supply relation because of the biological nature of cherry and apple production. That is, significant supply response to price increases cannot take place during the current period because it takes some four to six years to bring an apple or cherry tree into production. Nonetheless, estimation of equation (8) requires the use of a simultaneous equation estimation procedure for two reasons. First, since much of the explanation of variation in prices is expected to be due to the influence of substitutes in the market, the market price of a substitute (P_t^S) is included as a current endogenous variable. In particular, the prices of frozen tart cherries and frozen apple slices are considered to be jointly determined. Therefore, the above model is specified for both the cherry and apple industries for purposes of estimation. Since the use of both cherry and apple models involves simultaneity and (in this case) over-identified systems, an appropriate estimation procedure is two-stage least squares (2SLS). If the disturbances are autocorrelated when lagged dependent variables are present, then OLS estimation is not the appropriate method [7]. Hence, the use of 2SLS by allowing the price of substitutes to be endogenous in the system is further justified by the fact that OLS is inappropriate if lagged dependent variables are present.

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[1] The use of a lagged endogenous variable, say P_{t-1}, imposes first-order serial correlation when the adaptive expectations model is used and when it is assumed that the original disturbances are not autocorrelated. On the other hand, if the original disturbances are autocorrelated then introduction of a lagged endogenous variable will cause the disturbances in the derived model to be nonautocorrelated.

Annual data were available from 1957 to 1976 [3, 4]. These data
were used to obtain the parameter estimates of equation (8) and are pro-
vided in Tables 1 and 2, where PRFC is defined as the season average
price of frozen cherries (¢/lb); PRFAS is the season average price of
frozen (Spy) apple slices (¢/lb); DINC is disposable personal income ($);
TSUPC is the total new crop supply of cherries for processing (mil. lbs);
ESUPA is the new crop supply of apples in eastern processing states (mil.
lbs);[2] BEGIC is the beginning inventory or carryin of frozen cherries
(mil. lbs); BEGIA is the beginning inventory of frozen apple slices (mil.
lbs); LPRFC is the price of frozen cherries lagged one period; LPRFAS is
the price of frozen apple slices lagged one period; and CPI is the con-
sumer price index (1967 = 100). All data were transformed to natural
logarithms for estimation.

Table 1

Estimated Price Relations for Cherries, 1957-1976[a]

	Model Ia OLS		Model IIa 2SLS (uncorrected)		Model IIIa 2SLS (corrected)[b]	
	Estimated Coefficients (t-ratios)					
CONST	4.6095	(5.18)	4.6095	(5.18)	5.1749	(6.28)
PRFAS	0.6836	(3.85)	0.6843	(3.30)	0.7040	(4.00)
DINC	0.4379	(1.96)	0.4376	(1.88)	0.3208	(1.60)
TSUPC	-0.7447	(9.44)	-0.7446	(8.81)	-0.8015	(9.50)
BEGIC	-0.1686	(4.72)	-0.1686	(4.58)	-0.1212	(2.57)
LPRFC	0.0504	(1.53)	0.0504	(1.53)	0.1811	(1.84)
CPI	-0.3838	(0.97)	-0.3839	(0.96)	-0.4071	(1.20)
ρ[c]	--		--		0.260	
R^2[d]	.976		N/A		N/A	
DW	N/A		N/A		1.87	

[a] The price of frozen tart cherries is the dependent variable. See text
for the specific definition of the independent variables.

[b] Corrected for first-order serial correlation.

[c] Rho is the first-order autocorrelation parameter,
i.e., $e_t = \rho e_{t-1} + \omega_t$.

[d] The simple correlation coefficient between the actual and estimated
dependent variable is 0.99 for both Models II and III respectively.

[2] The eastern apple processing states include: Michigan, New York,
Maryland, Pennsylvania, Virginia, and West Virginia.

Table 2
Estimated Price Relations for Apples, 1957-1976[a]

	Model Ib OLS		Model IIb 2SLS (uncorrected)		Model IIIb 2SLS (corrected)[b]	
	Estimated Coefficients (t-ratios)					
CONST	2.3150	(1.46)	3.1047	(1.84)	2.5057	(1.92)
PRFC	0.1258	(1.34)	0.0458	(0.44)	0.1195	(1.52)
DINC	0.5881	(2.80)	0.6433	(2.95)	0.6408	(3.69)
ESUPA	-0.4018	(2.09)	-0.5193	(2.51)	-0.3268	(2.06)
BEGIA	-0.1418	(2.11)	-0.1390	(2.01)	-0.2050	(3.46)
LPRFAS	-0.0081	(0.20)	0.0041	(0.10)	0.3255	(2.56)
CPI	0.0121	(0.03)	0.0098	(0.03)	-0.3720	(1.13)
ρ[c]	N/A		N/A		0.23	
R^2[d]	.953		N/A		N/A	
DW	N/A		N/A		2.62	

[a] The price of frozen Spy apple slices is the dependent variable. See text for the specific definition of the independent variables.

[b] Corrected for first-order serial correlation.

[c] Rho is the first-order autocorrelation parameter,
i.e., $e_t = \rho e_{t-1} + \omega_t$.

[d] The simple correlation coefficient between the actual and estimated dependent variable is 0.99 for both Models II and III respectively.

The parameter estimates of three separate model specifications for apples and cherries are given in Tables 1 and 2. Model Ia is estimated by OLS where the price of cherries is the dependent variable and the price of frozen apple slices is assumed exogenous. Model Ib is also estimated by OLS where the price of apples is the dependent variable and the price of frozen cherries is assumed exogenous. However, since frozen cherries and apples are highly interdependent and simultaneously determined, the second set of estimated parameters (Model II) is the 2SLS specification unadjusted for autoregressive bias. Models IIa and IIb are jointly estimated. The third set of estimated parameters (Model III) is identical to Model II except that it is adjusted for first-order serial correlation using the Cochran-Orcutt iterative procedure. Models IIIa and IIIb are jointly estimated. Again, because of the introduction of serial correlation when lagged dependent variables are present, Model III is considered statistically superior to either Model I or Model II.

In the cherry model, the parameter estimates in each equation have the expected direction of influence on the price of frozen cherries.

However, in the apple model the signs of the parameters are not correct for Models IIb and IIIb but appear as expected only after the 2SLS estimate is corrected for first-order serial correlation. In addition, a high degree of confidence can be ascribed to the parameter estimates in light of their small standard errors relative to the size of the regression coefficients. The standard errors of the estimate for the cherry model (IIIa) and the apple model (IIIb) are 1.57 and 0.84, respectively. In addition, the proportion of variation in cherry and apple prices explained by the models is quite high as indicated by the coefficient of determination for the equations estimated by OLS.

In general, the parameter estimates of the cherry model are relatively insensitive to the choice of the estimation technique. The only conspicuous disparity among the estimated cherry relations is a substantial reduction in the magnitude of the coefficient of lagged cherry price in Model IIIa due to the adjustment for serial correlation bias. For apples, the parameter estimates for Models Ib and IIb were nearly identical; however, some dramatic changes occurred in Model IIIb when the residuals are corrected for first-order serial correlation. The effect of the new crop supply of apples on price decreased substantially while the effect of carryover levels on apple price increased. The coefficient on the lagged apple price increased to a more feasible value while the consumer price index parameter assumed the correct sign together with a reasonable magnitude. In light of these empirical estimates, Models IIIa and IIIb were selected to further examine their potential ability to provide reasonable price forecasts.

Forecasting ability

In Figure 1 the actual values of the price of frozen tart cherries are plotted along with the estimated prices obtained from Model IIIa. Clearly, the estimated model has the ability to effectively capture changes in direction during the sample period. Moreover, it has the ability to capture very large changes in direction, e.g., 1973 and 1976. During the sample the only missed turning point of Model IIIa was in 1958. The calculated Theil's inequality coefficients are $U_1 = 0.03$ and $U_2 = 0.16$.[3]/

In Figure 2 the actual and fitted values for Model IIIb are plotted. Similar to the cherry model (IIIa), the frozen apple slice model (IIIb)

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[3]/ U_1 and U_2 are forecast evaluation statistics. When $U_1 = 0$, the model forecasts perfectly and when $U_1 = 1.0$, the worst possible forecast is obtained where $0 \leq U_1 \leq 1.0$ [6]. U_2 incorporates the turning point definition and $0 \leq U_2 \leq \infty$. If $U_2 = 0$, all forecasts are perfect; if $U_2 = 1.0$, the naive no-change model is implied and since U_2 can be greater than 1.0 it is possible to forecast worse than the naive model [5].
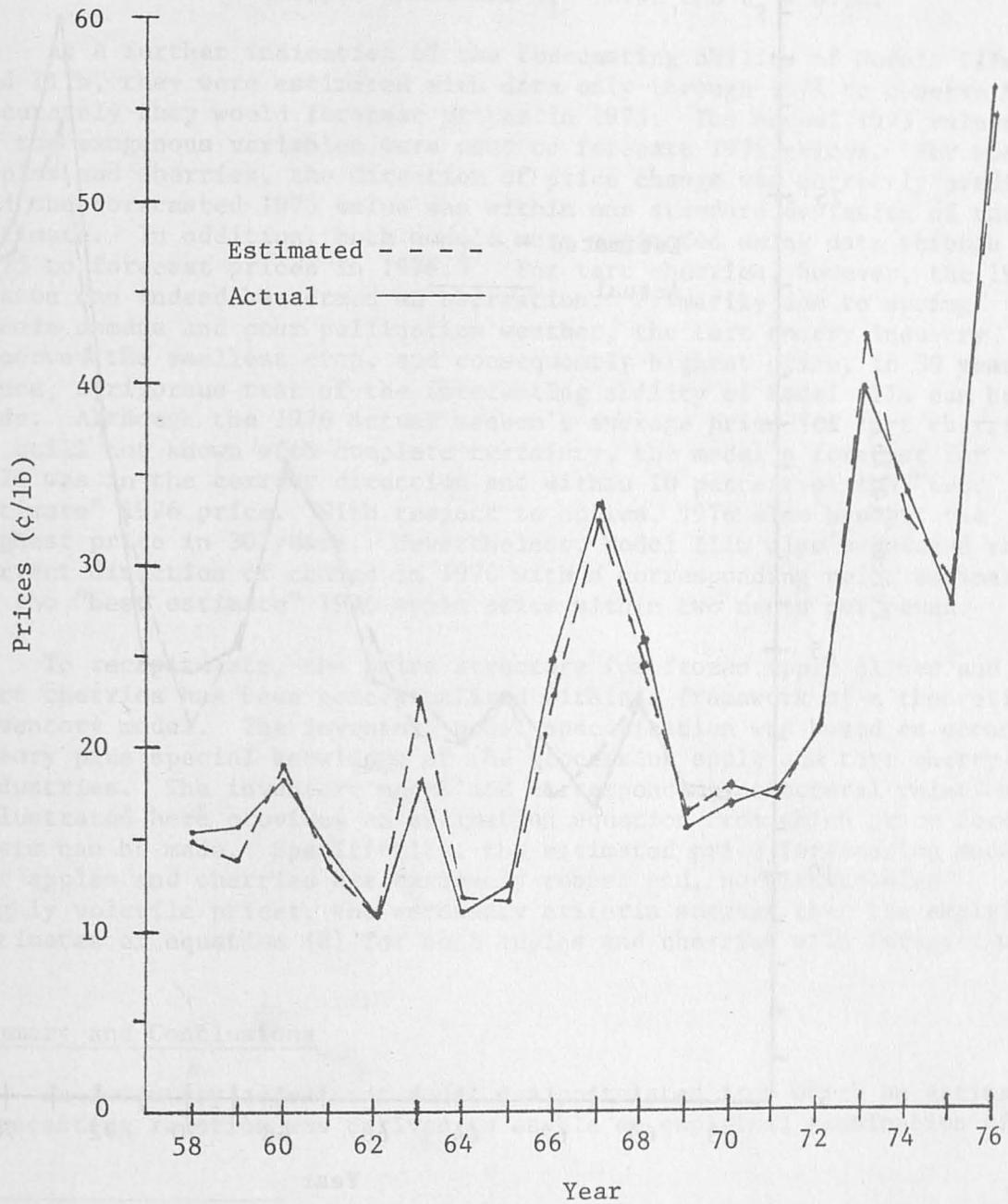
Figure 1. Actual and estimated prices of frozen tart cherries--
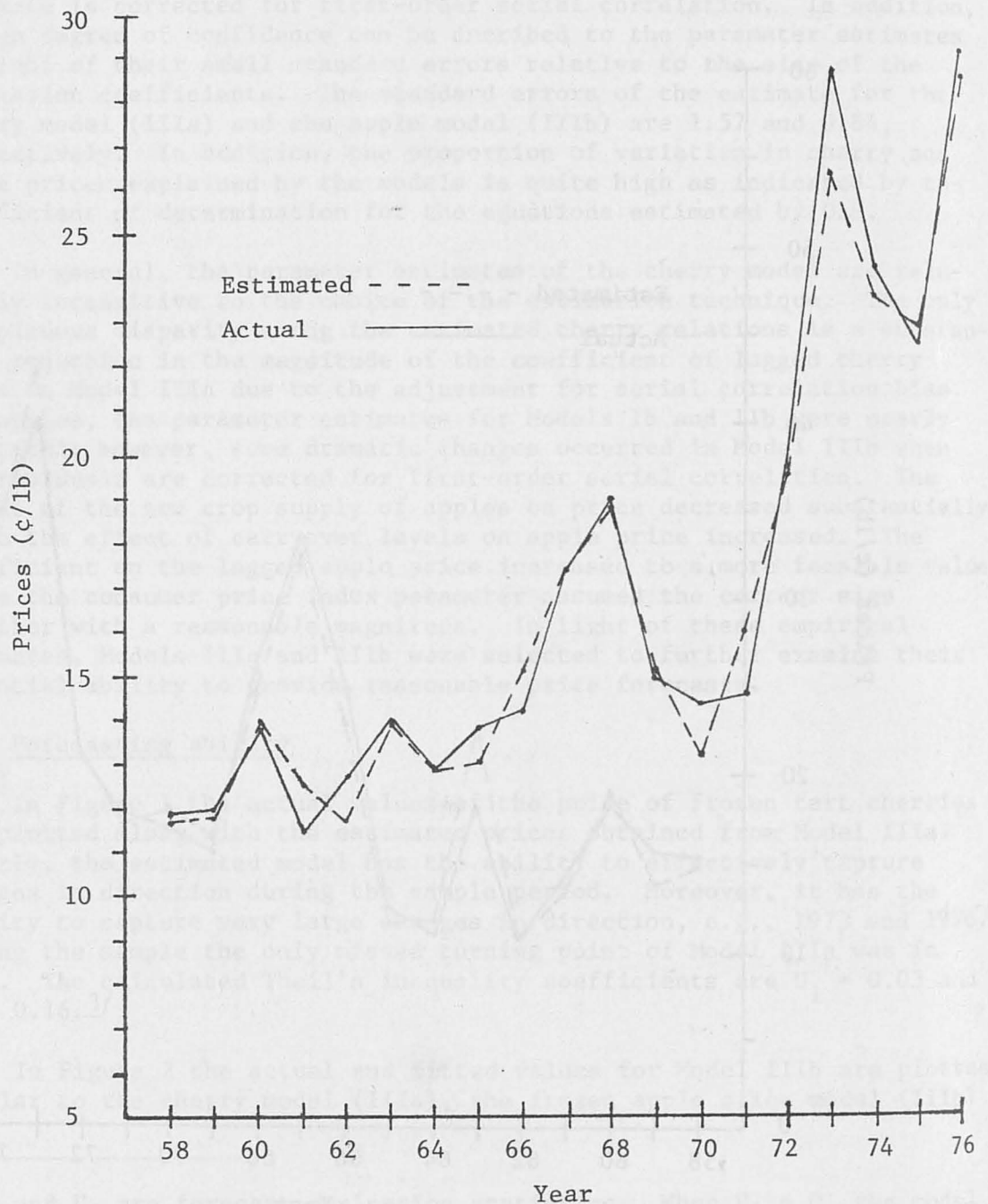Model IIIa (1958-1976)

Figure 2. Actual and estimated prices of frozen (Spy) apple slices--
Model IIIb (1958-1976)

has the ability to effectively capture changes in direction--especially the large changes which occurred in 1972 and 1973. The only turning point missed was in 1962. Also, the calculated Theil's inequality coefficients for the apple model are U_1 = 0.02 and U_2 = 0.24.

As a further indication of the forecasting ability of Models IIIa and IIIb, they were estimated with data only through 1974 to observe how accurately they would forecast prices in 1975. The actual 1975 values of the exogenous variables were used to forecast 1975 prices. For both apples and cherries, the direction of price change was correctly predicted and the forecasted 1975 value was within one standard deviation of the estimate. In addition, both models were estimated using data through 1975 to forecast prices in 1976.[4] For tart cherries, however, the 1976 season can indeed be termed an aberration. Primarily due to spring freeze damage and poor pollination weather, the tart cherry industry observed the smallest crop, and consequently highest price, in 30 years. Hence, a rigorous test of the forecasting ability of Model IIIa can be made. Although the 1976 actual season's average price for tart cherries is still not known with complete certainty, the model's forecast for 1976 was in the correct direction and within 10 percent of the "best estimate" 1976 price. With respect to apples, 1976 also brought the highest price in 30 years. Nevertheless, Model IIIb also predicted the correct direction of change in 1976 with a corresponding point estimate of the "best estimate" 1976 apple price within two cents per pound.

To recapitulate, the price structure for frozen apple slices and tart cherries has been conceptualized within a framework of a theoretical inventory model. The inventory model specification was based on economic theory plus special knowledge of the processing apple and tart cherry industries. The inventory model and corresponding structural relations illustrated here provides an estimation equation from which price forecasts can be made. Specifically, the estimated price forecasting models for apples and cherries are extremely robust and, notwithstanding highly volatile prices, the necessary criteria suggest that the empirical estimates of equation (8) for both apples and cherries will forecast well.

Summary and Conclusions

An inventory adjustment model was postulated from which an estimated forecasting relation was derived to enable an empirical examination of

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[4] When using separate data series through 1974 and 1975, the parameter estimates of the cherry model were comparable to those obtained when data were used through 1976 as shown in Table 1. For the apple models, the parameter estimates were also similar when using the two shorter time series with the exception of the OLS estimate where the sign on lagged apple price for the shorter time periods was positive albeit not statistically significant.

price behavior within the U.S. frozen tart cherry and apple slice industries. Because the equation of interest is a part of a larger simultaneous model, the parameter estimates were obtained using the technique of two-stage least squares. OLS estimates are provided for comparison. In addition, due to the presence of lagged endogenous variables an interative procedure was used to correct for serially correlated residuals. Statistically superior estimates were obtained from the corrected model vis-a-vis other specifications. Notwithstanding volatile actual prices, the estimated model when corrected for autocorrelation performed exceptionally well when subjected to several ex post forecasting texts.

The model developed here delineates some of the major characteristics of the price structure for frozen apple slices and tart cherries. Cognizance of the effect of these determinants in the price determination process will enable industry officials to deal more effectively with uncertain market conditions.

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