Forecasting Price Relationships among U.S Tree Nuts Prices

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Abstract

This paper investigates a vector auto regression model, using the Johansen cointegration technique, and the autoregressive integrated moving average time series models to determine the better model for forecasting US tree nut prices over the period 1992-2006. The Johansen contegration test shows lack of long run relationship among pecan, walnut, and almond prices. As such, only autoregressive integrated moving average-type models were used in forecasting U.S. nut prices.

Keywords: substitutability, cointegration, tree nuts, long-run equilibrium forecasting.

Introduction

The U.S. is not only the world's leading producer, but also the leading exporter of tree nuts (Johnson, 1998). Tree nuts remain an important component of the American diet. The growth in demand for tree nuts may be attributed to the increase in knowledge of the health benefits of nuts, an increase in per capita income and the increase in introductions of new products by a rapidly expanding bakery and confectionery industry. U.S. tree nuts (henceforth referred to as 'nuts') are used in snacks, breakfast cereal, ice cream, and confections (Lin et al., 2001). The U.S. tree nut industry is a multibillion industry (USDA, 2003). Some of the most popular tree nuts are almonds, pecans, and walnuts. Although all kinds of nuts have very specific and different uses, some substitutability does occur between and among the nuts (Florkowski and Lai, 1997). For example, walnuts or almonds cannot be substituted for pecans in a pecan pie, but this can happen in a breakfast cereal or a nut mix snack.

As a consequence, a better understanding of the relationships among tree nut prices is crucial for the tree nut industry. The results of this study contribute to the exploration of the market structure, product substitutability, competitiveness of nut markets and price forecasts.

To our knowledge, there are no empirical studies dealing with forecasting price relationships among U.S. tree nut prices. Earlier studies, however, provide examples of how the cointegration technique is useful in the forecasting process (Florkowski and Lai, 1997; Lanza et al., 2005). In the context of nut prices, Florkowski and Lai (1997) studied the relationship between pecan and other edible nut prices using the cointegraton technique. The study found a cointegration between prices of pecans and almonds and pecans and walnuts. The results were used to improve price forecasts. The study used processor prices of two grades of each kind of nut.

The objective of this paper is to forecast cointegrated relationships among selected U.S. tree nut prices employing the Johansen and Juselius (1990) maximum likelihood procedure. For the purpose of comparison, an autoregressive integrated moving average, first introduced by Box and Jenkins (1976), is used in forecasting the univariate variables.

The Johansen Cointegration Procedure

Engle and Granger (1987) argue in the seminal paper that differencing used to make data stationary in the traditional Box and Jenkins type models causes the loss of information on the long run effects. The cointegration technique, which accommodates deviations from the equilibrium condition for two or more economic variables that are nonstationary when taken by themselves, was developed by Engle and Granger (1987) to address this problem. Since then, economists have extended and also applied the cointegration technique to wide ranging sets of economic data (Johansen, 1988; Johansen and Juselius, 1990; Luppold and Prestemon, 2003). In this study, the Johansen type of the contegration technique is used because it is more powerful than the Engle and Granger procedure (MacDonald and Taylor, 1994). Following Johansen and Juselius (1990), the error correction model can be written as

$$(1) \qquad \Delta X_t = \sum_{i-1}^{p-1} \Phi_i \Delta X_{t-i} + \Pi X_{t-1} + AD_t + \varepsilon_t$$

where $\Phi_i = -\left(I + \Gamma_1 +,\ldots,\Gamma_i\right)$

and $\Pi = -\left(I - \Gamma_1 -,...,- \Gamma_p\right)$.

Other terms in (1) include: ε_t are the error terms and are drawn from a p-dimensional i.i.d. normal distribution with covariance Λ; D_t is a deterministic term, which may contain a constant, a linear trend or seasonal dummy variables, or both. The impact matrix, Π, determines whether or not there are significant long-run relationships among variables in the system. If the rank of Π matrix r is $0 < r < p$, then there are two matrices α and β each with dimension p x r such that $\alpha\beta' = \Pi$, while r is the number of cointegrating relationships among variables in X_t. The matrix β of r cointegrating vectors consists of elements of $\beta' X_t$ that are stationary. The matrix of error correction parameters α measures the speed of adjustment in ΔX_t.

In order to use the cointegration technique in the forecasting process, the series must be cointegrated. Johansen (1988) proposes the following trace test statistic:

(2) $$\lambda_{trace}(r) = -T \sum_{j=t+1}^{n} \log\left(1 - \hat{\lambda}_j\right)$$

where T is the number of observations in the data. The trace test has its null hypothesis that there are at most r cointegrating vectors. The alternative hypothesis states that there are more than r cointegrating vectors in the system. The trace test has a non-standard distribution (Johansen and Juselius, 1990). The series are cointegrated if r is not equal to zero and there are r cointegrated relationships among the series, and the error correction method is appropriate for the data.

Univariate Time Series

The more popular autoregressive integrated moving average (ARIMA) method is applied in the case of the univariate time series. The ARIMA procedure (Box and

Jenkins-type model) generally involves four steps; identification, model estimation, diagnostics and forecasting. The technique assumes that the time series under consideration is stationary. Therefore, the first step in estimating an ARIMA model is to test for stationarity. If the series is not stationary then transformation or differencing is needed to make the time series stationary. The differencing of non-stationary series, however, results in a significant loss of information on long run trends (Engle and Granger, 1987).

The general form of the ARIMA model is written as ARIMA (p,d,q), where the p represents the autoregressive part of the model, d is the order of differencing to make the series stationary, and q represents the moving average part of the model. Algebraically, the general ARIMA (p,d,q) model is written as:

$$\phi_p(L)(1-L)^d Z_t = \theta_0 + \theta_q(L)\alpha_t$$

$\phi_p(L)$ represents AR part: $1-\phi L-...-\phi_p L^p$

$\theta_q(L)$ represents MA part: $1-\theta_1 L-...-\theta_q L^q$

α_t represents a zero mean white noise process with constant variance.

Data

Monthly prices of the U.S. shelled tree nut grades were obtained from USDA for the period beginning in January1992 through May 2006. The data include pecan “fancy halves”, walnuts “light halves and pieces”, and almonds “nonpareil supreme” prices. We chose to analyze the three price series because of the paucity of data for other kinds of tree nuts or because other domestically produced tree nuts (e.g., pistachios) are sold mostly as an in-shell product. Moreover, the chosen nuts appear to be the three most popular among the U.S. consumers. All data refer to the shelled basis, nominal and wholesale prices (free on board-FOB) from a location in the southeastern U. S.

Table 1 shows the summary statistics for the nut price series. The statistics refer to the high end grades of the three kinds of nuts and the mean prices reflect the overall availability of each nut and the domestic demand. Pecans were traded at a premium to both walnuts and almonds with mean prices \$1.41 and \$1.26 per pound higher, respectively. Pecan prices also showed the widest range between the minimum and the maximum price, which likely results from the tendency to pecan trees to bear in alternate years. Walnuts, on the other hand, sold at a premium to almonds with a mean price of \$0.15 per pound higher. However, almond prices showed the highest variability and the largest standard deviation among the three kinds of nuts considered in this study.

Figure 1 shows the plots of price series for pecans, almonds and walnuts between January 1992 and May 2006. During the period under consideration, the prices of pecans and walnuts were generally higher than those of almonds except in 1996 and 1997. In these two years the prices of pecans were lower than those of almonds or walnuts, while almond prices were on par or higher than walnut prices reaching the highest level between 1992 and 2002. Since 1997, the prices of three nut types returned to the pattern observed in the early 1990s.

Results

The first step in applying the cointegration technique is to test for stationarity. The results of the stationarity test are summarized in Table 2. All price series were found to be nonstationary. The trace statistic was used to test for cointegration. Table 3 shows results of the Johansen's test. The series are shown not to be cointegrated. Since the condition cointegration is not met the VECM model is not applicable. The results imply that there is no long run relationship among the substitutes. The findings are inconsistent with earlier conclusions by Florkowski and Lai (1997).

In order to provide some benchmarks to compare the quality of forecasts, we also fitted an ARMA time series model. This approach was applied to each of the nut series using the SAS program. Having confirmed that the series were stationary (see Table 2), the fitted were ARMA(0,0,3) for pecans, ARMA(0,0,3) for walnut and ARMA(0,0,4) for Almonds. The residuals were diagnosed for goodness of fit and are shown below:

Pecans model: ARMA (0,0,3)
And diagnosis of the residuals shows a good fit.

Autocorrelation Check of Residuals

To Lag	Chi-Square	DF	Pr > ChiSq	Autocorrelations					
6	1.52	4	0.8232	0.006	0.048	-0.006	-0.066	0.036	0.022
12	15.06	10	0.1298	-0.064	-0.027	-0.108	0.065	-0.080	-0.214
18	20.58	16	0.1951	-0.077	-0.090	-0.093	0.073	-0.032	-0.009
24	34.09	22	0.0481	0.019	-0.015	0.000	-0.029	0.120	0.226
30	38.57	28	0.0880	0.036	0.025	-0.052	-0.017	0.047	0.120

Walnuts: ARMA (0,0,3)

And diagnosis of the residuals shows a good fit.

Autocorrelation Check of Residuals

To Lag	Chi-Square	DF	Pr > ChiSq	Autocorrelations					
6	5.65	5	0.3419	-0.032	0.054	0.023	0.074	0.110	0.098
12	17.23	11	0.1012	0.090	-0.176	-0.130	-0.075	-0.021	0.039
18	22.89	17	0.1530	-0.057	-0.004	-0.158	-0.035	-0.014	0.012
24	34.12	23	0.0635	0.006	-0.005	-0.174	-0.050	-0.057	0.142
30	41.01	29	0.0688	-0.091	-0.108	-0.028	-0.064	-0.076	0.052

Almond Model: ARMA (0,0,4)
And diagnosis of the residuals shows a good fit.

Autocorrelation Check of Residuals

To Lag	Chi-Square	DF	Pr > ChiSq	Autocorrelations					
6	3.25	5	0.6619	0.102	0.075	-0.023	-0.018	-0.005	0.039
12	13.87	11	0.2401	-0.004	-0.104	-0.174	-0.071	-0.104	0.030
18	17.42	17	0.4262	-0.054	-0.030	-0.054	-0.055	-0.000	0.093
24	22.84	23	0.4701	0.133	0.048	0.067	-0.010	0.026	-0.046
30	27.60	29	0.5393	0.117	0.015	-0.033	-0.089	-0.005	-0.014

Forecasting

The intention of this paper was to find a better forecasting model between ARIMA and VEC models. But only ARMA models were used because the cointegration test showed lack of long run relationships among the nut prices, a prerequisite for using VECM to make forecasts. The estimated ARMA models outlined above were used to generate forecasts for monthly nut prices for the period June 2006 to march 2007. The forecasts are listed in Table 5.

Concluding Remarks

The result of no cointegration among the U.S. tree nuts was disappointing. Because, we think, there is usually some substitutability among nuts, we expect a relationship among those nut prices to exist. One possible answer to the lack of relationship is the data used in the study. Secondary data were used and the quality of the data is not known. We therefore conclude that, by default, the ARIMA-type models are better at forecasting U.S. nut prices. However, further examining of the data and re-constructing the VECM, to allow direct forecast performance comparison, is an important subject for further research.

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Table 1. Summary of Selected Tree Nut Prices in the U.S.

Nut price	Mean ($/lb)	Standard deviation	Coefficient of variation	Minimum ($/lb)	Maximum ($/lb)
Pecan	3.67	0.94	25.50	2.03	5.80
Almond	2.21	0.71	32.02	1.23	4.25
Walnut	2.26	0.39	17.03	1.58	3.05

Table 2. Results of the Dickey Fuller Unit Root Test on Selected Price Series.

a. DF test for Transformed U.S .Tree Nut Prices Before First Order Difference					
Variable	Type	Rho	Pr<Rho	Tau	Pr<Tau
Pecans	Zero Mean	-0.09	0.6608	-0.09	0.6519
	Single Mean	-12.79	0.0643	-2.33	0.1634
	Trend	-15.56	0.1548	-2.69	0.2441
Walnuts	Zero Mean	-0.07	0.6971	-0.07	0.7054
	Single Mean	-10.17	0.1243	-2.29	0.1773
	Trend	-10.16	0.4141	-2.28	0.4430
Almonds	Zero Mean	-0.41	0.5881	0.29	0.5791
	Single Mean	-7.26	0.2539	-1.88	0.3432
	Trend	-7.55	0.6123	-1.91	0.6448
b. DF test for Transformed US Tree Nut Prices After First Order Difference					
Variable	Type	Rho	Pr<Rho	Tau	Pr<Tau
Pecans	Zero Mean	-121.90	0.0001	-7.76	<.0001
	Single Mean	-122.25	0.0001	-7.75	<.0001
	Trend	-123.20	0.0001	-7.75	<.0001
Walnuts	Zero Mean	-150.90	0.0001	-8.64	<.0001
	Single Mean	-151.68	0.0001	-8.63	<.0001
	Trend	-151.74	0.0001	-8.61	<.0001
Almonds	Zero Mean	-128.79	0.0001	-8.00	<.0001
	Single Mean	-129.27	0.0001	-7.99	<.0001
	Trend	-129.26	0.0001	-7.96	<.0001

Table 3. Cointegration Rank Test for Transformed U.S. Tree Nut Prices

The Johansen Rank using trace test				
H_0: Rank=r	H_1: Rank>r	Eigenvalue	Trace statistic	5% Critical value
0	0	0.0608	16.3674	24.08
1	1	0.0313	5.5736	12.21
2	2	0.0006	0.1013	4.14

Table 4. Model Diagnostics for Transformed U.S. Tree Nut Prices

a. Univariate Model ANOVA Diagnostics				
Variable	R-square	Standard deviation	F value	Pr>F
Pecan	-	0.07722	-	-
Walnut	0.0568	0.05464	5.09	0.0098
Almond	0.0082	0.07768	0.70	0.4966

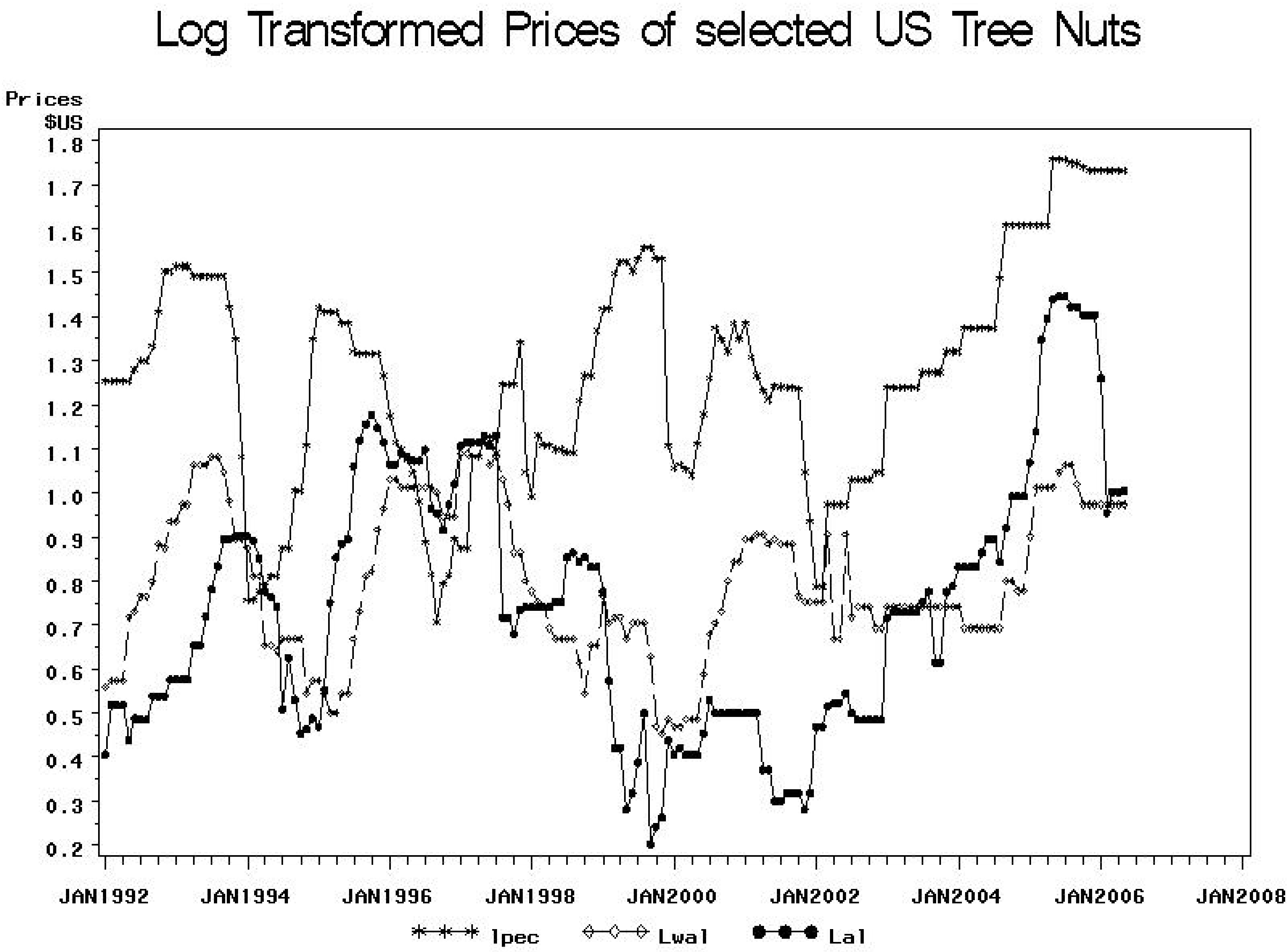
C. Univariate Model White Noise Diagnostics					
Variable	Durbin Watson	Normality		ARCH	
		Chi Sq	Pr>Ch sq	F value	Pr > F
Pecan	1.48784	560.20	<0.0001	1.46	0.2294
Walnut	2.00434	127.99	<0.0001	10.20	0.0017
Almond	1.82001	513.90	<0.0001	0.07	0.7923

C. Univariate Model AR Diagnostics								
Variable	AR1		AR2		AR3		AR4	
	F value	Pr>F	F value	Pr>F	F value	Pr>F	F value	Pr>F
Pecan	11.86	0.0007	5.88	0.0034	4.40	0.0053	3.97	0.0042
Walnut	0.00	0.9760	0.40	0.6731	2.43	0.0668	2.19	0.0719
Almond	1.23	0.2683	1.14	0.3225	0.08	0.4966	1.08	0.3675

Table 5. Forecasting for Pecans, Walnuts and Almonds

a. Forecasting for Pecan Prices			
Date	Forecast	95% Confidence Limits	
June 2006	5.65045	4.88444	6.5366
July 2006	5.65017	4.46751	7.1459
August 2006	5.65029	4.19220	7.6155
Sept. 2006	5.65029	3.93741	8.1083
Oct. 2006	5.65029	3.73295	8.5524
Nov. 2006	5.65029	3.56082	8.9658
Dec. 2006	5.65029	3.41160	9.3580
Jan. 2007	5.65029	3.27963	9.7345
Feb.2007	5.65029	3.16121	10.0992
Mar. 2007	5.65029	3.05376	10.4546
b. Forecasting for walnut Prices			
Date	Forecast	95% Confidence Limits	
June 2006	2.64942	2.37623	2.95402
July 2006	2.64884	2.27100	3.08955
August 2006	2.64884	2.19379	3.19827
Sept. 2006	2.64884	2.11064	3.32427
Oct. 2006	2.64884	2.04220	3.43567
Nov. 2006	2.64884	1.98337	3.53758
Dec. 2006	2.64884	1.931143	3.63271
Jan. 2007	2.64884	1.88474	3.72271
Feb.2007	2.64884	1.84220	3.80867
Mar. 2007	2.64884	1.80306	3.89135
c. Forecasting for walnut Prices			
Date	Forecast	95% Confidence Limits	
June 2006	2.59765	2.23169	3.02362
July 2006	2.61794	2.11201	3.24505
August 2006	2.61794	2.01219	3.40499
Sept. 2006	2.61794	1.94101	3.56298
Oct. 2006	2.61794	1.84985	3.73854
Nov. 2006	2.61794	1.77329	3.8997
Dec. 2006	2.61794	1.70690	4.05164
Jan. 2007	2.61794	1.64811	4.19619
Feb.2007	2.61794	1.59524	4.33524
Mar. 2007	2.61794	1.54717	44.46995

Figure 1. U.S. Tree Nut Prices, January 1992- May2006.



Source: Based on USDA price data.

Note: pprice = Prices of pecans; WalPrice = walnut prices; AlPrice = almond prices.

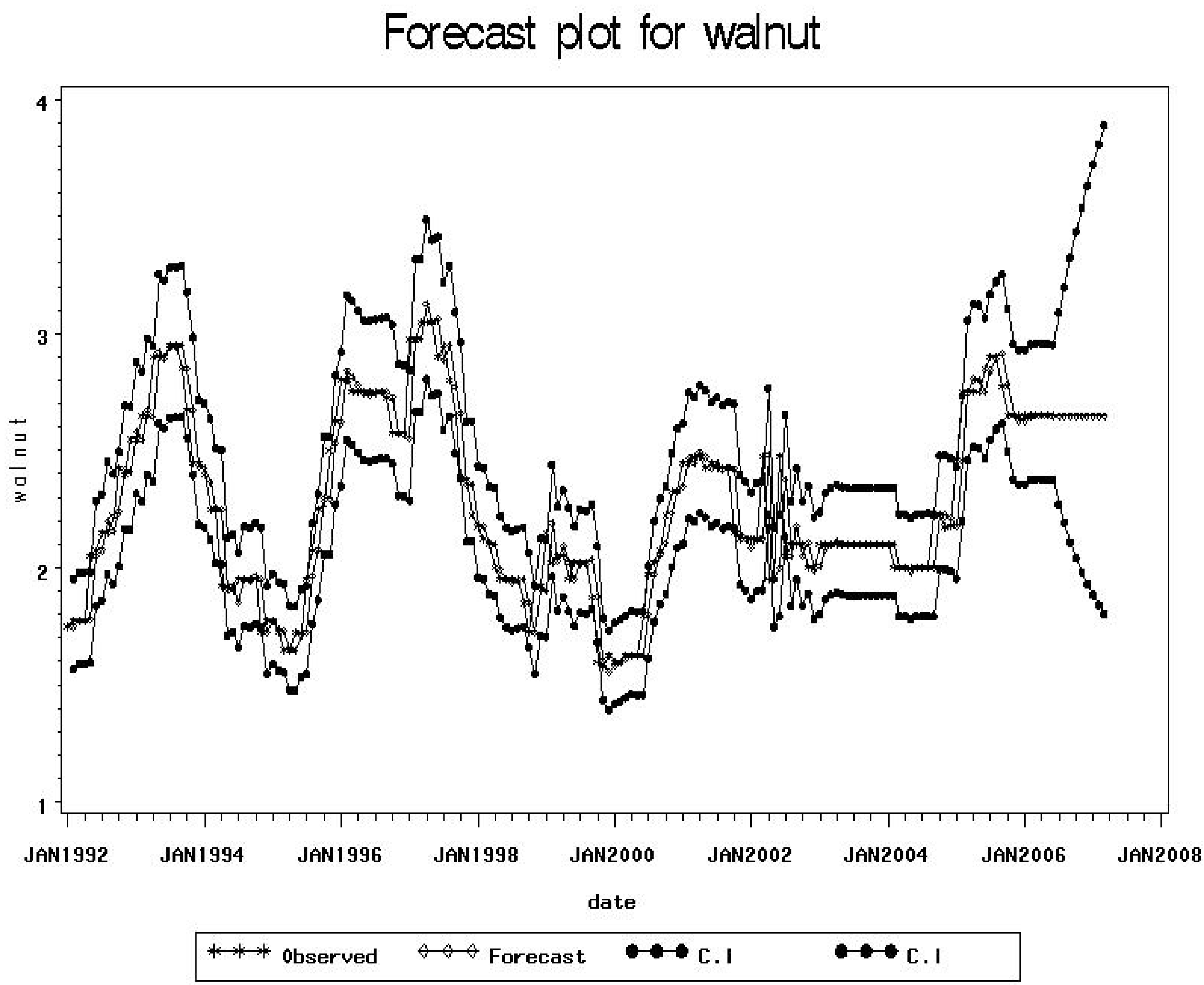


Figure 2. U.S. Walnut Price Forecasts, June 2006- March 2007.

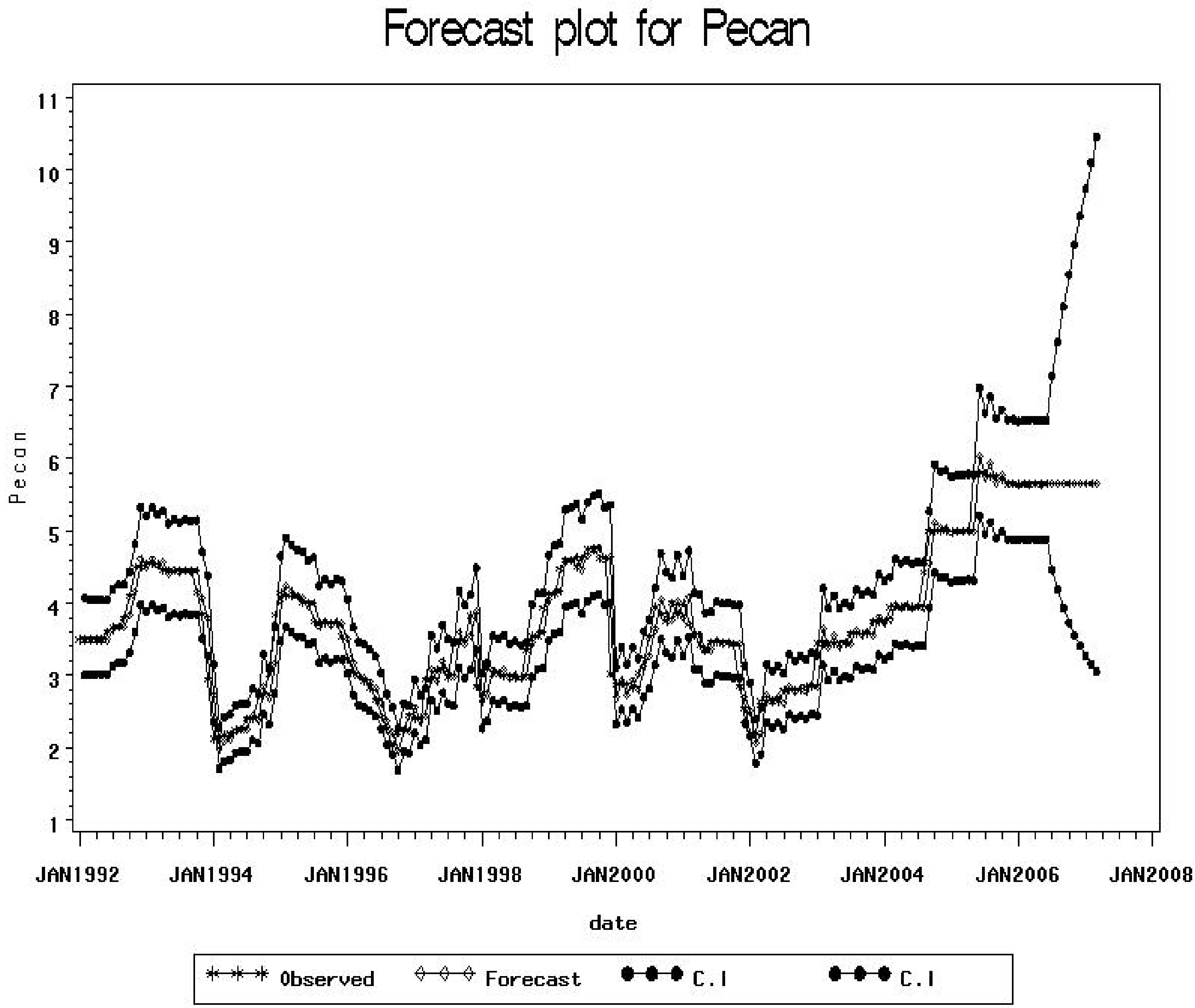


Figure 3. U.S. Pecan Price Forecasts, June 2006- March 2007.

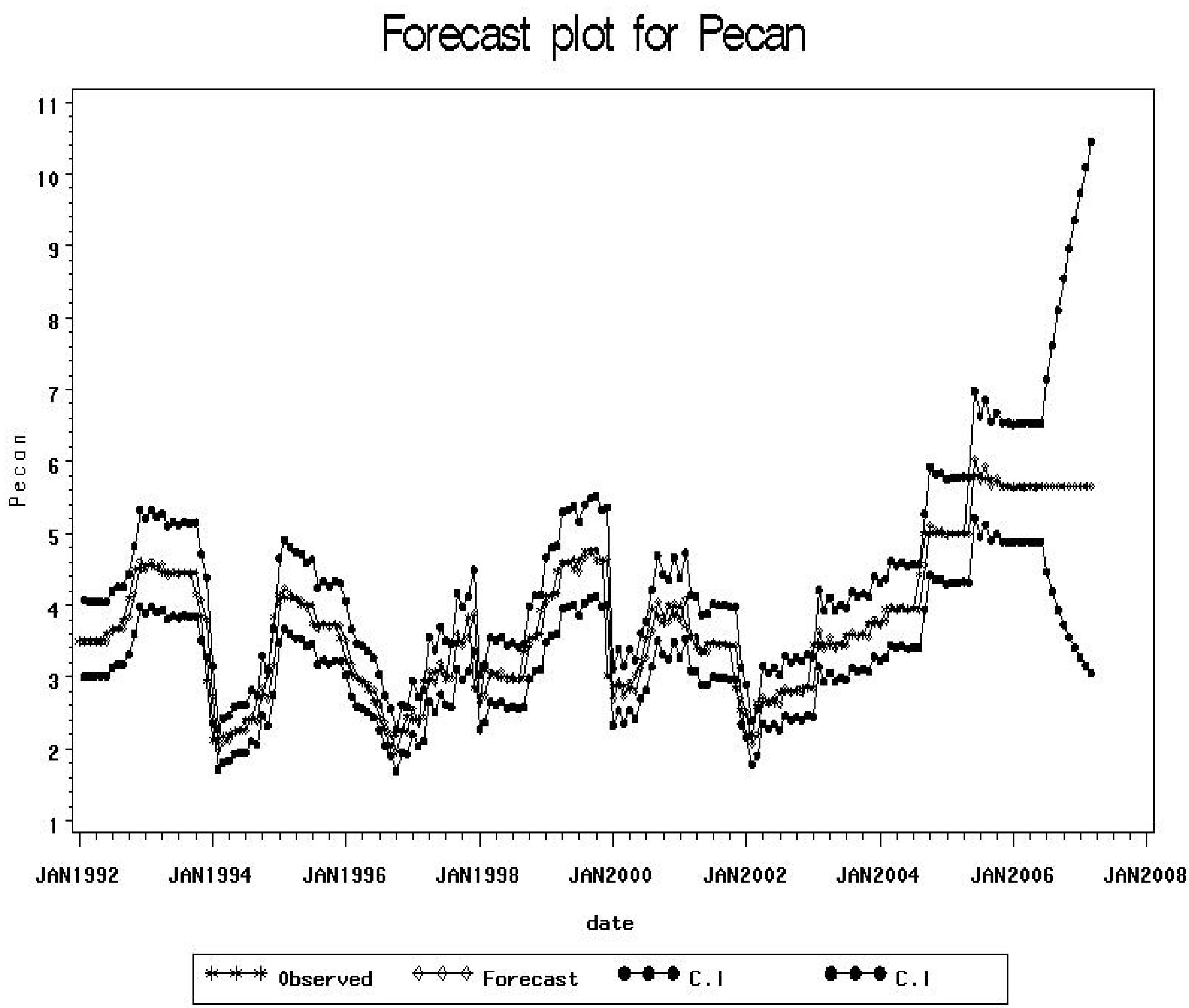


Figure 4. U.S. Almond Price Forecasts, June 2006- March 2007.