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**Price-Inventory Relationship in the Pecan Industry: A Study of
Long- and Short-Run Effects with Seasonal Consideration**

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*Selected Paper prepared for presentation at the Southern Agricultural Economics Association
Annual Tulsa, Oklahoma, February 18, 2004*

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Introduction

The pecan is the only tree nut indigenous to North America (Johnson, 1997). Almost half of the states grow pecans commercially with Georgia producing, on average, 43% of the total. The United States is the world-leading producer of pecans. Traditionally, pecans are used in making pecan pies which are served during the holiday season. Pecans are also used as ingredients in a variety of food products.

The pecan is classified as a specialty crop. The players in the pecan industry include growers, accumulators, and shellers. Growers include small-scale, backyard operations and commercial orchards extending over thousands of acres; accumulators are the middlemen between the small-scale growers and the shellers. The shellers are the commercial processors of pecans and they convert in-shell nuts into the tradable form of shelled pecans.

An investment in a commercial pecan orchard involves a relatively large sunk cost and resources cannot be easily reallocated once committed. Pecans also take a very long time to bear fruit and are characterized by the (imperfect) alternate bearing pattern. Like many perennial crops, pecans require processing before being marketed.

Storage is very important in the pecan industry. Pecans are semi-perishable nuts and, therefore, need proper care to prevent rancidity. Shellers are primary owners of pecan inventories in cold storage. Shelled pecans kept in cold storage represent inventories used to meet contractual commitments of shellers. The processing of in-shell pecans replenishes the shelled pecan inventory. Lots of shelled pecans are shipped to buyers.

The fact that the supply of pecans is predetermined, while the demand is relatively stable, stresses the importance of accurate information on inventory levels. Information about pecan inventory figures is, however, reported on a voluntary basis and little can be done to change this

system. Growers have expressed a great deal of dissatisfaction with the voluntary reporting system. Some have suggested that the inventory figures are inaccurately reported and, consequently, provide little informational value to the market. Hence, inaccurate and insufficient information is used in the process of discovery prices paid to growers and paid by end users.

In the general absence of similar studies for pecans, this study provides insights into the potential role of the pecan inventories. A formal analysis of the effects of inventories on prices improves understanding of the complexities of the pecan market and dispels some of the misinterpretations and uncertainty. Results provide insights into the response of shelled pecan prices to inventories of shelled, in-shell, and the total stored volume of pecans. Knowledge of inventory-price relationships is of use to the pecan industry and the pecan users. Specifically, the results of the study will enable shellers to efficiently perform their tasks. Growers could assess how useful and profitable is the storage of in-shell pecans. The knowledge of the price–inventory relationship enables food manufacturers to efficiently plan their procurement programs despite large fluctuations in production.

The general purpose of the study is to examine the role of the sheller in the pecan industry and on the pecan market. Shellers try to maintain the operation of shelling plants and maximize prices received for shelled pecans. Shelled pecans are the primary product traded on the market and their prices are said to dictate the range of prices paid to growers. Because price fluctuations result from changes in the supply and the supply is predetermined due to the perennial nature of the crop, pecan inventories play an essential role in shaping prices for shelled pecans. The specific objectives of this study testing the interaction between in-shell pecan inventories and shelled pecan prices, the interaction of shelled pecan inventories and shelled

pecan prices, and an examination of the effects of total inventories (both in-shell and shelled) on shelled pecan prices.

Earlier Studies

Few studies attempted to describe the relationship between prices and inventory (Weymar, 1968; Antonini, 1988). Weymar (1968) explicitly incorporated the supply of storage function to explain both spot and futures prices of cocoa. Antonini (1988) used a macroeconomic approach to describe price and inventory dynamics by assuming rational expectations. Similarly, Deaton and Laroque (1992) used rational expectations model to describe the commodity price behavior. Miranda and Glauber (1993) modeled the price-inventory relationship using annual crops (soybeans). Peterson and Willett (2000) in their analysis of the supply and demand of U.S. kiwifruit, developed a modeling framework for the specialty crops with the limited available data.

Florkowski and Wu (1990) and Shepherd (1998) examined the possibility of Georgia pecan growers increasing profits by adopting optimal storage decisions. Florkowski and Wu used a 3SLS method in their estimation process, while Shepherd applied the Bayesian approach. Both studies found storage at the farm-level not to be economically feasible. Weymar's model seems to be more appropriate to this study and we shall, therefore, follow his (1968) study.

Theoretical Framework

Pecan shellers are motivated not only by profit maximization, but also by the need to maintain operation of shelling plants. Assuming that price fluctuations result from the changing supply and that supply is predetermined due to the crop's perennial nature, pecan inventories may play an essential role in shaping prices for shelled pecans. Shelled pecans are the primary

product traded on the market, and their prices are said to dictate the range of prices paid to growers.

The processor keeps inventory for two main reasons (Kaldor, 1939). First, processing a primary commodity in many cases involves enormous capital investment: The more inventories held, the less the possibility of having capital equipment sitting idle as a result of temporary outages. This behavior is referred to as “the avoidance of stockout.” The processor in effect reduces cost adjustment through production smoothing. Second, a processor may wish to sustain a relatively stable, but competitive output price. By increasing the normal level of inventory coverage, the processor can change prices less often and still remain competitive at the industry level. The inventory coverage yields a return known as “coverage yield.”

Price Determined by the Supply of Storage Function

Let us assume both production and consumption to be functions of lagged prices. Equation (1) illustrates the estimation of the spot price.

$$P_t = P_t^* + f(s_t) + e_t \quad (1)$$

The equation states that the determinants of current shelled pecan price include the expected price, the inventory level via the supply of storage, and an error term.

Suppose the supply of storage function is stated in a way such that the expected fraction change in price becomes a linear function of the inventory level:

$$\frac{P_t^* - P_t}{P_t} = \mathbf{a}[s_t - \bar{s}] + e_t \quad (2)$$

where $\mathbf{a} > 0$ and \bar{s} represents the average value of inventory. The adopted linear form represents an approximation of the usual supply of storage curve. The system is said to be in

equilibrium when the inventory level is at its average value and the current price equals the expected price (Weymar, 1968).

According to Weymar, $\frac{P_t^* - P_t}{P_t} \approx \ln\left(\frac{P_t^*}{P_t}\right)$, where $\ln\left(\frac{P_t^*}{P_t}\right)$ is defined as the expected price

ratio. Substituting for the expected fraction change in price and inventory level, equation (2) becomes

$$\ln\left(\frac{P_t^*}{P_t}\right) = \mathbf{a}[(s_{t-1} + H_t - C_t) - \bar{s}] + e_t \quad (3)$$

Expanding the right hand side of equation (3) and some rearrangement result in

$$\ln P_t = [\ln P_t^* + \mathbf{a}(\bar{s})] - \mathbf{a}(H_t) + \mathbf{a}(C_t) - \mathbf{a}(s_{t-1}) + e_t \quad (4)$$

Suppose $[\ln P_t^* + \mathbf{a}(\bar{s})]$ is assumed to be a constant and the coefficients of C_t and H_t are required to be equal in magnitude, then equation (4) becomes

$$\ln P_t = a - \mathbf{a}(H_t + s_{t-1}) + e_t \quad (5)$$

where $a = \text{constant}$.

The model indicates that a reduction or growth in the total inventory of, say, pecans will result in an increase or decrease in the output price (i.e., shelled pecan price), respectively. This theoretical model is consistent with the microeconomic theory.

According to the model, in the first quarter of the pecan marketing year, the total supply of pecans is the sum of carryover inventory plus the currently harvested crop. In the second and subsequent quarters, however, the supply of pecans will consist of carryover only from the immediately preceding period.

The Empirical Model

Many agricultural commodity market time series, including pecans, contain significant seasonal components. The existence of unit roots at the seasonal frequencies and possible cointegration is, therefore, expected. Seasonal cointegration, proposed by Hylleberg, Engle, Granger, and Yoo (1990) [HEGY] and extended by Engle, Granger, Hylleberg, and Lee (1993), is a technique used to determine long-run relationships between two or more economic variables. The seasonal error correction model (SECM), on the other hand, is used to reconcile the short-run behavior of an economic variable with its long-run behavior. It is, therefore, appropriate to employ both seasonal cointegration tests and error correction model techniques to determine the long-run and short-run relationships of the shelled pecan price and inventories.

The HEGY test is a test for the presence of seasonal and non-seasonal unit roots in quarterly time series. The test may or may not fail to reject the hypothesis of the existence of seasonal unit roots in a series. The testing strategy works as follows.

Starting with a single inventory series y_t , the following auxiliary equation can be used to determine the existence of unit roots at the zero (long-run) and seasonal frequencies

$$\mathbf{j}(L)y_{4t} = \mathbf{p}_1 y_{1t-1} + \mathbf{p}_2 y_{2t-1} + \mathbf{p}_3 y_{3t-2} + \mathbf{p}_4 y_{3t-1} + \mathbf{e}_t \quad (6)$$

where $y_{1t} = (1 + L + L^2 + L^3)y_t$ (unit root left at the zero frequency);

$y_{2t} = -(1 - L + L^2 - L^3)y_t$ (unit root left at the \mathbf{p} frequency); $y_{3t} = -(1 - L^2)y_t$ (unit root left at the

$\frac{\mathbf{p}}{2}$ frequency); $y_{4t} = (1 - L^4)y_t = \Delta_4 y_t$. The ordinary least squares (OLS) estimates of equation

(6) are said to be superconsistent. Additional lags of y_4 may possibly be added to whiten the errors. Similarly, a constant, seasonal dummies, and a trend can be added to the equation.

If \mathbf{p}_1 is not significantly different from zero, then the procedure fails to reject the existence of a unit root at the zero frequency. If \mathbf{p}_2 is not significantly different from zero, the test fails to reject a seasonal unit root at the semiannual, \mathbf{p} , frequency, and if neither \mathbf{p}_3 nor \mathbf{p}_4 is significantly different from zero, then the test fails to reject a seasonal unit root at the annual, $\frac{\mathbf{p}}{2}$, frequency. The procedure, therefore, requires tests for $\mathbf{p}_1 = 0$ and $\mathbf{p}_2 = 0$ and a joint test for $\mathbf{p}_3 = \mathbf{p}_4 = 0$.

Seasonal cointegration may apply between two or more variables at the seasonal frequencies if these variables contain unit roots at the seasonal frequencies. If p_t and y_t are seasonally integrated of order 1, SI(1), then the transformed variables p_{it} and y_{it} , where $i = 1, 2, 3$, will relate to the nonseasonal and seasonal frequencies. The linear combinations of these variables are expected to be stationary, I(0), at all frequencies:

$$\mathbf{w}_{1t} = p_{1t} - \mathbf{a}_{12}y_{1t} \quad (7)$$

$$\mathbf{w}_{2t} = p_{2t} - \mathbf{a}_{22}y_{2t} \quad (8)$$

$$\mathbf{w}_{3t} = p_{3t} - \mathbf{a}_{32}y_{3t} - \mathbf{a}_{41}p_{3,t-1} - \mathbf{a}_{42}y_{3,t-1}. \quad (9)$$

Tests for cointegration at the zero and semiannual frequencies are conducted by testing the residuals from the cointegrating regressions. The test is meant to detect any remaining unit roots at the zero frequency and semiannual frequency ($\frac{1}{2}$). Equation (9) is, however, treated differently. The cointegrating relation between p_{3t} and y_{3t} is estimated by regressing p_{3t} on y_{3t} and $y_{3,t-1}$. The estimates are superconsistent and can be used in the two-step estimation procedure of the ECM. Also, in this case, the residuals will be used to test for seasonal cointegration at annual frequency $\frac{1}{4}$.

The regression can be run with or without deterministic parts. Similarly, the regression can also be augmented by the necessary lagged values of $\Delta \mathbf{e}_t$. The test critical values can be found in Engle and Yoo (1987).

With cointegration at each of the long run and seasonal frequencies, the ECM can be written as

$$\Delta_4 p_t = \mathbf{I}_1 \mathbf{w}_{1t-1} + \mathbf{I}_2 \mathbf{w}_{2t-1} + \mathbf{I}_3 \mathbf{w}_{3t-2} + \mathbf{I}_4 \mathbf{w}_{3t-1} + \mathbf{h}_{1t} \quad (10)$$

where \mathbf{h}_{1t} are stationary disturbances. The two-step cointegration procedure of Engle and Granger (1987) can be used in the estimation of the ECM in a seasonal setting.

Data

The data are inshell, shelled, and total pecan inventories, and shelled pecan prices from 1991:2 to 2002:1. Shelled pecan price series are quotes from published industry sources for the highest grade. The ‘total’ pecan series (shelled) is the sum of the volume of shelled pecan and the volume of inshell pecan (divided by 2.5).

From the standpoint of practical use of the results, the pecan industry and pecan buyers may view quarterly data as adequate given the timing of their marketing decisions. The first quarter is (October – December), second quarter is (January – March), third quarter is (April - June), and the fourth quarter is (July – September). The cold storage inventory level for each quarter was the sum of both the in-shell and shelled pecan volume, respectively. The volume data are reported in millions of pounds. In case of the price for shelled pecans, the simple monthly average was based on monthly quotations of the three consecutive months aggregated into a quarter. Prices are in dollars per pound.

Seasonal Integration

The results for the HEGY test at different frequencies are summarized in Table 1. The values of the 't' and 'F' tests are reported for each series. The auxiliary regressions are estimated using the OLS with lags of the dependent variable to whiten the residuals. Statistically significant lags up to two years are added because of the alternate bearing nature of pecans. Deterministic components such as a constant (I), a trend (Tr), and seasonal dummies (SD) are also included. Seasonal dummies are included in all the regressions, because the loss of power resulting from their inclusion when unnecessary is insignificant compared to the bias which results from their omission when necessary (Beaulieu and Miron, 1993).

Results indicate that the inshell series fails to reject unit roots at the zero and seasonal frequencies at the one percent significance level. Total inventory, shelled inventory, and price series all have unit roots at both zero and biannual frequencies. Unit roots are, however, rejected at the annual seasonal frequency. Results indicate that shelled pecan prices, the dependent variable, the total pecan inventory and the shelled pecan inventory series are stationary ($I(0)$) at the annual frequency, while the inshell pecan series is clearly nonstationary. Hence, cointegration of price and the pecan inventory series at the annual frequency is ruled out.

All the series are found to have unit roots at zero frequency. The shelled pecan price, the shelled pecan inventory and the total pecan inventory series show unit roots at bi-annual frequency whereas an annual frequency unit root is found in the inshell pecan inventory series. The existence of stationary seasonal patterns within a given series requires the rejection of both the 't' test of $p_2 = 0$ and the joint test of $p_3 \cap p_4 = 0$. We conclude that the price, shelled and total series exhibit stationary seasonal patterns. But, we can not reject the null hypothesis of seasonal unit roots for the inshell inventory series. A unit root at the biannual frequency is

present in all auxiliary equations. The HEGY test, however, has the limitations of power (Canova and Hansen, 1995). Thus not rejecting the null hypothesis cannot be interpreted as evidence of the presence of seasonal unit roots. For the preceding reasons we conclude that all of the variables have stationary seasonal patterns. Deterministic seasonal dummies will, therefore, be added to capture any significant seasonality in each quarter.

Cointegration Tests

After establishing that all the series are integrated of order one at the zero frequency and stationarity at the seasonal frequencies, the Engle and Granger (1987) test for cointegration is used to test for non-cointegration. The alternative hypothesis is that the series are cointegrated. The cointegrating regression is run with an intercept and one and eight lags of the dependent variable to whiten the data. The model to be estimated will now be of the form:

$$P_t = \mathbf{a}_0 + \mathbf{a}_1 x_{it} + \mathbf{e}_{it}$$

$$\Delta \hat{\mathbf{w}}_{it} = \mathbf{a}_1 \hat{\mathbf{w}}_{it-j} + \mathbf{e}_{it}$$

where i = various pecan series; j represents number of lags.

Table 2 reports the results for the zero frequency. Table 2 also shows that both in-shell and shelled inventory series are cointegrated with shelled pecan prices at the long-run frequency. For the total pecan inventories, however, the test fails to reject the null hypothesis.

Error Correction Model

Once the cointegration relationships are conducted, the ECM can now be written as follows:

$$\Delta P_t = \mathbf{a} + \mathbf{a}_1 \Delta x_{it-1} + \mathbf{a}_2 \Delta p_{t-1} + \mathbf{a}_2 \hat{\mathbf{w}}_{it-1} + \mathbf{h}_{it} \quad (11)$$

where i = various pecan series. The ECM models use the residuals, where $\hat{\mathbf{w}}_{it}$ from the first stage. The residuals are lagged by one period and substituted as explanatory variables in the

second step of the Engle-Granger technique as in equation 11. The coefficients of the error terms show the speed of adjustment.

In Table 3, the speed of adjustment for shelled pecan inventory at the zero frequency is -.3929. In other words, when regressor deviates from the long-run equilibrium, the dependent variable will change at a rate of 39.29% of the deviation to return to equilibrium. Similarly, in the case of in-shell inventory series, a deviation from the long equilibrium will result in a change at the rate of 33.35 %.

Conclusion

We gained insights into the shelled pecan price-pecan inventory behavior. Results confirmed the argument that the assumption about the absence of unit roots in the system other than at zero frequency may often be invalid. The HEGY test results could not confirm the presence of seasonal unit roots at seasonal frequencies. All the series, however, were integrated at the bi-annual frequency. The ECM indicated a 39.29 percent discrepancy between the actual price of shelled pecans and the equilibrium value.

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Table 1. Results of the test for seasonal unit roots

VAR	Auxiliary regression	Lags	't': p_1 (zero frequency)	't': p_2 (bi-annual)	'F': p_3 n p_4 (annual)
Inshell pecan inventory	I, SD, Tr	1,4	-2.1263	2.0089	2.2342
Total inventory	I, SD, Tr	1,5	-4.4418	3.3094	13.8200**
Shelled pecan inventory	I, SD, Tr	-	-2.9413	3.6481	19.8624**
Price	I, SD, Tr	-	-2.8291	3.4605	12.7385**

** Indicates the rejection of the null hypothesis in question at the 1% significance level

Note: Null hypotheses: $p_1 = 0$, $p_2 = 0$, $p_3 = 0$, $p_4 = 0$, $p_3 \cap p_4 = 0$;

I=constant; Tr = trend; SD = seasonal dummies.

Table 2. Cointegration test results.

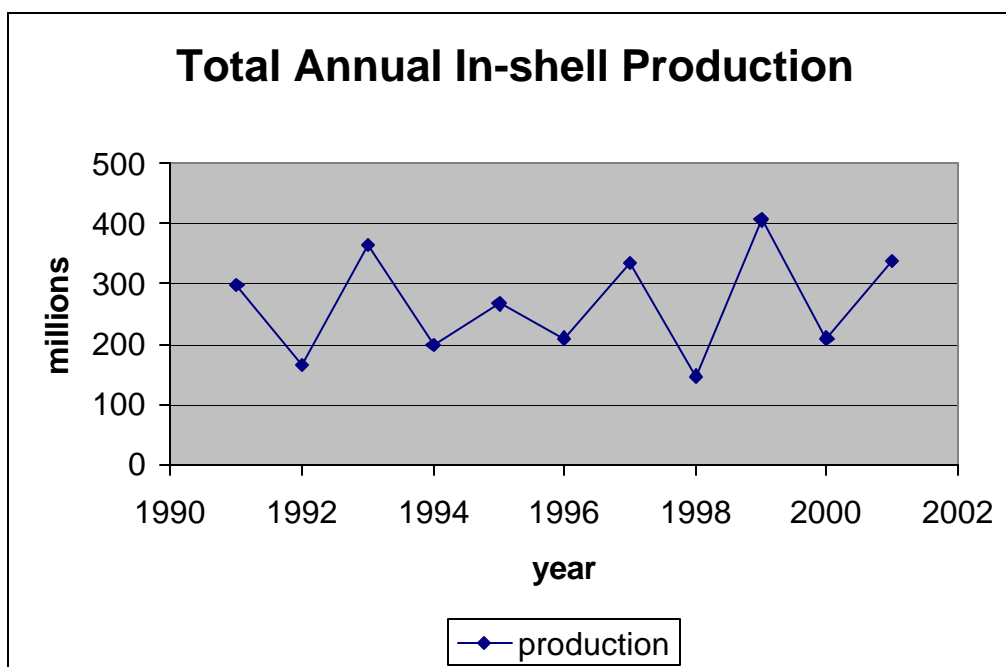
Variable	Lags	Zero frequency
Price-inshell	1, 8	-3.320**
Price-shelled	1, 8	-4.468**
Price-total	1,8	-3.088

** Indicates the rejection of the null hypothesis at the 10% significance level.

Table 3. Results of the test for error correction

Series	Coefficient	't' Stat	DW	\bar{R}^2 (adj)
Price-inshell inventory	-0.3335	-3.200*	1.98	0.28
Price-shelled inventory	-0.3929	-4.152*	2.10	0.44

* The null hypothesis is rejected at the 10% significance level.



Source: USDA, 2002