SIMULATING IMPACT OF PECAN STORAGE TECHNOLOGY ON FARM PRICE AND GROWERS' INCOME

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Abstract

Pecan growers can increase income by storing pecans if economically feasible storage technology is available. The marginal conditions under which growers would store pecans were derived. Revenue changes due to storage and impact of storage on price variations were simulated, suggesting the price that growers could pay for new storage technology.

Key words: marginal revenue, storage technology, pecans, income, price stability

Pecan output is influenced by the alternate annual bearing pattern of pecan trees, which is reflected in the price time series where high prices and low prices alternate through the years (Pecan Marketing Summary); however, price fluctuations could also be attributed to the lack of storage. The development of affordable storage technology should help stabilize prices and increase pecan growers' income. Yet, no empirical studies have been conducted to support these hypotheses and to indicate the price that growers would be willing to pay for storage.

Historically, cold storage of pecans has occurred at the wholesale market. Statistics on storage have been available since 1970 (Wells *et al.*). Shellers, who purchase pecans from growers or accumulators, own or rent storage space for storing in-shell and shelled pecans. Shellers have an interest in pecan storage beyond the shelling plant and research on packaging pecans has been conducted (Stein, Kays).

However, storage by growers has been limited to a few cooperatives organized by growers for the purpose of producing, shelling, and marketing pecans. For the growers' needs, an in-shell storage technology would be desirable in order to avoid shelling cost prior to storage. In-shell pecans store roughly twice as long as shelled pecans at the same temperature (Wagner) and maintain comparable quality. For example, in-shell pecans at 50° can be stored for nine months while storage of shelled pecans should not exceed six months. On-farm storage of in-shell pecans would not have to extend for more than 12-14 months. Except during the period of a few weeks beyond harvest, pecans are not stored on farms. As a result, growers cannot take advantage of pecan price increases that may occur several months following the harvest or during the next harvest when the alternate-year bearing pattern causes a short crop.

Introduction of a storage technology to maintain pecan quality for an extended period of time at the farm could benefit growers. Research that results in economically feasible storage technology would impact farmers, pecan shellers, end users of pecans, agricultural engineers, storage equipment manufacturers, and policy-makers.

The purpose of this study was to offer guidance in the development of pecan storage technology based on cost of storing and volume stored. Effects of storage on stabilizing output prices and producers' income were simulated assuming a perfectly competitive industry. The first section of this article focuses on developing a storage formula for pecan growers. The second section presents a determination of the pecan price relationship. The third section presents data and estimation of the price equation followed by a fourth section on testing the profit maximizing condition. Next, the maximum cost of an affordable technology is estimated in section five, followed by an analysis of the effects of storage on pecan price variability and growers' incomes in section six. The last section presents implications of the study.

TO STORE OR NOT TO STORE?

Producers' profit from pecan sales, without consideration of production costs, is determined by the difference between sales revenue and storage cost of pecans:

(1a) $\pi = P(Y_d)\, Y_d - C(S)$

(1b) $S = Y - Y_d$

where π is the sale profit; P is the pecan price, which is a function of the quantity of pecans sold, Y_d; C is an unknown storage cost function, which is a function of the quantity stored, S; Y is the total output.

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The maximum profit is determined by differentiating (1a) with respect to Y_d:

$$(2)\quad \frac{\partial\pi}{\partial Y_d} = \left(\frac{\partial P}{\partial Y_d}\right) Y_d + P(Y_d) + \left(\frac{\partial C}{\partial S}\right) = 0.$$

Since the marginal storage cost in (2) is positive, a maximum will exist only if the sum of the first two terms is negative, *i.e.* the marginal revenue from sales turns negative. Therefore if the real situation is described by (2), pecan growers will not store pecans under the condition of negative marginal return from pecan sales. However, some pecan growers are likely to form price expectations in anticipation of future price fluctuations and the associated opportunity to profit from sales of stored pecans. Therefore, equation (1a) can be rewritten following the introduction of the expected pecan price as:

$$(3)\quad \pi = P(Y_d)\, Y_d + \left(\frac{1}{1+r}\right) P^*(S)S - C(S)$$

where P^* is expected price during the next harvest and r is the discount rate (market interest rate) used to calculate present value of future returns. It is assumed that the price-quantity relationship $P(Y_d)$in the current year will hold during the next year, so $P = f(Y_d)$ and $P^* = f(S)$. The maximum of (3) is found by setting first order conditions equal to zero:

$$(4)\quad \frac{\partial\pi}{\partial Y_d} = \left(\frac{\partial P}{\partial Y_d}\right) Y_d + P(Y_d) - \frac{1}{1+r}\left(\left(\frac{\partial P^*}{\partial S}\right) S + P^*(S)\right) + \frac{\partial C}{\partial S} = 0.$$

The second order derivative of (3) can be obtained to ensure the existence of a maximum:

$$(5)\quad \frac{\partial^2\pi}{\partial Y_d^2} = \left(\frac{\partial^2 P}{\partial Y_d^2}\right) Y_d + 2\frac{\partial P}{\partial Y_d} + \frac{1}{1+r}\left(\left(\frac{\partial^2 P^*}{\partial S^2}\right) S + 2\frac{\partial P^*}{\partial S}\right) + \frac{\partial^2 C}{\partial S}.$$

The negativity of equation (5) will be tested after estimating the relationship between P and Y_d. It is tentatively assumed that equation (5) is negative and a maximum of equation (3) exists.

Rearranging equation (4) results in formula for finding the marginal cost of storage:

$$(6)\quad \frac{1}{1+r}\left(\left(\frac{\partial P^*}{\partial S}\right) S + P^*(S)\right) - \left(\left(\frac{\partial P}{\partial Y_d}\right) Y_d + P(Y_d)\right) = \frac{\partial C}{\partial S}.$$

Equation (6) suggests that profit is maximized if expected marginal revenue during the next harvest season exceeds marginal revenue in the current harvest, and the difference is greater than the marginal cost of storage.

The left-hand side of equation (6) can be evaluated once the expected price P^* is known. Pecan growers have an advantage in predicting next year's price. Historical data reveal that price variations through the years have been largely dominated by the alternate-year pattern of pecan bearing: a large crop is frequently followed by a short crop, causing year to year low and high average prices. Defining a low price as $PPC_t < PPC_{t-1}$, and a high price as $PPC_t > PPC_{t-1}$, pecan growers would have correctly predicted change in the next year's price direction 15 out of the past 21 years by assuming that a low price is followed by a high price.

The six wrong predictions were as follows: 1967, when expected price was low while actual price was high (8 cents or 20 percent higher than in 1966); 1968, when expected price was low while actual price was high (3.5 cents or 9 percent higher than in 1967); 1978, when expected price was high while actual price was low (6 cents or 9 percent lower than in 1977); 1980, when expected price was low while actual price was high (13 cents or 19 percent higher than in 1970); 1984, when expected price was high while actual price was low (8 cents or 12 percent lower than in 1983); 1986, when expected price was low while actual price was high (1 cent or 1 percent higher than in 1985). Out of all wrong predictions, four were about low prices when the actual prices were high. Such events represented a windfall for a grower. Only twice during the period under consideration was a grower faced with a situation when, instead of expected high price, the actual price was low.

The assumption that cost of storage does not change from year to year by any significant amount is plausible because of the large investment cost and relatively small costs of operating a storage facility. Thus, if producers store pecans in a low price year expecting a higher price next year, they have about a 68 percent chance to realize their expectations about change in price direction and, conversely, a 32 percent chance of miscalculating. The marginal condition of equation (6) thus becomes:

$$(7)\quad q\left[\frac{1}{1+r}\left(\left(\frac{\partial P^*}{\partial S}\right)S+P^*\right)-\left(\left(\frac{\partial P}{\partial Y_d}\right)Y_d+P\right)\right]+(1-q)\left[\frac{1}{1+r}\left(\left(\frac{\partial P^*}{\partial S}\right)S+P^*\right)-\left(\left(\frac{\partial P}{\partial Y_d}\right)Y_d+P\right)\right]=\frac{\partial C}{\partial S}.$$

The left-hand side of (7) is the expected value of marginal revenue; q is the probability that the direction of next year's price movement is correctly predicted; (1-q) is the probability of an incorrect prediction. This condition states that producers' profit is maximized when expected gain in marginal revenue equals marginal cost of storage. Simplifying notations results in:

$$(8)\quad q\,MR^+ + (1-q)\,MR^- = \frac{\partial C}{\partial S}$$

where MR^+ is the gain in marginal revenue when the prediction is right and MR^- is the loss in marginal revenue when the prediction is wrong. This model assumes only short term, year to year storage.

In order to calculate a gain (MR^+) or loss (MR^-), it is necessary to obtain an estimate of the price equation $P = f(Y_d)$. The estimation is also necessary for evaluating the second order derivative equation (5) discussed earlier. This task is accomplished in the following section.

THE PRICE RELATIONSHIP

Growers sell pecans to shellers or accumulators only during the harvest season from October to January. Because no storage takes place at farms, the price-quantity relationship can be presented by total output (volume sold) and price and specified as an inverse demand equation:

$$(9)\quad PPC_t = \beta_0 + \beta_1 PEPR_t + \beta_2 PPN_t + \beta_3 IMP_t + \beta_4 EXP_t + \beta_5 INC_t + e_t$$

where PPC is the annual average price of Georgia pecans in ¢/lb; PEPR is the annual Georgia pecan output in lbs; PPN is the annual average price of Georgia peanuts, a substitute, in ¢/lb; IMP and EXP are the annual total U.S. imports and exports of pecans, respectively, in lbs.; INC is the annual U.S. disposable per capita income, in dollars; β_0 is the constant; and e is the disturbance term.

Pecan price is unknown until harvest starts. Therefore, pecan output is not affected by the current year's price. Thus, there is no simultaneous determination of price and output. In other words, pecan output (PEPR) can be treated as an exogenous variable. The price of peanuts, a pecan substitute (Hsuen), is also an exogenous variable because of the influence of the government peanut program. The peanut price can affect the pecan price but not vice versa. Per capita disposable income is included as a proxy for buyers' preferences. Export and import of pecans are added to account for a change in quantity of pecans on the market.

Simultaneity enters the model when exports and imports are considered. Domestic prices influence exports and imports. Simultaneity bias would result if the relationship between total output and pecan price were estimated as a single-equation model (Gujarati, p. 342-344). Because volume of imports is larger than volume of exports and is among growers' concerns, an equation is specified for pecan imports:

$$(10)\quad IMP_t = \alpha_0 + \alpha_1 PPC_t + \alpha_2 XCH_t + u_t$$

where α_0 is a constant and XCH is the index of total U.S. agricultural imports; u_t is the disturbance term. The variable XCH is a proxy for the exchange rate.

It is also assumed that error terms are normally distributed with their expected values equal to zero and that no correlation exists among error terms from a single equation. The cross-equation correlations are unknown.

DATA AND ESTIMATION RESULTS

Although limited information methods such as two-stage least squares (2SLS) can be applied to the estimation, a full information estimation method is more appropriate if cross-equation correlations are present (Pindyck and Rubinfeld, p. 334). Three-stage least squares (3SLS) was used to estimate the model which is asymptotically equivalent to a full information maximum likelihood estimator (Theil, p. 526).

Annual time series data were obtained from Agricultural Statistics, Statistical Abstracts of U.S. and Georgia Agricultural Facts for the period from 1965 to 1986. In preliminary estimations, following the graphic analysis of the data, two functional forms were compared: linear and logarithmic. The model in log form systematically outperformed the one in linear form as indicated by the F-test, adjusted R^2s, and the t-tests associated with estimated coefficients.

Table 1. 3SLS Estimates of Equations for Pecan Price at the Farm Level and U.S. Pecan Imports

Variable name	Estimated coefficient	Standard error	t-value
Equation 9			
Constant	-25.3623	6.267	-4.05
LPEPR	-.4229	.0915	-4.62
LPPN	-.2055	.2885	-.71
LIMP	.0435	.0288	1.51
LEXP	.1410	.0560	2.52
LINC	3.6530	.7815	4.67
Log likelihood ratio $x^2(6)$ = 161.60			
Equation 10			
Constant	15.3287	16.020	.96
LPPC	4.7823	1.752	2.73
LXCH	-6.0441	4.702	-1.29
Log likelihood ratio $x^2(3)$ = 72.66			

Results of the model estimated in log form (Table 1), showed a significant, negative influence of pecan output on pecan price. The coefficients of exports and income were also significant with expected positive signs. The coefficient of the peanut price had the expected negative sign although the t-value suggested that the coefficient did not differ significantly from zero. Estimation results of the second equation suggested the significance and positive impact of the pecan price on pecan imports.

TESTING THE SECOND ORDER CONDITION

Given the coefficient estimates of equation (9), the negativity of the second-order condition, equation (5), can be tested. Antilogs of the estimated coefficients from the log form of equation (9) could be substituted in equation (5) to verify the first- and second-order derivatives of price with respect to quantity. Prior to testing the second-order condition, equation (5) can be rewritten substituting the estimated coefficient of pecan production, β_1 , from equation (9). The following equation (11) was obtained because of the homogeneity of the price equation $P = f(Y_d)$ (Intriligator, p. 467):

$$(11)\quad \frac{\partial^2 \pi}{\partial Y_s^2} = \beta_1(1-\beta_1)\frac{\partial P}{\partial Y_s} + 2\frac{\partial P}{\partial Y_s} + \frac{1}{1+r}\left(\beta_1(1-\beta_1)\frac{\partial P^*}{\partial S} + 2\frac{\partial P^*}{\partial S}\right) - \frac{\partial^2 C}{\partial S}.$$

Table 2. Acceptable Average Storage Cost at Different Storage Levels

Storage as a percent of total ouput	Average storage cost (¢/lb)[a]	Standard error
0	7.253	3.019
1	6.828	3.030
2	6.404	3.136
5	5.544	3.206
10	3.607	3.388

[a] In 1982 prices.

The sum of all right-hand side terms will be negative with the exclusion of the last term. The last term represents the second derivative of the storage cost function and can be either positive or negative. It is plausible to assume the second-order derivative of C to be positive or negative, but small, to ensure the negativity of equation (11).

STORAGE COST

Average marginal revenue gain (MR^+) and loss (MR^-) in equation (8) can be evaluated following the testing of the second-order condition. The left-hand side of equation (8) is a gain in marginal revenue that growers could expect if they store pecans whenever a low price occurs ($P_t < P_{t-1}$). Calculations were made for 22 years from 1965 to 1986.

The expected marginal revenue depends on the level of storage S. As S increases, marginal revenue in the current year increases, whereas expected marginal revenue in the next year will decline. As a result, possible gains (MR^+) can be smaller if the prediction is correct, while possible losses (MR^-) can be larger if the prediction is erroneous. The larger the storage, the lower the expected marginal revenue and vice versa.

If producers maximize profit, expected marginal revenue is also the marginal storage cost at different storage levels as indicated by equation (8). If a storage technology offers a marginal cost lower (higher) than expected marginal revenue at a certain storage level, producers would increase (decrease) storage so that expected marginal revenue will decline (rise) until it equals marginal cost. Marginal costs at five different storage levels (as a percentage of total output) were evaluated (Table 2). Marginal cost of storage was assumed to be approximated by average cost because of the large fixed costs and a relatively small cost of operating a storage facility.

Since marginal cost is calculated using the means of MR^+ and MR^- , it is stochastic in nature. Assuming an independent normal distribution of MR^+ and MR^-, the calculated marginal cost is also normally distributed. Then, variances can be computed and statistic inferences can be developed. The variance was computed as follows:

(12) $MR = F(MR^+, MR^-)$

$$\sigma_{MR} = \left(\frac{\partial F}{\partial MR^+}\right)\left(\frac{\partial F}{\partial MR^-}\right)\begin{bmatrix}\sigma^2_{MR^+} & 0 \\ 0 & \sigma^2_{MR^-}\end{bmatrix}\begin{bmatrix}\dfrac{\partial F}{\partial MR^+} \\ \dfrac{\partial F}{\partial MR^-}\end{bmatrix}$$

Standard errors are also reported in Table 2.

Table 2 provides a cost structure reference for research and development of pecan storage technology. As storage increases to 10 percent of total output, the acceptable average storage cost per pound quickly decreases from 7.2¢ to 3.6¢ (in 1982 prices). The average cost at zero storage level sets the maximum cost acceptable to growers. The average storage cost must be less than 7.25¢/lb or no pecans will be stored at the farm level. The prohibitive cost of on-farm pecan storage has likely been true because actual annual storage cost per pound is about 9.6¢ in 1982 prices at the sheller level (Christiansen). The average cost represents the maximum average cost an economically feasible storage technology can incur at specific storage levels. The increasing standard deviation (and variance) as storage increases reflects the increasing uncertainty in producers' expectations when the carry-over stocks become larger.

Pecan storage is characterized by economies of scale. Average cost decreases as volume stored increases. Economies of scale are reflected in Table 2. However, when storage exceeds 10 percent of production, expected gain from storage becomes somewhat precarious as an indicator of the acceptable average cost.

IMPACT OF STORAGE ON PRICE AND INCOME

A simulation was conducted to assess the impact of storage on Georgia pecan growers' income and the variation of pecan price for a 22-year period, 1965-1986 (Table 3). The change in income reflects possible gains and losses due to incorrect predictions. Storage costs have been deducted from income changes.

The second column in Table 3 indicates income changes from storing pecans if a storage technology could reduce storage costs below levels shown in Table 2. Thus, for example, if storage costs were 6.828¢ or less at a 1 percent storage level (Table 2)

Table 3. The Impact of Pecan Storage on Pecan Growers' Income and Price

Quantity of production stored	Change in income	Price variation[a]	Change in price variation
(%)	(%)		(%)
0	0	18.586	0
1	5.65	18.335	-1.35
2	5.91	18.090	-2.67
5	5.05	17.391	-6.43
10	2.96	16.355	-12.00

[a]Standard error calculated for the average pecan price between 1965 and 1986 in ¢/lb.

in a "low price" year, growers' income would have, on the average, increased by 5.65 percent during the 22-year period. The gain in income decreases as storage increases because price differences from year to year are reduced.

The stabilizing effects of storage on price variations are substantial. Storage of 5 percent of annual output would reduce price variation by 6.4 percent and storage of an additional 5 percent of annual pecan output would decrease price variation by 6 percent.

IMPLICATIONS

This study explores the economic feasibility for development of new storage technologies. The development of economically feasible on-farm storage technology for pecans would increase the flexibility of timing pecan sales and increase growers' income. The flexibility of pecan sales would permit growers to concentrate on pecan harvest. Pecan marketing would be shifted forward. This would contribute to improved planning and implementation of marketing strategies as storage permits separation of harvesting from marketing.

Pecan storage will become more important as the supply from newly planted orchards in traditional producing areas increases (Hubbard *et al.*) and as new orchards in Arizona and California reach bearing age. The expected increase in pecan supply mandates that growers improve marketing skills. Growers in regions with less developed infrastructures will need to explore opportunities to maintain quality of pecans by storage in an atmosphere- and temperature-controlled environment.

The implementation of a pecan marketing agreement (The Pecan Press) in consort with advertising and promotion will increase demand for pecans and provide an incentive for a stable year-round supply. The development of new markets in states where pecans do not grow will provide an incentive to maintain a stable year-round supply of quality pecans. Storing pecans will assure a uniform supply and limit price fluctuations, thereby encouraging repeated purchases of pecans.

Storage of pecans will mitigate price changes caused by alternate bearing. In the past, price fluctuations have been exploited only by middlemen who owned pecan inventories. The farm level pecan prices were highly variable while wholesale prices remained fairly stable.

The expected growth of the pecan industry and the opportunity for growers to increase income through on-farm storage should create a demand for on-farm storage facilities. Cooperation between private and public research institutions which invest in developing inexpensive storage for in-shell pecans may benefit pecan growers and growers of other tree nuts. The development and adoption of such storage technology would represent a structural change by potentially diminishing or eliminating farm level seasonal marketing of pecans.

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