Short Run and Long Run dynamics in the Demand of U.S Tree Nuts

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Abstract

There has been significant shifts in both international and domestic demand for U.S tree nuts over the past decade with potentially mixed effects for U.S producers and consumers. This paper investigates short run and long run dynamics in the domestic demand for six brands of tree nuts (pecan, almonds, walnuts, macadamias, pistachios and hazelnuts) using annual time series data for utilization and value. A static and a dynamic Almost Ideal Demand system (AIDS) was estimated with Seemingly Unrelated Regression. We analyzed consumers responsiveness to price and expenditure using parameters derived from the model

Keywords: Tree nuts, Demand analysis, Long run, Short run, AIDS, SUR

1. Introduction and Background

Over the last two decades, the U.S tree nut industry has experienced remarkable changes in terms of production and consumption. Total production of shell tree nuts increased by 400% from half a billion in 1980 to 2.5 billion pounds in 2011 (USDA, ERS 2011). At the same time U.S per capital consumption of all shell tree nuts increased from a little under 2 lbs to over 3 lbs. Per unit nominal price for each nut has risen by at least 100%, far outstripping the rate of inflation. Recent surge in per unit price of tree nuts within the past years has been linked to significant increase in foreign demand, particularly from Asia. For example exports of pecan to China has skyrocketed within the last 4 years by 5000% from 141 thousands lbs in 2007 to 7.3 million lbs in 2011. In addition, exports to Vietnam have soared during the same period by 500% from 165 thousands lbs to 10.2 million lbs. The

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increase in the presence of U.S. tree nuts in foreign markets is also due to extensive marketing effort of producer's organizations supported in part by Federal government programs.

The tree nut industry is one of the least investigated areas by Applied Economists. Recent shifts in both international and domestic demand for tree nuts could presents both an opportunity and a drawback, if not carefully exploited. Recent trends in the demand of tree nuts could curtail supply in domestic markets putting pressure on per unit price of tree nuts and forcing consumers to change their consumption behavior. The degree to which U.S and foreign consumers are responsive to changes in prices of tree nuts and real income could determine the overall profitability of the U.S and foreign markets in the long and short run. This information if available will help producers to make more strategic investments. Tree nuts generally take a couple of years from planting to maturity, and production from onset of maturity is low and gradually increases to its peak. Therefore, in deciding what to plant and how much of to plant requires careful consideration of consumers' behavior in both short and long run. Without proper consideration, differential profit margins induced by recent high international demand of certain tree nuts could entice producers to make poor investment choices such as shifting investment to less profitable tree nuts, while crowding out investment in the more profitable ones.

This study empirically investigates short run and long run dynamics in the domestic demand for six brands of tree nuts (pecan, almonds, walnuts, macadamias, pistachios and hazelnuts) using a static and a dynamic Almost Ideal Demand system (AIDS). The model specification is based on analysis of time series properties the data (trend, stationarity and cointegration). Estimates from the model are use to uncover Marshallian elasticities of each tree nut type.

Results based on our analysis showed that almonds and pecan are more sensitive to changes in own price both in the long and short run.

Findings from this study will benefit tree nut growers interested in developing an efficient pricing strategy and creating an optimal investment portfolio of the types of tree nuts. Results form this study will also be relevant to policy makers in updating or creating new trade and tariff policies for the tree nut sector. Moreover, this study provide updated demand elasticity estimates that can be use in theoretical economic models to investigate policy changes ex-ante.

The rest of the paper is organized as follows. In section two, we specify the AIDS model. Section three discusses the data while section four presents results and discussions. Finally, we conclude with a summary of major findings and the policy implications.

2. Model specification and estimation

The theoretical framework use in this study is based on the AIDS model first developed by Deaton and Muellbauer (1980) and subsequently extended and popularized by Chalfant (1987); Greene and Alston (1990); Hayes et al. (1990). The AIDS model have been extensively used by applied econometricians and is widely accepted based on the string empirical analysis published since the early nineties. The flexible form of model made it superior to the Rotterdam model in conducting demand analysis (Trimidas, 2000).

For completeness, we separately specify the static and dynamic AIDS model use in examining the long run and short run demand for six tree nuts in the U.S.

Following Deaton and Muellbauer (1980), the static model takes the form

$$W_{i,t} = \alpha_i + \beta_i ln(\frac{\mathbf{M_t}}{\mathbf{P_t}}) + \Sigma_{i=1}^{n} \varphi_{ij} ln(p_j) + \nu_{i,t}, \quad i = j = 1, .., n \tag{1}$$

Where $W_{i,t}$ is the budget share of tree nut i at time t, p_j is the price of tree nut j, $\mathbf{M_t}$ is the total expenditure on all six tree nuts at time t, $\mathbf{P_t}$ represents value of a price index, α_i, β_i and φ_{ij} are the parameters, n=6 is the number of tree nuts in the system of equation, and $\nu_{i,t}$ the error term. The stone's price index is use for the linear approximation of the AIDS model and is defined as:

$$ln\mathbf{P_t} = \Sigma_i^n W_{i,t} log\mathbf{P_{i,t}} \tag{2}$$

Consistent with the economic theory of demand, the model parameters are restricted following adding up ($\Sigma \alpha_i = 1, \Sigma \beta_i = 0, \Sigma_i \varphi_{ij} = 0$), homogeneity ($\Sigma_j \varphi_{ij} = 0$) and symmetry ($\varphi_{ij} = \varphi_{ji}$) restrictions. Where α_i is the estimated budget share of tree nut i, and represent the commodity expenditure coefficient which captures the variation of good is expenditure when real income changes. The coefficients on the price (φ_{ij}) captures how the budget share of good i changes with a percentage change in the price of good j holding the real expenditures fixed.

Estimation of the model was done by iterative Seemingly Unrelated Regression (SUR). The parameter estimates were then use to derive the expenditure elasticity ($\varrho = 1 + \frac{\beta_i}{W_{i,t}}$) and Marshallian elasticity ($\zeta^M = -\tau_{ij} + \frac{\varphi_{ij}}{W_{i,t}} - \frac{\beta_j W_j}{W_i}$). Where τ is the Kronecker delta with $\tau_{ij} = 1$ for $i = j$, and $\tau_{ij} = 0$ when $i \neq j$.

The static model assumes consumer's behavior is in equilibrium, and thus do not change over time. Since equilibrium is attain in the long run, this model therefore predicts demand behavior in the long run. However, in reality, it takes a while for consumers to fully adjust back to equilibrium once out of it (Sulghan and Zapata, 2006). During this time factors such as, habit formation, adjustment costs, imperfect information and incorrect expectations may cause some adjustment time to changes in prices and consumer income (Jaffry and Brown, 2008). Mindful of this, we investigated the time series properties of the data by testing for stationary using the augmented Dickey-Fuller (ADF) test and the Phillips-Perron. Conditional on the order of integration, we then tested for cointegration of the model variables. If the null hypothesis is rejected in the later test, an AIDS Error Correction Model (AIDS-ECM) will be fitted, and takes the form.

$$\Delta W_{i,t} = \Sigma_{i=1}^{n} \delta_i \Delta W_{i,t-1} + \beta_i \Delta ln(\frac{\mathbf{M_t}}{\mathbf{P}}) + \Sigma_{i=1}^{n} \varphi_{ij} \Delta ln(p_{j,t}) + \gamma_i \hat{e}_{i,t-1} + \nu_{i,t}, \tag{3}$$

Where Δ represents the difference operator, $\hat{e}_{i,t-1}$ is the estimated residuals from the cointegrated equation (1), $\gamma_i, -1 < \gamma_i < 0$ is the speed-of-adjustment parameter, and $\nu_{i,t}$ the error term. If γ_i is close to zero, there is rapid adjustment and system falls back to equilibrium. On the other hand, if γ_i is close to zero, the adjustment is slow. The $\Delta W_{i,t}$ variable captures the short-run disturbances in the share of each tree nut in total expenditure while $\hat{e}_{i,t-1}$ captures the long-run equilibrium relationship [1].

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[1]Structural change could impact estimation involving time series data. We tested for this using the

3. Data

Data used in this study was obtained from the Economic Research Serverce (ERS) of the United State Department of Agriculture (USDA) and include annual production (1000 lbs) and unit prices (cents/lbs) from 1981 to 2011. We converted the annual production into per capital output by dividing it with the respective U.S. annual population. Yearly population data for the U.S. was obtained from the U.S. Federal reserve web site. To proceed, we first tested the data (budget shares and log of prices) for stationarity using Dickey-Fuller and Phillips-Perron test and fail to reject the null hypothesis that budget shares and prices of the six tree nuts contain unit root. However, after first difference the data became stationary based on the same test. The results for the test before (L) and after first difference (D) are presented in table 1. We report the test statistic (Z_t) and the MacKinnon approximate p-value (p) within the parentheses. Next, we tested the demand system for cointegration with a Phillips-Perron test based on a (1,1) order of integration. The results showed that the budget shares and prices were cointegrated and thus lending credibility to the dynamic model in equation 3. To prevent linear dependence in the system of equation and the covariance

Table 1: Unit root test for level (L) and differenced (D) data

	Dicky=Fuller		Phillips-Perron	
	L	D	L	D
Budget share	$Z_t(p)$	$Z_t(p)$	$Z_t(p)$	$Z_t(p)$
Almonds	-2.58(0.10)	-6.22(0.00)	-2.64(0.08)	-6.35(0.00)
Hazelnuts	-9.27(0.00)	-16.33(0.00)	-8.84(0.00)	-21.83(0.00)
Pecan	-2.76(0.06)	-8.75(0.00)	-2.71(0.07)	-9.86(0.00)
Walnuts	-2.96(0.04)	-8.01(0.00)	-2.82(0.05)	-9.54(0.00)
Macadamias	-0.73(0.84)	-7.72(0.00)	-0.42(0.91)	-7.97(0.00)
Pistachios	-2.79(0.06)	-14.85(0.00)	-2.77(0.06)	-17.14(0.00)
Log of price	$Z_t(p)$	$Z_t(p)$	$Z_t(p)$	$Z_t(p)$
Almonds	-2.71(0.07)	-7.23(0.00)	-2.84(0.05)	-7.31(0.00)
Hazelnuts	-1.53(0.52)	-8.25(0.00)	-1.44(0.56)	-8.73(0.00)
Pecan	-2.13(0.23)	-7.73(0.00)	-1.91(0.33)	-8.75(0.00)
Walnuts	-2.48(0.12)	-7.49(0.00)	-2.35(0.16)	-8.99(0.00)
Macadamias	-2.17(0.22)	-4.16(0.00)	-2.30(0.17)	-4.08(0.00)
Pistachios	-3.64(0.00)	-9.68(0.00)	-3.72(0.00)	-9.97(0.00)
Expenditure	-1.62(0.47)	-9.16(0.00)	-1.21(0.67)	-12.24(0.00)

matrix, we dropped one equation (the hazelnut) from the system prior to estimation, and recovered their parameters after estimation using the adding-up restriction. The restricted demand system models were each estimated using the Seemingly Unrelated Regression (SUR) iteratively. Different specifications of the static model was also estimated with sine and

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cumulative sum and cumulative sum squared test and failed to reject the null hypothesis

cosine function, and trend to capture seasonality and technological evolution. The AIDS model including the time trend stood out in terms of fit. Therefore, our final specification for the static model is

$$W_{i,t} = \alpha_i + \beta_i ln(\frac{\mathbf{M_t}}{\mathbf{P_t}}) + \Sigma_{i=1}^{n} \varphi_{ij} ln(p_j) + \phi_i t + \nu_{i,t}, \quad i = j = 1, .., n, \tag{4}$$

With the additional restriction of $\Sigma_{i=1}^{n} \phi_i = 0$.

4. Results and Discussion

Tables 2 and 3 present estimated parameters from the static and dynamic model respectively. The expenditure coefficient (β_i) for almonds, walnuts and macadamia are statistically significant at $\alpha = 0.1$ or less. However, the sign on the coefficient for almond is positive suggesting that almond is a luxury good. The time trend coefficient is statistically significant for pecan indicating its budget share has been increasing over the study period. These parameter estimates were subsequently used to derive short-run and long-run elasticities.

Table 2: Estimates of Long run demand model for U.S tree nuts

Parameter	Almonds	Pistachios	Pecan	Walnuts	Macadamias	Hazelnuts
α_i	0.1995 (0.097)	0.1055 (0.061)	0.3205 (0.063)	0.3052 (0.047)	0.0570 (0.006)	0.0123
φ_{i1}	0.1742 (0.037)	-0.0363 (0.021)	-0.0530 (0.022)	-0.0737 (0.019)	-0.0103 (0.002)	-0.0008
φ_{i2}	-0.0363 (0.021)	0.0164 (0.024)	0.0164 (0.014)	0.0006 (0.015)	-0.0003 (0.002)	0.0033
φ_{i3}	-0.0530 (0.022)	0.0164 (0.014)	0.0613 (0.018)	-0.0190 (0.013)	-0.0040 (0.002)	-0.0017
φ_{i4}	-0.0737 (0.019)	0.0006 (0.015)	-0.0190 (0.013)	0.0986 (0.021)	-0.0093 (0.003)	0.0029
φ_{i5}	-0.0103 (0.002)	-0.0003 (0.002)	-0.0040 (0.002)	-0.0093 (0.003)	0.0249 (0.003)	-0.0010
φ_{i6}	-0.0008 (0.004)	0.0033 (0.005)	-0.0017 (0.003)	0.0029 (0.005)	-0.0010 (0.002)	-0.0027
β_i	0.1841 (0.068)	-0.0425 (0.042)	-0.0660 (0.044)	-0.0570 (0.033)	-0.0209 (0.004)	0.0022
t	-0.0010 (0.002)	0.0046 (0.001)	-0.0030 (0.002)	-0.0007 (0.001)	0.0003 (0.000)	-0.0001

1=almonds; 2=hazelnuts; 3=pecan; 4=walnuts; 5=macadamias; 6=pistachios.

Table 3: Estimates of short run demand model for U.S tree nuts

Parameter	Almonds	Pistachios	Pecan	Walnuts	Macadamias	Hazelnuts
δ_i	-0.5066 (0.066)	-0.4393 (0.063)	-0.4660 (0.065)	-0.4661 (0.064)	-0.0639 (0.099)	0.990
φ_{i1}	0.1792 (0.031)	-0.0152 (0.018)	-0.0544 (0.016)	-0.0880 (0.022)	-0.0144 (0.003)	2.942
φ_{i2}	-0.0152 (0.018)	0.0020 (0.020)	0.0224 (0.014)	-0.0099 (0.016)	-0.0001 (0.002)	0.993
φ_{i3}	-0.0544 (0.016)	0.0224 (0.014)	0.0509 (0.019)	-0.0148 (0.014)	-0.0027 (0.001)	1.001
φ_{i4}	-0.0880 (0.022)	-0.0099 (0.016)	-0.0148 (0.014)	0.1097 (0.024)	-0.0050 (0.002)	1.008
φ_{i5}	-0.0144 (0.003)	-0.0001 (0.002)	-0.0027 (0.001)	-0.0050 (0.002)	0.0231 (0.004)	0.999
φ_{i6}	-0.0072 (0.005)	0.0007 (0.003)	-0.0015 (0.003)	0.0079 (0.004)	-0.0009 (0.002)	1.001
β_i	0.2125 (0.041)	-0.0193 (0.032)	-0.0758 (0.035)	-0.0906 (0.032)	-0.0270 (0.004)	0.999
γ_i	1.3439 (0.182)	-0.3854 (0.145)	-0.6104 (0.190)	-0.2791 (0.143)	-0.0173 (0.015)	0.948

1=almonds; 2=hazelnuts; 3=pecan; 4=walnuts; 5=macadamias; 6=pistachios.

Table 4 and 5 present long-run and short-run uncompensated price elasticities for the six tree nuts. Expectedly, all own-price elasticities in both short and long run are negative

indicating an inverse relationship between prices and expenditure shares of the different commodities.

The estimated Marshallian own-price elasticities for almonds, hazelnuts, pecan, walnuts, macadamias and pistachios based on the static model are -1.062, -1.000, -0.906, -0.877, -0.963 and -0.956 respectively. The estimates show high similarity between all six tree nuts in the long run conditional on expenditures, with almonds being the most sensitive to its own price change, while walnut is the least. Specifically, a 1 % increase in the price of almonds and walnut will lead to a 1.062% and 0.877% decrease in the demand of almonds and walnuts.

The estimated Marshallian own-price elasticities from the dynamic model also show high similarity to those derive from the static model in terms of magnitude. The own-price elasticity estimates from the dynamic model are -1.133, -0.994, -0.924, -0.861, -0.963 and -0.964 for almonds, hazelnuts, pecan, walnuts, macadamias and pistachios respectively. Again, these results show that almonds is the most sensitive tree nut to its own price change, while walnut is the least sensitive to its own price change. In this case, a 1 % increase in the price of almonds leads to a 1.133 % decrease in its demand, while a similar increase in the price for walnut will lead to a 0.861 % decrease in its demand.

While the values of the elasticity estimates are similar in both the static and dynamic model, it does show that almonds and pecan are slightly more sensitive to their own price change in the short-run than in the long-run. Conversely, hazelnuts and walnuts are less sensitive to their own price change in the short-run than in the long-run, while macadamias and pistachios are about as sensitive to their own price change in the short-run as much as the long-run.

Table 4: Long run Marshaillian (uncompensated) price elasticities for U.S. tree nuts

	Almond	Hazelnuts	Pecan	Walnuts	Macadamias	Pistachios
Almond	-1.062 (0.057)	-0.196 (0.071)	-0.325 (0.111)	-0.244 (0.076)	-0.211 (0.076)	-0.396 (0.146)
Hazelnuts	-0.003 (0.007)	-1.000 (0.010)	-0.005 (0.013)	0.000 (0.010)	-0.003 (0.009)	-0.007 (0.018)
Pecan	0.018 (0.025)	0.046 (0.029)	-0.906 (0.046)	0.035 (0.031)	0.045 (0.031)	0.090 (0.061)
Walnut	0.005 (0.026)	0.051 (0.035)	0.073 (0.050)	-0.877 (0.040)	0.054 (0.035)	0.119 (0.069)
Macadamias	0.012 (0.003)	0.017 (0.004)	0.027 (0.006)	0.014 (0.004)	-0.963 (0.004)	0.040 (0.008)
Pistachios	-0.008 (0.016)	0.024 (0.024)	0.036 (0.031)	0.021 (0.022)	0.022 (0.022)	-0.956 (0.042)

Table 5: Short run Marshaillian (uncompensated) price elasticities for U.S. tree nuts

	Almond	Hazelnuts	Pecan	Walnuts	Macadamias	Pistachios
Almonds	-1.133(0.056)	-0.187 (0.075)	-0.317(0.115)	-0.249(0.082)	-0.228(0.078)	-0.433(0.151)
Hazelnuts	-0.001(0.006)	-0.994 (0.010)	0.010(0.014)	0.013 (0.011)	0.006(0.010)	0.016(0.020)
Pecan	0.036(0.025)	0.041(0.029)	-0.924(0.047)	0.030(0.032)	0.043(0.032)	0.086(0.062)
Walnuts	0.028(0.024)	0.052(0.036)	0.089 (0.052)	-0.861(0.045)	0.072(0.037)	0.152(0.073)
Macadamias	0.014(0.002)	0.019(0.003)	0.021(0.005)	0.018(0.004)	-0.963 (0.005)	0.043(0.006)
Pistachios	0.015 (0.014)	0.021(0.021)	0.064(0.065)	0.012(0.021)	0.019(0.020)	-0.964(0.038)

Interestingly, all cross-price elasticities for almonds in the short and long run are negative and statistically significant at $\alpha = 0.01$, indicating that almonds, hazelnuts, pecan, walnuts, macadamias and pistachios are complements. Meaning an increase in price of one commodity

will lead to a decrease in quantity demanded of both commodities. For example, a 1% increase in the price of almonds in the short (long) run will lead to a 0.317 (0.325) % decrease in the quantity demanded of pecan short (long) run. Conversely, all cross-price elasticities for macadamia are positive and significant, thus indicating that almonds, hazelnut, pecan, walnut and pistachios are substitutes, meaning an increase in price of one commodity will lead to an increase in quantity demanded of the other commodity. For example, a 1% increase in the price of macadamias in the short (long) run will lead to a 0.043 (0.040) % increase in the quantity demanded of pistachios demanded in the short (long) run.

Table 6: Long run and Short run expenditure elasticities for U.S. tree nuts

Tree nuts	Long run	Short run
Almonds	1.129347(0.0478)	1.139674(0.0493)
Pistachios	0.986104(0.0139)	0.988115(0.0125)
Pecan	0.970315(0.0198)	0.971865(0.0201)
Walnuts	0.96157 (0.0225)	0.952035(0.0234)
Macadamias	0.986781(0.00253)	0.98555 (0.00214)
Hazelnuts	1.00166 (0.00583)	0.995426(0.00618)

The expenditure elasticities in the long run and short run are reported in table 6. The values estimated from both models are very similar and show that hazelnuts, pecan, walnuts, macadamias and pistachios are normal goods, while almonds is a luxury good.

5. Conclusion

This study investigated a demand analysis of six tree nuts in U.S using yearly time series data for total production and average yearly prices from 1981 to 2011. We estimated a static and dynamic AIDS model to investigate the long run and in the short run behavior of U.S. consumers.

The results showed that almonds and pecan are slightly more sensitive to their own price change in the short-run than in the long-run. Conversely, hazelnuts and walnuts are less sensitive to their own price change in the short-run than in the long-run, while macadamias and pistachios are about as sensitive to their own price change in the short-run as much as the long-run. In addition, almonds was found to be the most sensitive to consumer's expenditure behaving as a luxury good while the rest of the tree nuts appeared to be normal goods.

The policy implication of these results are three folds: First, growers can benefit from these results by using the elasticity estimates derived as a guide for investment and pricing. Secondly, these results can also help guide policy makers in updating or creating new trade and tariff policies targeting the growth of domestic and international trade in U.S tree nuts. Moreover, results from this study will come handy to researchers conducting ex-ante policy changes using theoretical economic models.

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