CONSUMER DEMAND FOR AVOCADOS - A CASE OF MARKET DIFFERENTIATION FOR GENERICALLY-RELATED PRODUCTS

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ABSTRACT

This paper addresses specification problems in estimating demand functions for avocados in the Honolulu market. Both the Hausman specification test and a priori industry findings confirmed predeterminedness of price. On this basis, quantity was accepted as the dependent variable although it was also indicated to be predetermined in the empirical findings. Tests for equality of sets of coefficients indicate that Hawaii and California avocados, although of the same generic group, are not perfect substitutes in the Honolulu market. Demand functions suggest that own price and price of California avocados are the primary determinants of per capita consumption for Hawaii avocados, but only own price is significant for California avocados. Per capita disposable income was significant for both sources of avocados and was positive for California avocados as expected, but negative for Hawaii avocados. Because of the specialized uses of avocados, neither competing nor complementary products were identified as statistically significant determinants of per capita consumption.

KEYWORDS: avocados, demand analysis, endogeneity, functional form, specification

INTRODUCTION

Recent literature has identified problems in estimating aggregate demand for products of the same generic group, but treated as separate commodities in the marketplace. Pertinent empirical studies include works by Eales and Unnevehr; Grisley, Stefanou and Dickerson; Hayes, Wahl and Williams; and Okunade and Cochran.

The present study is concerned with consumer differentiation of Hawaii and California avocados in the Honolulu market. Related issues are functional form and predetermination of price and quantity.

Annual per capita purchases of avocados in Honolulu during the 17-year period from 1975 to 1991 averaged 1.6 pounds as compared with 1.5 pounds for in the entire U.S. Unloads of avocados in the Honolulu market for the 1975-91 period consisted of 65 percent from Hawaii and 35 percent from California (Hawaii State Department of Agriculture).
Size, price and perceived quality tend to differentiate buyers of Hawaii and California avocados (Scott and Sisson). Most Hawaii avocados range from one to 2 pounds in size and are sold on a per pound basis, which averaged a real price of 66 cents during the 1975-91 period (1980=100). California avocados, which weigh approximately 1/2 pound, are sold by the piece and averaged an equivalent of $1.84 per pound during the same period.

Aggregating the two sources of avocados in the Honolulu market might be expected to cause statistical problems in estimating demand functions if the two sources of avocados are not perfect substitutes. Okunade and Cochran determined that improved and seedling pecans differ significantly in price and compete with different nuts at the farm level, which causes a problem in data averaging.

The indication that Hawaii and California avocados are treated as separate products in the Honolulu market does not strictly conform to the term "separability" as used in the theoretical literature, although references concerning disaggregation are found primarily under separability. Separability in demand analysis includes several different concepts, each of which requires a different set of parametric restrictions (Hayes, Wahl and Williams; Pudney). Pudney relates separability to decentralization of preference structures, including direct and indirect separability of utility, cost or distant functions.

Madalla indicates that the term aggregation is also used in different senses and may be separated into aggregation of relations and aggregation of variables. Theil's pioneering work addresses aggregation over individuals, time periods and commodities. Green; and VanDaal and Merkies treat aggregation as related to individual preferences and production functions and consider goods adaptable to aggregation if quantities or prices of the components vary proportionately.

Hayes, Wahl and Williams tested for separability of meat products in Japan by using parameter restrictions on an AIDS model. Both Fisher and Pudney applied clustering as a tool for aggregating. Eales and Unnevehr tested for weak separability among meat products by applying an adjusted nonlinear Wald test to an AIDS model.

Conceptual Framework

Linear demand functions for avocados in the Honolulu market for 1975-91 provide the basic models for specification tests in the present study. Choice of functional form is based on likelihood ratio tests of nested forms in relation to the Box-Cox functional form. The Hausman specification test as adapted by Thurman is used to test for predeterminedness of price and quantity. The Gujarati dummy variable modification of the Chow test is used to determine if Hawaii and California avocados are perfect substitutes or separate commodities.

The paper is organized into four sections, consisting of functional form, endogeneity tests for predeterminedness of price and quantity and empirical findings. Tests for correct functional form provide the basis for subsequent specification tests.

Data

Availability of time series data limited the period of analysis to 1975-91. Prices were recorded at the Honolulu wholesale level, except for five years of missing Honolulu wholesale prices for California avocados, which were estimated by applying a conversion factor of 1.47 to
Los Angeles wholesale prices. Wholesale price data were converted to the retail level to reflect primary demand by a multiplier of 1.55, derived from years for which both retail and wholesale prices were available and margins available for other fruit products.

Time series data for the study were obtained from the following sources: Honolulu wholesale prices, Hawaii supermarket audit trends and Honolulu arrivals of fresh fruits and vegetables from the Hawaii State Department of Agriculture; California grower prices, per capita consumption and price indices from the USDA Economic Research Service; and Honolulu de facto population data from the Annual Data Book of the Hawaii Department of Business, Economic Development and Tourism. Cross-sectional data are from a study of consumer demand for avocados in Honolulu by Scott and Sisson. Honolulu retail and wholesale produce buyers were interviewed for data on avocado buying practices.

**Functional Form**

The specification problem of functional form is extensively examined in consumer demand literature (Judge, Hill, Griffiths, Lutkerpol and Lee). The power transformation for the Box-Cox functional form as specified by Box and Cox is:

\[
(1) \quad y^{(\lambda)} = \begin{cases} 
(y^\lambda - 1)/\lambda & \lambda \neq 0 \\
\ln y & \lambda = 0 
\end{cases}
\]

The transformed variables are included in a linear function to allow specification and estimation of generalized models of the following form (Spitzer):

\[
(2) \quad y^{(\lambda)} = \beta_1 + \beta_2 x_2^{(\lambda_2)} + \ldots + \beta_k x_k^{(\lambda_k)} + \varepsilon
\]

The Box-Cox models are expected to minimize misspecification and functional approximation errors if likelihood ratio tests indicate that they are more appropriate than the restrictive functional forms (Spitzer). Problems and attributes of the Box-Cox transformation are well documented and addressed among others by Box and Cox; Gemmill; Savin and White; Spitzer; and Zarembka.

Likelihood ratio tests for linear and doublelog functional forms against the more flexible Box-Cox form were applied to the following models for Hawaii, California and aggregated avocados in the Honolulu market. Only a quantity dependent equation is tested for aggregated avocados because the two sources of avocados are priced separately.

\[
(3) \quad HOPC = b_{10} + b_{11} HOPD + b_{12} HCPD + b_{13} PCDI + u_1
\]

\[
(4) \quad HOPD = b_{20} + b_{21} HOPC + b_{22} HCPD + b_{23} PCDI + u_2
\]

\[
(5) \quad HCPD = b_{30} + b_{31} HOPD + b_{32} HCPD + b_{33} FAT + u_3
\]
(6) \[ HCPP = b_{40} + b_{41}HCPD + b_{42}PCDI + b_{43}FAT + u_4 \]

(7) \[ HOPTO = b_{50} + b_{51}HOPD + b_{52}TREND + u_5 \]

Where HOPC and HCPC are per capita consumption of Hawaii and California avocados, respectively; HOPD and HCPD are retail prices of Hawaii and California avocados, respectively; PCDI is Honolulu disposable per capita income, FAT is Honolulu price index of fresh fruits and vegetables and HOPTO is aggregate per capita consumption of Hawaii and California avocados.

Based on test results in Table 1, the double log functional form is selected for Hawaii avocados and the linear form for California avocados for both quantity dependent and price dependent equations. The selected forms are equal to Box-Cox in the likelihood ratio tests and are less apt than Box-Cox to provide spurious results because of limited sample size. The Box-Cox form test more appropriate for aggregated avocados.

**Endogeneity Tests**

Predeterminedness of price and quantity in applied analysis is most often decided on an a priori basis (Heien; Houck; Thurman) and proper statistical specification has received little attention (Thurman). Also, the concept that the competitive market determines price and quantity simultaneously may be inappropriate in applied demand analysis (Theil, Vol. I). Theil postulates that prices in general are set by suppliers based on cost, independent of consumption, but suggests that it is preferable to treat quantity as predetermined for agricultural products (Theil, Vol. II). He reasons that if the market for agricultural products is cleared every year, the supply makes the i th quantity predetermined. The role of prices is then to ensure that the market is cleared.

Predeterminedness of price or quantity may reflect the level of analysis. Quantity may be predetermined at the farm level, but must interact with demand at a fixed price at the retail level. This is particularly true for perishable produce, such as avocados, where quantity in excess of that demanded becomes spoilage.

Honolulu produce buyers report that price is predetermined for both Hawaii and California avocados at wholesale and retail levels. Producer groups offer avocados at predetermined prices which reflect size of crop and production costs. Buyers in turn anticipate the quantity that would be purchased at specified prices and adjust their purchases accordingly. Timing of price-quantity relationships in the marketplace suggests that choice of dependent variable may be problematic in spite a priori findings and the need for a confirming empirical test is suggested. The Hausman test as adapted by Thurman is used for this purpose. The basic model is as follows:

(8) \[ M = q^{r} \cdot \left[ V(q) \right]^{-1} \cdot q \]

where \( M \) = the test statistic, which is chi square;
\[ \hat{q} = (b_1 - b_o); \]

\[ \hat{V}q = (V_1 - V_o); \]

\( b_o \) and \( V_o \) are OLS estimator and variance, respectively, \( b_1 \) and \( V_1 \) are 2SLS (instrumental) estimator and variance.

Models used in the Hausman test for predeterminedness of price or quantity in the current study are as follows for predetermined quantity:

(9) \[ P = b_o \cdot bQ \cdot b_1X_1 \cdot e \]

and for predetermined price:

(10) \[ Q = b_o \cdot bP \cdot b_1X_1 \cdot e \]

where \( Q \) is per capita consumption, \( P \) is deflated wholesale price and \( X \) is a vector of right-hand side variables. 2SLS models for instrumental variables in the test for predeterminedness of quantity and price, respectively, are:

(11) \[ P = b_o \cdot bQ \cdot b_1X_1 \cdot b_2X_2 \cdot e, \text{ and} \]

(12) \[ Q = b_o \cdot bP \cdot b_1X_1 \cdot b_2X_2 \cdot e. \]

where \( P, Q \) and \( X_1 \) are as defined above and \( X_2 \) is a vector of exogenous variables in the system.

In compliance with the likelihood ratio tests in Table 1, the double log functional form is used for the efficient estimator for the Hausman test of predeterminedness of quantity and price for Hawaii avocados. The linear form is used for the same purpose for California avocados. 2SLS models are used for the consistent estimator in both instances. Instrumental variables in the 2SLS equations for both sources of avocados are: U.S. indices of fertilizer cost, total production costs and fuel and energy cost; California avocado production; Hawaii field worker
wage and Honolulu index of fruit and vegetable prices. All price variables are expressed in real terms (1980=100).

Hausman test results for predeterminedness of price and quantity for Hawaii and California avocados are shown in Table 2. The test statistic, M, is less than the critical value for both price and quantity for both sources of avocados, indicating predeterminedness or endogeneity in all instances. This suggests that none of the equations is mispecified and that either price or quantity is an appropriate predictor variable. Although the results confirm predeterminedness of price, they fail to confirm the expectation that quantity is the exogenous, dependent variable that adjusts to clear the market. Eales and Unnevehr also found the Hausman specification test to be inconclusive for testing for endogeneity, but with both price and quantity testing endogenous, indicating that either would be appropriate as the dependent variable (Eales and Unnevehr). Since both the Hausman test and a priori findings suggest that price is predetermined, quantity was accepted in this analysis as the dependent variable.

**Tests for Equality of Hawaii and California Avocados**

Demand relationships between Hawaii and California avocados suggest that they may not be perfect substitutes and that aggregation in demand analysis may give spurious results. Thirty-five percent of consumers were willing to buy California avocados at a mean price 2.8 times that of Hawaii avocados during the period of analysis. Also, prices of the two types of avocados were minimally correlated as indicated by an R² of 0.10.

For a more conclusive indication of equality, tests to determine whether sets of coefficients belong to the same regression are frequently applied (Chow; Gujarati; Litchenberg). The Gujarati dummy variable procedure for the Chow test is used in this analysis. The basic equation for Gujarati’s dummy variable procedure as an alternative to the Chow test is:

\[
Y_{ij} = \beta_1 + \beta_{11} X_{1j} + \beta_{12} X_{2j} + u_{ij}
\]

\[i = 1, \text{ and } 2, \quad j = 1 \ldots, \ N.\]

where \(X_{1j}\) and \(X_{2j}\) are predictor variables

and \(u\) is the stochastic error term

In this equation, differential intercept and differential slope coefficients between groups are determined and the actual values can be derived from these coefficients.

The Gujarati dummy variable test requires common demand functions for the two sets of coefficients. To satisfy this requirement predictor variables most applicable to both Hawaii and California avocados were utilized to constitute the models, although the significance of the variables in the respective equations varied between the two regions. Since the Gujarati dummy
variable test requires a common functional form for products being tested for equality of coefficients, the linear form was selected for this purpose. Based on the likelihood ratio tests, the linear form fitted the data best in the quantity dependent equation for California avocados and was only minimally inferior to the double log form for Hawaii avocados. In addition, the linear form permits use of the HETCOV correction for unknown heteroskedasticity. The demand functions developed for the Gujarati dummy variable test are as follows:

\[
(14) \ HOPC = b_{10} + b_{11}HOPD + b_{12}HCPD + b_{13}PCDI + b_{14}FAT + u_1
\]

\[
(15) \ HCPC = b_{20} + b_{21}HOPD + b_{22}HCPD + b_{23}PCDI + b_{24}FAT + u_2
\]

Where variables are as defined in the tests for functional form.

The Gujarati dummy variable test, like the Chow test, assumes normal and independent distribution of stochastic disturbances with zero mean and constant variance. Results may be severely affected by uncorrected specification errors (Gujarati; Thursby). When tested separately, both equations (14) and (15) tested in the indecisive zone for autocorrelation based on the Durbin-Watson d test. But the combined data of the two equations in the test for equality of coefficients indicated no significant autocorrelation. Goldfield-Quant, Breusch-Pagan-Godfrey and Harvey tests all indicated no heteroskedasticity, either for the equations separately or in combination for the test for equality of coefficients. As a further precaution, White's HETCOV correction (heteroskedastic-consistent covariance matrix estimation) was applied in the analysis to account for unknown heteroskedasticity.

The null hypothesis of equality of complete sets of coefficients for equations (14) and (15) was decisively rejected with an F-statistic of 39.94 with 5 and 24 degrees of freedom at a critical value of 2.62 at the .05 level. Separate tests for slope and intercept had F-statistics of 18.72 (cv=2.78) and 36.19 (cv=4.20), respectively. The two products could still be perfect substitutes if only the intercepts differed significantly (Hays, Wahl and Williams), but this is not the case. The results clearly suggest that Hawaii avocados and California avocados are separate and competing products in the Honolulu market, with own price of each functioning as a cross-price for the other.

**Empirical Findings for Demand Functions**

Parameter estimates of demand functions for Hawaii, California and aggregated avocados are shown in Table 3. For California and Hawaii avocados, each equation requires a different set of predictor variables, which may be expected since the Gujarati dummy variable test indicated that the two sources of avocados are not perfect substitutes. R² values are acceptably high and all predictor variables are significant at the .05 level for each equation. Goldfield-Quandt, Breusch-Pagan-Godfrey and Harvey tests indicated no significant heteroskedasticity for either of the models. The Durbin- Watson d test detected no autocorrelation for either equation.

Predictor variables for per capita consumption differ significantly between Hawaii and California avocados as determined by the Gujarati dummy variable test. Per capita consumption for Hawaii avocados is a function of own price, California avocado price and per capita
disposable income. Per capita consumption of California avocados, on the other hand is a function of own price, Honolulu fresh fruit and vegetable price index, per capita disposable income and an adjustment factor for distorted California avocado price-quantity relationships during 1990 and 1991. Price of Honolulu avocados had the correct sign as a cross-price for California avocados, but was statistically insignificant. This finding is consistent with Hausman specification test results, which indicate that both price and quantity of California avocados are predetermined. The highly volatile short term cycles in California avocado production play a major role in price-quantity relationships at retail and wholesale levels as well as at the producer level. The fact that the price of California avocados in the Honolulu market is determined largely by total industry production does not in itself invalidate the finding that Hawaii and California avocados are competitive rather than perfect substitutes. This is evidenced by the decisive rejection of equality in the Gujarati dummy variable test results and the fact that the California avocado price is a major determinant of per capita consumption of Hawaii avocados.

In spite of predictor variable differences, own price elasticity of the two sources of avocados was almost identical, amounting to -1.10 for Hawaii avocados and -1.16 for California avocados. But per capita disposable income, although positive as expected for higher priced California avocados, was negative for Hawaii avocados. This is consistent with findings in the cross-sectional consumer demand study for avocados in Honolulu by Scott and Sisson in which the income effect for Hawaii avocados was offset by high per capita consumption by low income ethnic groups. The per capita demand function for the aggregate of Hawaii and California avocados is a function of Hawaii avocado price and time trend, only, which is inconsistent with the individual demand functions for the two products. This suggests that a meaningful analysis of demand for avocados in Honolulu cannot be obtained by aggregating the two sources of avocados.

Demand for avocados is unique in the sense that no significant competing or complementary products have been identified, except that Hawaii and California avocados are not perfect substitutes and are treated as separate products in the marketplace. Avocados are comparable to other soft fruits physiologically, but are consumed differently. Avocados are consumed primarily in salads, individually or with varying amounts and kinds of other ingredients, in sandwiches and as guacamole (Scott and Sisson). Complementary products include mayonnaise, sugar, onions, tomatoes, lettuce and other vegetables, but the use of these products with avocados is minimal and price changes would not likely have a significant effect on avocado consumption.

CONCLUDING COMMENTS

Various specification tests are applied to demand functions for avocados in the Honolulu market to increase statistical precision in demand analysis. The Hausman specification test as adapted by Thurman for testing for endogeneity of price and quantity of chicken is applied to Hawaii and California avocados in the Honolulu market for the same purpose. The test indicates that both quantity and price are endogenous, which is inconsistent with a priori findings of predetermination of price, only, with quantity being the market clearing mechanism. This finding, plus unexpected results obtained by
Thurman; and Eales and Unnevehr may suggest serious limitations in the use of specification tests for dependent variable selection.

The Gujarati dummy variable procedure for the Chow test decisely rejected the null hypothesis of equality of coefficients for Hawaii and California avocados for both intercept and slope, suggesting that the two types of avocados are separate products in the market. Because the two types of avocados have significantly different parameter values, aggregating or averaging might likely provide coefficients that misrepresent the market clearing process. Findings of the study might be expected to have implications in other demand analyses involving dependent variable selection and aggregation of generic products that are differentiated in the market place.

LITERATURE CITED


J.HAW.PAC.AGR. (1994)


<table>
<thead>
<tr>
<th>Model &amp; Dep. &amp; Var.</th>
<th>Log Likelihood Function</th>
<th>Likelihood Ratio Test Statistic*</th>
<th>Test Result</th>
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<tr>
<td><strong>Hawaii Avocados</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(3) HOPC</td>
<td>Box-Cox</td>
<td>13.80</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Linear</td>
<td>11.53</td>
<td>4.52</td>
</tr>
<tr>
<td></td>
<td>Loglog</td>
<td>13.79</td>
<td>0.02</td>
</tr>
<tr>
<td>(4) HOPD</td>
<td>Box-Cox</td>
<td>50.73</td>
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<td>Linear</td>
<td>51.93</td>
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<td></td>
<td>Loglog</td>
<td>50.74</td>
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<tr>
<td><strong>California Avocados</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(5) HCPC</td>
<td>Box-Cox</td>
<td>11.50</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Linear</td>
<td>11.56</td>
<td>0.28</td>
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<tr>
<td></td>
<td>Loglog</td>
<td>7.11</td>
<td>8.78</td>
</tr>
<tr>
<td>(6) HCPD</td>
<td>Box-Cox</td>
<td>11.89</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Linear</td>
<td>11.82</td>
<td>0.14</td>
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<td></td>
<td>Loglog</td>
<td>6.86</td>
<td>10.96</td>
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<tr>
<td><strong>Aggregate</strong></td>
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<td></td>
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<tr>
<td>(7) HOPTO</td>
<td>Box-Cox</td>
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<tr>
<td></td>
<td>Linear</td>
<td>4.45</td>
<td>9.32</td>
</tr>
<tr>
<td></td>
<td>Loglog</td>
<td>7.00</td>
<td>4.22</td>
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</table>

* Procedure for determining whether the restricted functional form models differ from that obtained by maximizing the Box-Cox likelihood function. The test statistic is twice the difference of the likelihood ratios between the Box-Cox transformation and each of the restricted forms. The test statistic is chi-square with one degree of freedom and a critical value of 3.84 at .05 level of significance.
Table 2. Hausman Test Results for Predeterminedness of Price and Quantity for Hawaii and California Avocados

<table>
<thead>
<tr>
<th>Avocado Source</th>
<th>Dependent Variable</th>
<th>Variable Tested</th>
<th>Test Results*</th>
</tr>
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<tbody>
<tr>
<td>Hawaii</td>
<td>Q HOPC</td>
<td>HOPD</td>
<td>3.30 (Acc)</td>
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<tr>
<td></td>
<td>P HOPD</td>
<td>HOPC</td>
<td>1.96 (Acc)</td>
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<tr>
<td>California</td>
<td>Q HCPC</td>
<td>HCPD</td>
<td>2.03 (Acc)</td>
</tr>
<tr>
<td></td>
<td>P HCPD</td>
<td>HCPC</td>
<td>1.78 (Acc)</td>
</tr>
</tbody>
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* Statistics are chi-square with 3 degrees of freedom. The critical chi-square value at .05 is 7.81. Non-rejection indicates that the test variable is predetermined or that the equation is not misspecified.
Table 3. Parameter Estimates of Demand Functions for Hawaii and California Avocados in the Honolulu Market

<table>
<thead>
<tr>
<th>Model</th>
<th>Dependent Variable</th>
<th>Explanatory Variables*</th>
<th>F</th>
<th>Adj R²</th>
<th>Durbin-Watson</th>
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<td>(16)</td>
<td>HOPC</td>
<td>CONST HOPD HCPD PCDI</td>
<td>22</td>
<td>.80</td>
<td>1.74</td>
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<tr>
<td></td>
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<td>18.72 -1.17 0.41 -2.27</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.75  -5.26 4.40 -2.87</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>18.72 -1.17 0.41 -2.27</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(17)</td>
<td>HCPC</td>
<td>CONST HCPD PCDI FAT C</td>
<td>12</td>
<td>.73</td>
<td>2.20</td>
</tr>
<tr>
<td></td>
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<td>-4.52  -0.01 0.01 0.02</td>
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<td>-7.93  -1.10 6.36 3.10</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>(18)</td>
<td>HOPTO</td>
<td>CONST HOPD TREND</td>
<td>23</td>
<td>.73</td>
<td>1.59</td>
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<tr>
<td></td>
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<td>50.82  -57.28</td>
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<td></td>
<td></td>
<td>6.28  -6.23</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>88.26  -0.91</td>
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* The first row for each equation specifies regression coefficients; the second row, t-ratios; and the third row, elasticities at the means. All parameters are significant at the .05 level.