FUNCTIONAL FORMS AND FARM-LEVEL DEMAND FOR PECANS BY VARIETY

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Abstract

Recent developments in the U.S. pecan industry appear to limit the utility of past research. The importance of pecan variety has emerged as an issue which could alter past results. The linear and double-log models previously fitted to all-pecans (averaged) data may be too restrictive and hence, are less useful for variety-specific analysis. Past research also analyzed price turning points using nominal data. This study investigated functional form and data-averaging problems by fitting separate flexible Box-Cox price-dependent models for all-pecans and each variety of pecans (1970/71-1988/89 deflated data). Results indicate: other nuts substitute for different pecan varieties, estimated all-pecans price flexibility is biased and clouds variety-specific flexibilities, and restrictive functional forms are inappropriate.

Key words: flexible functional approximations, blend pecans, Box-Cox estimation, varieties, price flexibilities, misspecification, demand

Pecans are important agricultural crops on southern U.S. farms (Shafer). Pecans generated over $1.6 billion in farm revenues during the 1988/89 season (USDA/ERS, p. 58). Farm level studies on pecans continue to interest researchers of agricultural commodities. However, the marketing implications of recent developments in this industry (Hubbard, Florkowski, and Purcell 1989) appear to limit the usefulness of previous research in several aspects. Specifically, (1) the commonly fitted linear and double-log demand models, which form the basis for computing the price flexibilities, may not be consistent with the data on pecans; (2) use of data averaged across improved and native "varieties"[1] of pecans makes previous results less useful for variety-specific analysis; and (3) post-sample forecasts of price turning points constructed from models fitted with nominal price and income time-series data erroneously assume a constant rate of inflation over time.

This study investigated the extent to which past research results may have been affected by the above-mentioned problems. Thus, new estimates of price-dependent farm-level demand functions were obtained separately for blend pecans (or all-pecans) and disaggregated (variety-specific) pecans based on the longest annual time series data (1970/71-1988/89) currently available. Unlike past research, the price data used in this study have been deflated (1982=100) and flexible Box-Cox models were fitted in which the linear and double-logarithmic specifications are nested. Therefore, this paper addresses issues pertaining to *a priori* specification of restrictive functional forms and data averaging in past models of farm-level demand for pecans. In this regard, the paper extends in two directions an earlier work by Wells et al. in which misspecification due to the omission of pecan inventories was investigated.[2]

This paper proceeds as follows. The next section focuses on functional forms and data averaging issues in previous research. Section three presents the theoretical framework and the flexible Box-Cox demand specification. Section four discusses em-

[1] By "varieties" is meant the improved and native types of pecans, on which data are published by the USDA/ERS. In the strict sense, there are in excess of two dozen individual varieties of pecans grown throughout the United States, depending on the geographical location (Hubbard, Purcell and Crocker, p. 5).

[2] Pecans in storage, while not storable for indefinite time periods without spoilage, are important in moderating price movements associated with cyclical production (Epperson and Allison, p. 476; Wells et al., p. 157; Shafer and Hertel, p. 12; Shafer, p. 98). Moreover, since annual changes in June cold storage stocks are not consistently large relative to either the October crop estimate or final production, pecan inventories are normally assumed to be sufficiently exogenous in the model specification. Data on cold storage carry-in pecan stocks were not published before 1970.

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pirical results, and the last section concludes the study with implications of the findings.

FUNCTIONAL FORMS AND DATA AVERAGING IN PAST STUDIES

Unfortunately, economic theory offers limited assistance to a researcher on the choice of an appropriate functional form model (Judge et al., pp. 885-886). One relatively recent solution to this dilemma is to fit an *a priori* flexible functional form model, which allows the data to speak for themselves. The typical alternative is to take a linear approximation to the true, but unknown underlying curvature. While a linear approximation model is convenient, computationally inexpensive, and facilitates inference, the researcher runs the risk of functional approximation errors. The undesirable consequences of this misspecification problem are well documented in the econometrics literature (for example, see Judge et al.). Thus, the choice of functional form appears to be crucial (Sarkar).

Previous research on pecans fitted linear (e.g., Fowler; Huang et al.; Wells et al.; Shafer), double-log (e.g., Epperson and Allison; Florkowski and Wu; Shafer and Hertel), and Box-Cox (Okunade 1989a; Okunade 1989b) models to all-pecans (averaged) data. Strictly linear functional approximations may not sufficiently capture curvatures in the data; a constant elasticity (double-log) model specified *a priori* is not necessarily consistent with the theory of demand; and forecasts of price turning points for all-pecans in past studies proceeded mostly from the analysis of nominal data when, in fact, annual rates of inflation varied during the period covered by the time-series data analyzed.

Disaggregated data usually contain more information than when they are aggregated or averaged (Orcutt et al.). In other words, inappropriate aggregation of variables has undesirable consequences for least squares regression estimates (Lichtenberg). Therefore, previous price-dependent demand models (except the 1981 study by Shafer and Hertel, where 1960-1980 annual data were used) fitted with price and quantity data averaged over the two classes of pecans, may be of limited use to pecan growers, accumulators, shellers, and industry analysts (whose interests may lie in variety-specific analysis). This is because the various determinants of pecan prices at the farm level may impact differently on blend-pecans compared to the native and improved varieties. Support for this hypothesis is implied by the recent finding that differences in pecan quality perceptions exist at the farm and wholesale levels (Hubbard, Florkowski, and Purcell 1990). Moreover, the 1970/71-1988/89 historical price series (USDA/ERS, p. 58) also shows that improved varieties of pecans are usually priced above the native/seedling variety. In particular, prices of native varieties averaged about 48 cents/lb. and prices of improved varieties averaged 73 cents/lb. during the 1980/81-1988/89 period. Thus, the blend (all-pecans) price for the two items clearly shows they are not perfect substitutes based on the 34.25 percent [i.e., (73¢-48¢)/73¢] price differential. Further, these two prices occasionally move in opposite directions as in 1970/71, 1977/78, and, particularly, 1978/79, although they are, in general, highly correlated. Further still, it should be noted that production of the low-priced native variety is declining while production of the high-priced improved variety is increasing. Consequently, the value of blend-pecans is increasing due to increases in total volume (production) and changes in the compositional mix by variety.

Thus, the observed price differential across varieties may signal differences in quality perception by the first handlers. The inability of most past studies (except Shafer and Hertel; Okunade 1989a; and Huang et al.) to detect a substitution relationship between all-pecans and other closely related tree nuts may have been induced by problems associated with functional forms and/or data averaging across different pecan varieties.

THEORETICAL FRAMEWORK AND FUNCTIONAL SPECIFICATION

The lag between growers' decisions to produce and subsequently sell pecan crops to shellers and accumulators at the farm level generally predetermines quantities (Houck). Therefore, it is standard practice to model the price-quantity relationship for pecans at the farm level with an inverse demand function. This approach has been shown to be theoretically consistent with the framework of classical demand theory (Huang, p. 902). Pecans have been modeled for price explaining/forecasting purposes using this simplified methodology (Shafer, p. 98). Past studies were price-dependent, single-equation ordinary least squares (OLS) models (see literature review in Wells et al., pp. 157-158). Season-to-season variations in pecan prices have usually been specified as dependent on total quantities of production and cold storage carry-in stocks (on the supply side) and on per capita income or time (on the demand side).

Potential impacts of closely related nuts (e.g., almonds, peanuts, hazelnuts, walnuts) on pecan prices, usually reported as insignificant (Epperson and Allison, p. 478; Wells et al., p. 158, fn.2; Florkowski and Wu, p. 220) or dismissed as irrelevant

(Shafer, p. 98) in past studies, were examined in this study. Shafer and Hertel previously justified the inclusion of related substitute nut prices in an inverse demand specification for pecans. This is because a producer organization like the Almond Board of California implicitly sets almond prices by explicitly setting its quantities (Bushnell and King, p. 28). Similarly, the price of peanuts, a potential substitute for pecans, is influenced by the government peanut program (Fu et al., p. 910). Therefore, the exogenously-determined price of another nut could affect pecan prices. In addition, one recent study (Hubbard, Purcell, and Crocker, p. 4) urgently calls for the aggressive marketing of Georgia pecans, to combat growing competition from pecan trees of more recent vintage, other domestically produced (and better marketed) rival nuts, and pecans imported from Mexico. These observations legitimize the need to examine the potential effects of rival nuts on the prices of different varieties of pecans.

Pecan exports historically constituted a small share of the total market (Huang et al., p. 28). However, foreign demand for pecans has continued to show gains (USDA/ERS, p. 59) along with other tree nut exports (USDA/ERS, p. 5; Huang and Conway, pp. 26-27). Principal outlets for U.S. pecans include Canada, W. Germany, Mexico, Sweden, and Australia. Others include Spain, Italy, and some pecan producing countries, such as South Africa and Saudi Arabia. More precisely, U.S. pecan exports to the European Community (EC) have shown sharp gains and pecan imports (mostly from Mexico) constitute an insignificant part of the U.S. supply (Huang et al., p. 30; Florkowski and Wu, p. 220). The impact of lagged almond exports (predetermined) on current season's price of almonds was found to be significant in an inverse demand for almonds (Huang and Conway). Consequently, increasing importance of the exports market for pecans mandates that lagged values of exported pecans be included in the pecan price function as a separate argument, to proxy the "expectations effect" on current pecan prices of the rising exports trend. This effect is expected to be positive, *ceteris paribus*, as increased volume of previous pecan exports could encourage current season's allocation for exports, reduce domestic availability (given current supply) and, as a result, increase current season's domestic prices (the dependent variable). Since lagged pecan exports are predetermined in the current season's price equation, pecans exported in the preceding period could appear as a regressor in the current pecan price function. In effect, the potential effect of one-period lagged pecan exports on current season's pecan prices is also evaluated in this study.

The variance stabilizing, flexible Box-Cox (power family of transformations) model is a popular device for generalizing functional forms, being relatively *a priori* unrestrictive. The advantage of its use will be discussed after a brief description of the model. The Box-Cox transformation of strictly positive values (Zarembka) of a continuous variable V, is of the form:

$$(1)\quad V^{(\lambda)} = \frac{[V^{\lambda} - 1]}{\lambda}, \text{ if } \lambda \neq 0; \text{ and } V^{(\lambda)} = \log V, \text{ as } \lambda \rightarrow 0.$$

The extended flexible Box-Cox specification (EB-C)[3], where the regressors and the dependent variable are power-transformed with the same value of the λ transformation parameter (found to be naturally consistent with the true data), is used to approximate the parameters of the following price-dependent farm-level demand model for pecans:

$$(2)\quad RP_i^{(\lambda)} = \alpha_0 - \alpha_1 Q_i^{(\lambda)} - \alpha_2 QBS^{(\lambda)} + \alpha_3 RP_j^{(\lambda)} + \alpha_4 QL1X^{(\lambda)} + \alpha_5 RINC^{(\lambda)} + \varepsilon$$

where RP_i is real price per lb. of ith pecan variety (with i=all-pecans, improved variety, native variety), Q_i is the corresponding U.S. production (million lbs.) of the ith type of pecans, QBS is quantity of cold storage carry-in pecan stocks (million lbs.), RP_j is deflated price per lb. of a substitute tree nut (j = al and wa for almonds and walnuts, respectively), QL1X is quantity of one-period lagged pecan exports (million lbs), RINC is U.S. per capita deflated disposable income (thousand \$), and ε is the error term. Moreover, income and all prices are deflated variables because (1970/71-1988/89) annual time-series data are utilized. The data to which model (2) is fitted are from USDA/ERS sources (Shafer, p. 103).

[3]The Classic Box-Cox model involves power transformation of only the dependent variable without similarly transforming any of the independent variables. However, the Extended Box-Cox (EB-C) introduces more flexibility in the functional form because the dependent and each independent variable receive the same value of the power transformation parameter in statistical estimation of the model. The dependent variable and each regressor can also receive different λ transformations, to test for the consistency of the semilog, reciprocal, or Ramsey exponential specifications (with observed data) using the Box-Tidwell framework. However, the EB-C model (with a single λ value for transforming all variables) was specified here to reduce complexities typical of the combined Box-Tidwell estimation for small samples. In addition, the more generalized Fourier (Sobolev-flexible) form, which introduces additional parameters requiring statistical estimation, cannot be implemented due to insufficient data points (Gallant).

Two of the general advantages of the EB-C specification are its flexibility and relative objectivity, in that the λ parameter is free to take on any real value. The estimated λ value for an equation determines the appropriate functional form, and is that which maximizes the sample nonlinear log-likelihood function.[4] Thus, the flexibility of the EB-C model opens up the possibility that equation (2) can become a linear (if =1), a double-log (as λ 0), or some other functional form that is consistent with the data on pecans. In applied econometric analysis, it is common practice to adopt an *a priori* unrestrictive functional form model, such as the Box-Cox, in order to minimize functional approximation errors (given observed data). In addition to this general reason, there may be an *ex-ante*, commodity-specific justification for adopting a flexible-form model in place of the simpler (linear or log-log) functional form. However, both the general and commodity-specific justifications are legitimate and may be mutually reinforcing.[5]

While large samples are preferable, Box-Cox estimates have been obtained with small samples consisting of 25 (Pope et al.) and as few as 17 (Amemiya; Sarkar) observations in past statistical studies. Increased efficiency of estimated parameters of the EB-C model (2) were obtained in this study through an iterative maximum likelihood (ML)[6] estimation procedure (with a stepping value of 0.001) in which ρ, the model's first-order autocorrelation parameter, and λ, the best fitting (data-based) power transformation parameter, were simultaneously estimated (Savin and White).

EMPIRICAL RESULTS

Table 1 presents separate ML estimates for all-pecans (a), native (n), and improved (i) varieties. Parameter estimates were correctly signed for all equations; real pecan prices (RP_a, RP_n, RP_i) were inversely related to current production and cold storage carry-in stocks, and were positively influenced by lagged pecan exports, real income (except for native pecans[7]), and the real prices of substitute tree nuts. The adjusted R^2s indicated very good fits. The residuals of each equation were sufficiently independent (as indicated by Durbin-Watson test). None of the estimated (within-data) turning points in real pecan prices were missed, and the root mean square errors (Root MSEs) are small for all models.

Real farm prices of aggregated all-pecans and disaggregated native and improved varieties were strongly influenced by current production, one-period lagged exports (QL1X), and pecan cold storage carry-in stocks (QBS). However, large differences in the coefficients of QBS and QL1X across the three models appeared to signal how the use of aggregated (all-pecans) data may distort the sensitivities of individual pecan varieties to these determinants. The estimated Box-Cox direct price flexibilities (evaluated at the sample means) were -1.13, -2.50, and -1.29 for all-pecans, native, and improved varieties, respectively. That of native pecans differed significantly compared with all-pecans and the improved variety estimates. However, all of the Box-Cox direct price flexibility estimates were consistent with *a priori* theoretical expectations of inelastic farm level demands for agricultural commodities (Tweeten). Relative to past estimates, the all-pecans Box-Cox price flexibility was in accord with only those in Wells et al., and Shafer and Hertel (see Wells et al., p. 158, fn. 1). However, none of the past studies estimated variety-specific price flexibilities for pecans. Thus, they provided no basis for comparing the variety-specific flexibilities reported here. One implication of the flexibility estimates,

[4]The maximized log likelihood of (2) for given λ, except for a constant, is

$$L_{max}(\lambda) = -\frac{n}{2}\log\hat{\sigma}^2(\lambda) + (\lambda - 1)\sum_{t=1}^{n}\log RP_{it},$$

where RP is real price of pecans, t=1, 2, ...n indexes observations by time, and i indicates a specific type of pecan being modeled.

[5]We owe this insight to the SJAE editors and one of the anonymous reviewers. Since the structure of observed data implicitly reflects the underlying characteristics of a commodity's relationship, the demonstrated applicability of the flexible Box-Cox methodology may have indirectly captured the pecan price relationship. Thus, general and specific reasons for adopting a flexible model specification may not be mutually exclusive.

[6]There are four viable approaches to estimation of EB-C model (2), which yield results that are equivalent to maximum likelihood (ML) estimates (Spitzer, p. 308). These are: (a) maximizing the full log-likelihood function; (b) maximizing the concentrated log-likelihood function; (c) maximizing a function of the transformed sum of squares function (nonlinear least squares); and (d) minimizing the transformed sum of squares function by repeated use of OLS (iterated OLS). The iterative ML estimation method (b) adopted in this study obtained stable values to within three decimal places.

[7]For the native variety, an increase in real disposable income decreases the demand for native pecans. This puts a significant downward pressure on the real price of the native variety. However, for all-pecans and improved variety, rising real incomes tend to increase their demands, to put an upward pressure on the respective prices.

Table 1. Estimated Box-Cox Parameters of Price Dependent Demand Equations for Varieties of Pecans, 1970/71 - 1988/89

Regressors	Variable Definition (annual data)	Dependent Variable (Type of Pecan) RPa	RPn	RPi
Q_a	U.S. final production, all-pecans (million lbs.)	-0.160 (-12.018)***[a] [-1.13][b]		
Q_n	U.S. final production, native-pecans (million lbs.)		-0.414 (-4.437)*** [-2.50][b]	
Q_i	U.S. final production, improved-pecans (million lbs.)			-1.05 (-6.423)*** [-1.29][b]
RP_{al}	U.S. deflated price of almonds (¢/lb.)		0.344 (4.946)***	
RPwa	U.S. deflated price of almonds (¢/lb.)	0.397 (7.101)***		0.361 (4.407)***
QBS	June U.S. pecan stocks (cold storage, million lbs.)	-0.061 (-4.675)***	-0.436 (-4.284)***	-0.272 (-2.251)**
QL1X	U.S. pecan exports lagged one-period (million lbs.)	0.070 (3.434)***	0.145 (1.648)*	0.313 (3.581)***
RINC	Deflated U.S. per capita disposable income	0.019 (0.324)	-0.933 (-2.127)**	0.462 (0.717)
Constant		2.408 (5.783)***	7.068 (4.326)***	3.195 (1.73)*
R^2 (Adj. R^2)		0.97 (0.96)	0.92 (0.89)	0.90 (0.87)
Box-Cox λ @ ρ		0.303 @ -0.55	-0.011 @ -0.68	-0.062 @ -0.48
Root MSE		0.005	0.12	0.10
Durbin-Watson		2.18	2.04	2.30
X^2 (d.f. = 2)[c]		5.33	3.53	2.60
NTP Missed[d]		0	0	0

[a] Asymptotic t-ratios appear in parentheses. Statistical significance at the .01, .05, and .10 levels is indicated by ***, **, and *, respectively.

[b] Box-Cox direct price flexibilities evaluated at the sample means appear in brackets.

[c] Chi-Square normality test of the residuals. Ciritical value at the .05 level is 5.99.

[d] Number of price turning points (NTP) within the data missed by the estimated model.

however, is that use of averaged all-pecans data appears to distort the estimated direct price flexibility for the native variety of pecans. This distortion is rationalized below.

In the specific context of the transform-both-sides EB-C model estimated in this study, Huang and Grawe have shown that an elasticity (or flexibility) estimate is biased if, for the given model, the conditional mean function (CMF) elasticity estimate differs from that stemming from only the deterministic function of the relation (DFE).[8] The CMF elasticity (or flexibility) has practical importance, because it represents market behavior (Huang and Grawe). Smooth convergence of the ML estimates of the three EB-C models in Table 1 indicated that their CMFs exist, but did not guarantee unbiasedness of

[8] The deterministic part of the EB-C model $Q_t^{(\lambda)} = Q(G_t^{(\lambda)}, U_t)$ is $G_t^{(\lambda)}$, itself a function of k explanatory variables; that is, $G(X_t^{(\lambda)}) = G(X_{1t}^{(\lambda)}, \ldots, X_{kt}^{(\lambda)})$. In this regard, $G_t^{(\lambda)}$, the deterministic function, is non-stochastic. The conditional mean function (CMF) of $Q_t^{(\lambda)}$ (that is, $E(Q_t^{(\lambda)} \mid X_t^{(\lambda)})$) may not exist for some given values of the λ power transformation parameter. Moreover, even if the CMF exists, the properties of the deterministic portion of the relation (DFE) may not be preserved. The CMF elasticity estimate (with respect to an independent variable) will depart from that of the DFE when the estimated λ is non-negative or less than minus one (Huang and Grawe, p. 146). This will produce differences between the CMF and DFE elasticities (that is, computed elasticities are biased), because the error term U_t has a non-symmetric effect on $Q_t^{(\lambda)}$ in the EB-C model $Q_t^{(\lambda)} = Q(G_t^{(\lambda)}, U_t)$. Readers are directed to Huang and Grawe for the complete mathematical treatment of the CMF and DFE in the specific context of the Box-Cox power transformation model and the computation of elasticities.

the indicated direct flexibilities. However, the difference between the CMF and DFE flexibilities under the Box-Cox power transformation when $\lambda \geq 0$ or $\lambda \leq -1$, is, in general, relatively large (Huang and Grawe, p. 146). The elasticities or flexibilities computed from EB-C models with estimated $\hat{\lambda}$s in these ranges are biased. Thus, the $\hat{\lambda}$ value of 0.303 for the averaged all-pecans model, RP_a, in Table 1 clearly showed the direct flexibility of -1.13 was biased. However, the estimated ML $\hat{\lambda}$ s for the disaggregated variety-specific native ($\hat{\lambda} = -.011$) and improved ($\hat{\lambda} = -0.062$) pecans indicate their price flexibilities were not distorted because they fell in the unbiased range.

Whichever of the potentially substitutable nuts that best reflects the relationship with each variety of pecans was used in that equation. In the current study, and as reflected in a previous study by Shafer and Hertel (pp. 69, 73), inclusion of more than one related nut price did not augment the explanatory power of the model. When Shafer and Hertel included almond and walnut prices together in their inverse demand function for all-pecans, only walnut price was statistically significant and the estimated model missed one price turning point within the data (Shafer and Hertel, p. 67). However, when they removed the (insignificant) almond price variable from their estimated model, the model's adjusted R^2 and estimated coefficients remained unchanged, none of the price turning points were missed (that is, the model tracked better), and one degree of freedom was recovered (an important consideration, because a small sample was utilized). In the present context, both almond and walnut prices were initially included in the price-explaining Box-Cox regression model for each type of pecans. However, both prices were collinear, one turning point in pecan prices was missed, and only one of the substitute prices was significant in that regression model. Upon removal of an insignificant substitute from each model, the adjusted R^2 value increased slightly, no price turning point was missed, and the estimated parameters remained invariant. Therefore, removal of an insignificant substitute nut price improved model fit and an additional degree of freedom was recovered. Consequently, only the best-fitting substitute nut was retained in each of the models. In this regard,

Table 2. Results of Likelihood Ratio Tests of Alternative Functional Forms

Models	Value of Log Likelihood Function	Likelihood Ratio Test Statistic[a]	Test Result[b]
All-Pecans:			
Extended Box-Cox	33.32		
Double-Lorgarithm	29.74	7.16	Reject
Linear	22.96	20.72	Reject
Native Pecans:			
Extended Box-Cox	26.06		
Double-Lorgarithm	23.40	5.32	Reject
Linear	19.14	13.84	Reject
Improved Pecans:			
Extended Box-Cox	22.49		
Double-Lorgarithm	20.73	3.52	Do not reject
Linear	15.73	13.48	Reject

[a] The likelihood ratio test is a standard procedure used to determine whether a restricted functional form model (such as, linear or log-log; both being special cases of the Box-Cox) differs significantly from the functional form obtained by maximizing the likelihood function of a more flexible specification (such as the Box-Cox) given the data. The appropriate test statistic, $2\,[L_{max}(\hat{\lambda}) - L_{max}(\lambda)]$, is twice the difference of the maximized values of the log likelihood functions for the unrestricted and constrained models, respectively. It is approximately distributed as a X^2 with 1 degree of freedom, being the number of independent restrictions imposed under the null hypothesis.

[b] The critical value of the $X^2(1)$ distribution at the .05 level of significance is 3.84.

Table 1 shows strong substitution existed between almonds and native pecans, while walnuts were statistically significant substitutes for both all-pecans and improved varieties.[9] Interestingly, Shafer and Hertel (using 1960-1977 annual data) reported a similar relationship between walnuts and improved varieties of Georgia pecans.

This paper focuses on both the data-averaging problem (all-pecans) and the choice of an appropriate functional form for statistical estimation, given the data. The double-log and strictly linear specifications are special cases of the flexible EB-C model (Box and Cox). By estimating equation (2) separately[10] under the null hypotheses of the double-log ($\lambda \rightarrow 0$) and strictly linear ($\lambda = 1$) forms, restricted

[9] In empirical analysis, prices of substitutes are usually correlated. Therefore, only the best of the substitutes needs to be included in the statistical analysis.

[10] Under the null hypothesis of strict linearity, the λ transformation parameter was restricted to 1. λ was constrained to 0 for the null hypothesis of a double-log functional form. The alternative hypothesis in each case was represented by the unconstrained EB-C model. For all-pecans and improved variety models, the likelihood ratio test statistic rejected the linear and double-log nested forms. The double-log specification could not be rejected for the improved variety model, however.

maximum likelihood values in Table 2 were obtained. The standard likelihood ratio Chi-square statistic (Theil) for testing the consistency of each functional form with observed data was used separately to reject strictly linear functional forms for averaged all-pecans and disaggregated improved and native varieties (see Table 2). The double-log model was also rejected (at the .05 level) by all-pecans and native variety data sets. Thus, *a priori* impositions of the restrictive linear or double-log functional form on all-pecans data in past studies appear to be inconsistent with the data. However, improved varieties may be sufficiently modeled with the double-logarithmic framework.

IMPLICATIONS AND CONCLUSION

Results of this study have implications for the marketing of pecans at the farm level. The strong statistical evidence that different rival nuts compete with different varieties of pecans in many uses (such as for baking involving mixed nuts) signals the need for the pecan industry to avert the potentially serious marketing problems posed by the competing nuts (Hubbard, Purcell, and Crocker). The pecan industry in Georgia has taken the lead in recognizing the need for information on grades and standards at the farm and first-buyer levels (Hubbard, Florkowski, and Purcell 1988). The present farm-level analysis of pecan prices by varieties using U.S. data was an effort in that direction. Different varieties of pecans are priced differently to reflect quality (i.e., grade) differences. The results of this study indicate that the price impacts of the various determinants are not necessarily the same for all-pecans (averaged data) and native and improved varieties.

Findings of this study also have implications for empirical modeling beyond that of pecans, namely, that biases due to data-averaging problems and functional-form insufficiencies can have adverse effects on the estimated coefficients, computed elasticities, and study inferences. These two problems are common in past studies of farm-level demand for pecans. Therefore, illustration with the data on pecans points out the need for researchers to use the readily available disaggregated data on pecans (by variety), and to estimate an *a priori* flexible specification that allows the data themselves to determine the best fit. Results presented in this study extend an earlier caution expressed about a different kind of misspecification in past models of farm level demand for pecans (Wells et al.).

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