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US Demand for Citrus Beverages

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ABSTRACT

In 2017, the US was the second largest citrus producer with 711,000 bearing acres and a 7.77 million MT production. Despite the US annual orange juice production decreasing to 215,000 MT in 2017, per-capita domestic consumption increased to or remained above 41.75 lbs. With record low production levels and record high import levels over the last 17 years, it is important to obtain recent estimates of the US household demand for citrus beverages. This study uses the Almost Ideal Demand System (AIDS) and monthly data for the period of 2004-2018 from The Nielsen Company to estimate demand elasticities for various citrus beverages. Our Marshallian own-price elasticity estimates were of the expected negative signs and were greater than one in absolute terms indicating that the US demands were price elastic. The Hicksian cross-price elasticity estimates indicated both complementary relationships and substitutability between the selected citrus beverages, while the expenditure elasticities indicated mostly normal goods. The study's findings contribute to a better understanding of the citrus beverages market structure and provide insight into consumer demand behavior. The estimated elasticities are useful for analyzing US consumers' responsiveness to price changes and for providing insight in agricultural marketing and policy related decisions.

KEYWORDS: citrus beverages, demand system, elasticities

INTRODUCTION

Annual citrus fruit production in the world is estimated to be over 93.3 million metric tons (MT), covering nearly 18.7 million acres (NASS-USDA 2018). Brazil is the highest citrus producer with 17.34 million MT (NASS-USDA 2018) followed by the US. with 7.77 million MT (NASS-USDA 2018). In the US, California and Florida are the major citrus states with production shares of about 51% and 45% respectively (NASS-USDA 2018). With over 70% of the US orange consumption (30% sold as fresh fruits) being

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supplied by domestic production, per-capita consumption of fresh and processed oranges are estimated to be about 15.07 and 41.75 pounds (lbs.) respectively (ERS-USDA 2018a).

Orange juice and grapefruit juice consumption and production. Orange juice is the most consumed citrus juice in the US, followed by grapefruit juice (FAS-USDA 2018). Worldwide annual orange juice production for 2017 decreased by 16.02% to 1.73 million MT as production levels in the leading producers, Brazil, EU and the US fell by 16%, 9% and 32% respectively compared to 2016 (FAS-USDA 2018). Global consumption for 2017 also decreased by 5.78% to 1.63 million MT with the US and EU exhibiting the largest decreases, 10.53% and 2.74% respectively, compared to the previous year (FAS-USDA 2018). Figure 1 displays global citrus juice production and consumption for the period 2000-2017.

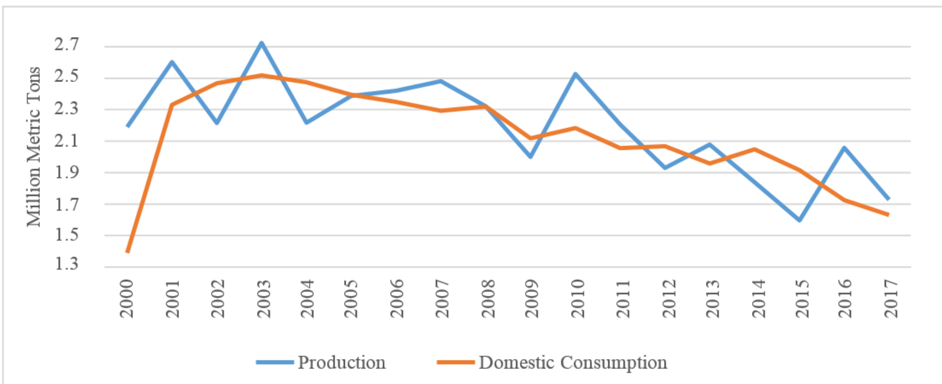

Figure 1. Global Citrus Juice Production and Consumption
Source: FAS-USDA (2018)

In 2017, Brazil, the US and the European Union were the world largest orange producers (ERS-USDA 2018b). US orange juice production decreased by 97,000 MT to 215,000 MT because fewer oranges were available for processing (Table 1). According to Figure 2, orange juice and grapefruit juice per-capita consumptions have declined drastically since the early 2000s to record low levels in 2015 of 2.87 gallons and 0.15 gallons, respectively (ERS-USDA 2018b). According to Figures 1 and 4, world citrus juice production in 2017 was among the lowest while US imports of orange juice were among the highest over the last 17 years.

Figure 3 displays orange and grapefruit juice price trends for the period 2004-2018. According to FAS-USDA (2018), the average price for one gallon of orange juice increased by $2.50, from $4.30/gallon in 2004 to $6.80/gallon in 2018. Average grapefruit juice prices increased proportionally with the average orange juice prices. Grapefruit juice price increased by $2.57/gallon, from $5.06/gallon in 2004 to $7.62/gallon in 2018.

Orange juice and grapefruit juice trade. US orange juice imports totaled 455 million single-strength-equivalent (SSE) gallons with an average price of $1.81 per SSE gallon in 2017. Single strength juice is either "Not from Concentrate" juice (fresh juice extracted or pressed from the fruit which has not been concentrated) or juice consisting of a concentrate and water, to reach the defined natural single strength brix (the percentage of solids present in the juice of a plant) level for that specific item. Orange juice imports (Figure 4) and the average import price increased compared to 2016 by 5% and 20% respectively, while orange juice exports (Figure 4) dropped by 19% and totaled 64.01 million SSE gallons with an average price of $3.95 (down by 14%) per SSE gallon in 2017 (FAS-USDA 2018). The main import sources are Brazil and Mexico and the main export markets are Canada, South Korea, Netherlands and Belgium.

Table 1. US Orange Juice Supply and Utilization (MT), 2000-2017.

Year	Begin Stocks	Domestic Consum.	End Stocks	Exports	Imports	Product.	Total Distri.	Total Supply
2000	459	1,046	497	87	183	988	1,630	1,630
2001	497	1,030	492	129	134	1,020	1,651	1,651
2002	492	1,015	501	73	207	890	1,589	1,589
2003	501	1,031	584	88	158	1,043	1,703	1,703
2004	584	1,005	443	85	254	694	1,533	1,533
2005	443	934	326	98	213	703	1,359	1,359
2006	326	887	270	87	284	634	1,244	1,244
2007	270	829	465	98	292	830	1,392	1,392
2008	465	865	498	90	228	761	1,453	1,453
2009	498	832	400	106	236	603	1,337	1,337
2010	400	810	290	151	191	660	1,251	1,251
2011	290	699	322	110	160	681	1,131	1,131
2012	322	733	384	114	302	607	1,231	1,231
2013	384	700	347	113	300	476	1,160	1,160
2014	347	674	360	81	330	438	1,115	1,115
2015	360	670	294	66	280	390	1,030	1,030
2016	294	578	270	57	299	312	905	905
2017	270	510	260	45	330	215	815	815

Source: FAS-USDA (2018)

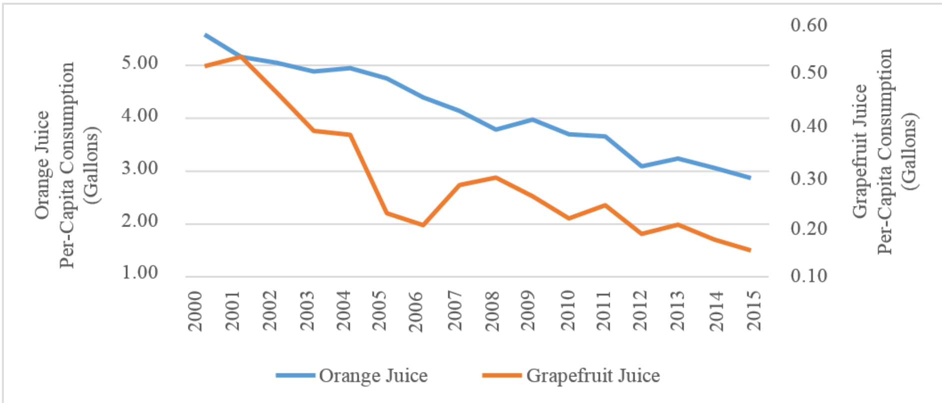

Figure 2. US Per-Capita Consumption of Orange and Grapefruit Juices
Source: FAS-USDA (2018)

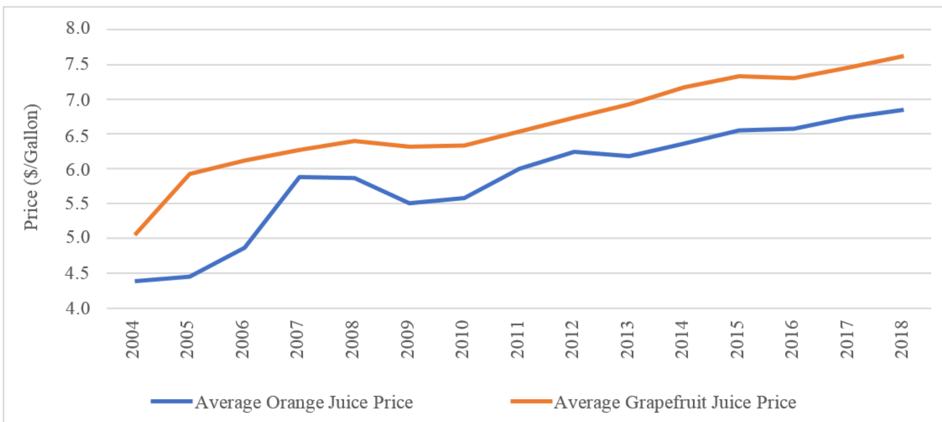

Figure 3. US Orange and Grapefruit Juice Prices, 2004-2018
Source: FAS-USDA (2018)

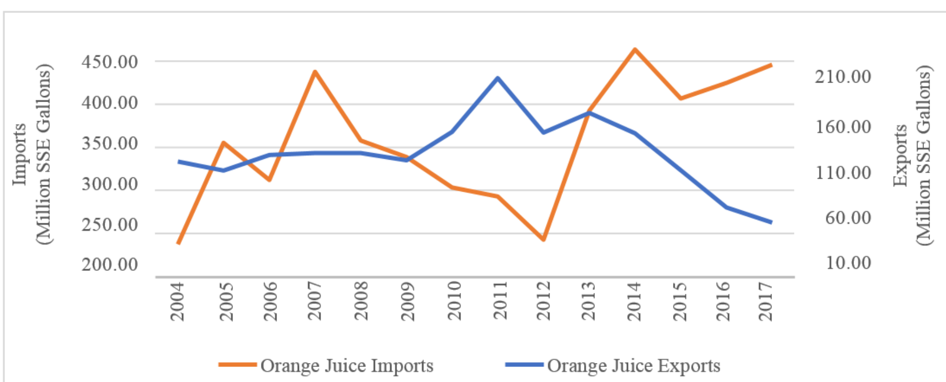

Figure 4. US Orange Juice Imports and Exports
Source: FAS-USDA (2018)

The US imports of grapefruit juice totaled 5.6 million SSE gallons (Figure 5) with an average price of $2.04 per SSE gallon in 2017, with Mexico and the Republic of South Africa being the major import sources (FAS-USDA 2018). Imports increased by 363% compared to 2016 (Figure 5) with a simultaneous increase in average price per SSE gallons of 16% (FAS-USDA 2018). US grapefruit juice exports decreased by 36.4% compared to 2016 and totaled 6.01 million SSE gallons in 2017 with an increase in average export price by 9% to $4.18 per SSE gallon, compared to 2016 (FAS-USDA 2018).

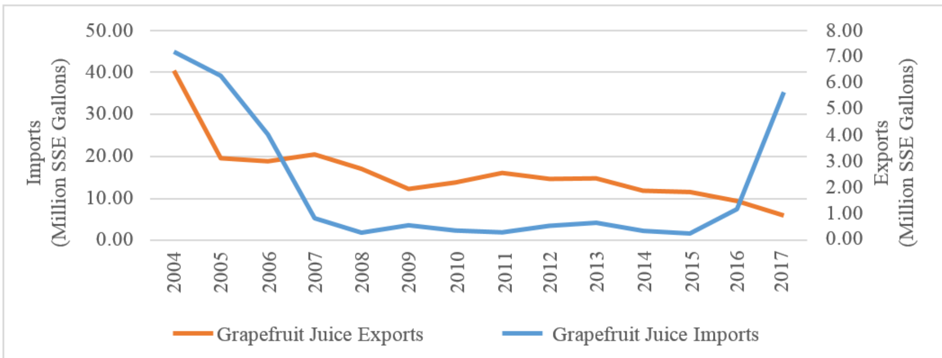

Figure 5. US Grapefruit Juice Imports and Exports
Source: FAS-USDA (2018)

Hurricane Irma considerably reduced the amount of fruit going into processing and severely damaged many U.S. citrus trees in 2017 (ERS-USDA 2018a). The decrease in US orange juice production and exports in 2017 (Table 1), the increase in orange and grapefruit juice imports in 2017 (Figures 4 and 5), and the decrease in orange and grapefruit exports in 2017 (Figures 4 and 5), may all had been consequences of Hurricane Irma, which hit Florida at the start of the 2017-2018 season in September 2017.

Statement of the problem. Declining trends in US orange and grapefruit juice production and consumption (see also Table 1), and increasing trends in imports (Figures 4 and 5), due to in part to recent hurricanes and increasingly devastating bacterial diseases, makes a recent economic analysis of the household demand for citrus beverages important and timely. Several studies have examined the factors affecting the retail demand for citrus juices, such as flu/cold season, promotion and advertisement (Lee and Brown 2009; Capps et al. 2004) and the import demand for fresh citrus including the seasonality aspects (Baldwin and Jones 2012). However, to the best of our knowledge, there have been no recent analyses done on the US orange and grapefruit juice retail demands. This study estimates the retail demands for orange and grapefruit beverages using an Almost Ideal Demand System (AIDS) model.

Objectives and purpose of the study. The purpose of this study is to examine the US household demand for orange and grapefruit beverages while the specific objectives of the study are to:

1. Provide an overview of the US processed citrus market, consumption and trade;
2. Estimate Marshallian own-price and expenditure elasticities of retail demand for

orange and grapefruit juices and discuss their responsiveness to price changes;

3. Estimate Hicksian cross-price and expenditure elasticities of retail demand for orange and grapefruit juices and discuss their economic interdependence.

LITERATURE REVIEW

Remarkable research efforts have been committed to estimate the US retail demand for citrus beverages and the US import demand for fresh citruses. Theoretical models and econometric procedures for both import demand and retail demand estimations include the Rotterdam model (Barten 1964), seemingly unrelated regressions, various time series regression models, and the AIDS model (Deaton and Muellbauer 1980). The AIDS is one of the most widely used model for demand estimations. With linear Engel curves for all commodities and system of budget share equations, the model estimates own-price, cross-price, and expenditure elasticities of demand. This section summarizes studies that examined both import and retail demands for citrus beverages and fresh fruits using the AIDS model.

Brown (1986) analyzed the single-flavor fruit juice market, including grapefruit juice, orange juice, grape juice, and apple juice. The study used National Purchase Diary (NPD) Research Inc. data on the number of households purchasing fruit juice, the quantity purchased, and sales price from December 1977 to April 1985 and US personal income, Consumer Price Index and the US population data from the Survey of Current Business. Two equations for each juice type were estimated using seemingly unrelated regressions: one is for a number of households purchasing fruit juice and one for the average quantity of fruit juice purchased per household.

The single-strength-equivalent gallons per household estimates indicated that income elasticities for orange and grapefruit juices were statistically significant, 0.76 and -0.029 respectively. The own-price elasticities for all juice types were negative and significant, including the own-price elasticity for orange juice of -0.728 and the own-price elasticity for grapefruit juice of -0.304. In addition, orange juice and grapefruit juice were found to be substitutes (Brown 1986).

Brown et al. (1994) analyzed the influence of income and price on US juice beverages demand using weekly sales data from The Nielsen Company for US stores with total annual sales higher than four million dollars for the period December 1988 to November 1992. Seven juice groups were selected, including grapefruit juice, orange juice, apple juice, blended juices, juice drinks, juice cocktails and remaining juices.

Alternative differential demand models combining the features of the Rotterdam model and AIDS were employed. Orange juice was found to be a necessary good with an expenditure elasticity of 0.8518 and an own-price elasticity of -0.8816. Moreover, the demand for orange juice was found to be price inelastic as the own-price elasticity is less than one. The high expenditure share of 0.33 and low demand elasticities for orange juice indicated that orange juice could be a staple juice. Grapefruit juice had an expenditure elasticity of 1.0070, making it a luxury good, and an own-price elasticity of -1.8791. Cross-price elasticities suggested a substitute relationship between orange juice and grapefruit juice.

Expenditure elasticity estimates for orange juice decreased from 0.86 in 1988-1989 to 0.84 in 1991-1992, while the magnitude of the own-price elasticity increased from 0.82 to 0.94 for the same period. This can be partially explained by the decrease in expenditure share of orange juice from 0.37 to 0.33. However, on average, orange juice and grapefruit juice had expenditure shares of 0.3487 and 0.0274, respectively, for the period 1988-1992. Last, Brown et al. (1994) found the magnitude of the own-price elasticity estimates had increased from 1.69 in 1988-1989 to 1.87 in 1991-1992, becoming more elastic.

Capps et al. (2004) examined the impact of the Florida Department of Citrus (FDOC) and branded advertising expenditures for the orange juice demand. Supermarkets and supercenters with sales exceeding $2 million per year were selected as the retail level of the marketing chains. Capps et al. (2004) used data from The Nielsen Company for several orange juices and orange juice products (frozen concentrate, refrigerated not from concentrate, refrigerated reconstituted and shelf-stable orange juice), including sales (dollars), volumes (gallons) and prices (dollars/gallons). They also used Competitive Media Reporting (CMR) data providing information about Florida Department of Citrus advertising expenditures on orange juice, branded advertising expenditures on orange juice and advertising expenditures on fruit juices and drinks, excluding orange juice. Similar data for grapefruit juice sales, quantity purchased, price and advertisement expenditures were used to examine if grapefruit and orange juice were substitute juices. Econometric and time-series vector autoregression models were used to analyze the data. The results suggested FDOC advertising efforts had a positive impact on total orange juice consumption, increasing it by 3.31% to 7.67% on average resulting in approximately 2.2 million to 5.2 million more gallons of orange juice sold monthly for the period of January 1989 to September 2002. However, the results showed that branded advertisement was not a statistically significant factor affecting the orange juice demand during the 1989-2002 period. The own price elasticity for orange juice was found to be -0.684 while orange juice and grapefruit juice were found to be substitutes, the cross-price elasticity of orange juice with grapefruit juice was found to be 0.388 (Capps et al. 2004).

Lee and Brown (2009) examined the impact of promotions and flu/cold incidences on the demand for orange juice. Panel data techniques were used to estimate the demand parameters. Weekly orange juice sales from grocery stores were obtained from The Nielsen Company and flu/cold incidences from Surveillance Data Inc. The results suggested that flu/cold incidences had no significant effect on orange juice sales, but they increased the effectiveness of retail promotions on the demand for orange juice. The own price elasticity of orange juice was -0.5741 while the cross-price elasticity of 100% grapefruit juice and orange juice products was 0.0231, indicating substitutability. Similarly, orange juice blends, grapefruit juice blends, and orange juice blend drinks are complements of orange juice (Lee and Brown 2009).

Baldwin and Jones (2012) analyzed the US import demand for citrus using an AIDS model and quarterly import data for the period 1989-2010 for five major citrus imported products (oranges, grapefruit, limes, mandarins and lemons). The estimated expenditure elasticities for oranges, grapefruit, limes, mandarins, and lemons were 1.442, 1.479, 0.518, 1.360 and 1.164, respectively. The findings suggest that as expenditures on citrus beverages increase, consumers tend to spend more on imported oranges, grapefruit, lemons and mandarins and less on limes. Oranges, mandarins, lemons and limes had inelastic own-price elasticities: -0.050, -0.359, -0.742 and -0.126 respectively. The study suggested the supplying countries can increase their revenues by decreasing the US quantitysupplied. The compensated cross-price elasticities were statistically insignificant; suggesting none of the fruits is a statistical significant substitute for fresh oranges. Grapefruits were found to be statistically significant complements for oranges, substitutes for mandarins and other citruses. All the sweeter citrus fruits and grapefruits were found to be substitutes, except for lemons and limes being in a complementary relationship. The study also concluded that the seasonality effect on the citrus fruit quantity demanded is in the highest point during the harvest time (Baldwin and Jones 2012).

Prior own-price and expenditure elasticity estimates are summarized in Table 2. Orange juice own-price elasticity estimates range from -0.7280 in Brown (1986) to -0.5741 in Lee and Brown (2009) while grapefruit juice estimates range from -1.8791 in Brown et al. (1994) to -0.3040 in Brown (1986). Prior studies consistently indicate an inelastic demand for orange juice, which suggests consumption of orange juice is generally irresponsive to changes in the price of orange juice. On the other hand, in the case of grapefruit juice, most recent studies indicate an elastic demand, meaning that changes in prices of grapefruit juice have an impact on quantity demanded.

Table 2. Demand Elasticities in Prior Studies.

Study	Commodity	Own-Price Elasticity	Expenditure Elasticity
Brown (1986)	Orange Juice	-0.7280	0.7620
Brown et al. (1994)	Orange Juice	-0.8816	0.8518
Capps et al. (2004)	Orange Juice	-0.6840	
Lee and Brown (2009)	Orange Juice	-0.5741	
Baldwin and Jones (2012)	Oranges	-0.0500	1.4420
Brown (1986)	Grapefruit Juice	-0.3040	-0.0290
Brown et al. (1994)	Grapefruit Juice	-1.8791	1.0070
Baldwin and Jones (2012)	Grapefruits	-1.1360	1.4790

DATA AND METHODS

Data. Data on orange and grapefruit beverages from The Nielsen Company for the period October 2004 to June 2018 were obtained from the Florida Department of Citrus (2018). The data reported in a four-week cycle included Homescan and scan track sales (in gallons) and price (in $ per gallon) for seven beverages types: 100% natural orange juice, 100% natural grapefruit juice, orange juice drink, orange juice blend drink, orange juice blend, grapefruit juice cocktail, and grapefruit juice blend. Table 3 provides a more detailed description of these seven citrus beverages. The Homescan data was from Walmart while scan track (point of sale) data was from drug stores with annual sales greater than or equal $1 million, grocery stores with annual sales greater than or equal $2 million, mass merchandisers (like Dollar General, Family Dollar), clubs (like Sam's), and military/Defense Commissary Agency.

Consumer Price Index reported by the US Bureau of Labor Statistics was also used to adjust the beverage prices for inflation; household income data reported by the US Census Bureau were used to address any possible endogeneity issue. All the data were publicly available.

Table 3. Names and Descriptions of the Selected Seven Citrus Beverage Categories.

Name	**Description**
Orange Juice Drink	Less than 100% orange juice with supplementary sweeteners
Orange Juice Blend Drink	Less than 100% orange juice with supplementary 100% other fruit juices and sweeteners
Orange Juice Blend	100% orange juice with added 100% other fruit juices
Grapefruit Juice Cocktail	Less than 100% grapefruit juice with supplementary sweeteners
Grapefruit Juice Blend	100% grapefruit juice with added 100% other fruit juices
100 % Orange Juice	100 % Natural Orange juice
100 % Grapefruit Juice	100 % Natural Grapefruit juice

Source: Florida Department of Citrus (2018).

Model. AIDS was first introduced by Deaton and Muellbauer in 1980. Since then, it has gained wide popularity and become more flexible and applicable. The AIDS model fully satisfies the axioms of choice and the circumstances for precise aggregation over the consumers. At each level of utility, the consumers minimize expenditure to generate the given utility (Deaton and Muellbauer 1980).

In the AIDS model, the expenditure or cost function, c, is

(1) $\log c(p, u) = (1 - u) \log(\mathrm{a}(p)) + u \log(\mathrm{b}(p))$

where p is a vector of prices, u denotes utility or satisfaction level on a scale from 0 (subsistence) to 1 (bliss) (for exemptions refer to Deaton and Muellbauer (1980)), $c(p, u)$ denotes expenditure as a function of prices and utility, log is the mathematical operator for logarithm, a(p) denotes the costs of subsistence which depends on prices, and b(p) denotes costs of bliss which also depends on prices. That is, consumers spend their money for a combination of subsistence and bliss.

Taking specific functional forms for log a(p) and log b(p) results in

(2) $$\log c(p,u) = \alpha_0 + \sum_k \alpha_k \log(p_k) + 0.5 \sum_k \sum_j \gamma_{kj}^* \log(p_k) \log(p_j) + u\,\beta_0 \prod_k p_k^{\beta_k}.$$

where α_i, β_j, and γ_{ij}^* are parameters. To calculate the quantity demanded, q_i, Shepard's Lemma can be used by taking the derivative of the expenditure function ($\log c(p,u)$) with respect to p_i, which will help to get the expenditure share of good i, using the following relation

(3) $$\frac{\partial \log c(p,u)}{\partial \log(p_i)} = \frac{p_i q_i}{c(p,u)} = w_i.$$

Therefore, the partial derivative of cost function with respect to log(p_i) yields the budget shares

(4) $$w_i = \alpha_i + \sum_j \left(0.5(\gamma_{ij}^* + \gamma_{ji}^*)\right)\log(p_j) + \beta_i(log(\textstyle\sum_{i=1}^n p_i q_i) - \log(P))$$

where $\gamma_{ij} = 0.5(\gamma_{ij}^* + \gamma_{ji}^*)$ and P is a nonlinear price index defined as

(5) $$\log(P) = \alpha_0 + \sum_k \log(p_k) + 0.5 \sum_j \sum_k \gamma_{ij} \log(p_k) \log(p_j).$$

The following are the AIDS model restrictions:

(6) adding-up: $\sum_{i=1}^n \alpha_i = 1,\quad \sum_{i=1}^n \gamma_{ij} = 0,\quad \sum_{i=1}^n \beta_i = 0,$

(7) homogeneity: $\sum_j \gamma_{ij} = 0$, and

(8) symmetry: $\gamma_{ij} = \gamma_{ji}$.

According to Green and Alston (1990), the uncompensated (Marshallian) price elasticities are calculated as

(9) $$\varepsilon_{ij} = -\delta_{ij} + \frac{\gamma_{ij} - \beta_i\left(\alpha_j + \sum_{k=1}^{n} \gamma_{jk} \log\left(p_k\right)\right)}{w_i}$$

where δij is the Kronecker delta with $\delta_{ij} = 1$ if $i = j$ (own-price elasticity), and $\delta_{ij} = 0$ if $i \neq j$ (cross-price elasticity).

Expenditure elasticities are calculated as

(10) $$\varepsilon_{ix} = 1 + \frac{\beta_i}{w_i},$$

while compensated (Hicksian) price elasticities can be calculated using the Slutsky equation,

(11) $$e_{ij} = \varepsilon_{ij} + w_i \varepsilon_{ix}.$$

Seasonal variations are very common in Agriculture. Prior to estimating the AIDS model, the data can be tested and, if necessary, treated for seasonality. In theory, there are several ways to capture and treat for seasonality, such as using harmonic regression or dummy variables. The dummy variable method introduces binary variables that take the value of 1 if a given season is applicable, and 0 otherwise. The method of harmonic regression adds to the model two trigonometric variables, sine and cosine (see also Mnatsakanyan and Lopez 2019; Tshikala and Fonsah 2012; Nzaku, Houston and Fonsah 2010; Arnade, Pick and Gehlhar 2005). That is,

(12) $$sin_i = f(trend, SL) = \sin\left(2\pi \frac{t_i}{12}\right)$$

and

(13) $$cos_i = f(trend, SL) = cos\left(2\pi \frac{t_i}{12}\right),$$

where t_i is the corresponding trend variable, taking the value of 1 for the first observation and the n^{th} value for last observation; π is a mathematical constant approximately equal to 3.1416; and *SL* is the seasonal length.

The assessment of the system of demand equations yields parameter estimates for the sine and cosine variables. The presence of statistical significance of those estimates defines whether the initial share equation presented statistically significant seasonality or not. The sums of coefficients of trigonometric variables were limited to zero (see also Mnatsakanyan and Lopez 2019; Tshikala and Fonsah 2012; Nzaku, Houston and Fonsah 2010; Arnade, Pick and Gehlhar 2005). That is,

(14) $$\sum_i s_i = 0,$$

(15) $$\sum_i c_i = 0,$$

where *i* represents the commodity, and c_i and s_i are the coefficients for the sine and cosine functions. This study employs the Harmonic regression model to deal with the issue of seasonality.

Endogeneity of expenditure is a modeling issue encountered in systems of demand equations (Attfield 1985). The expenditure share, w_i, defined as the ratio of the i^{th} expenditure share to the total expenditure, induces the endogeneity of the total expenditure. "[S]ince total expenditure is defined as the sum of expenditure on individual commodities and as these expenditures are assumed to be endogenous, we might expect total expenditure to be jointly endogenous" (Attfield 1985, p. 197). "If, for whatever reason, expenditure is correlated with the equation errors resulting estimators will be both biased and inconsistent" (Attfield 1985, p. 198). Following Attfield (1985), we model the logarithm of total expenditure as a function of the real household income and the real prices used to calculate the total expenditure to address any potential issue of endogeneity. That is,

(16) $\log(X) = \vartheta_0 + \sum_i \vartheta_i \log(p_i) + g\log(HI) + \varepsilon_i,$

where $\log(X)$ is the total expenditure logarithm; pi is the price of the i^{th} commodity; HI is the household income; ϑ_0, g and ϑ_i, are population parameters that are estimated; and ε_i is an error term.

In addition, the Durbin-Watson statistic was estimated by calculating the ratio of the sum of the squared differences of the residuals ($\hat{e}_t$) and their first lags to the sum of the squared residuals (Durbin and Watson 1951) to assess serial autocorrelation:

(17) $d = \frac{\sum(\hat{e}_t - \hat{e}_{t-1})^2}{\sum \hat{e}_t^2}.$

In this study the AIDS model is estimated as:

(18) $$w_{it} = \alpha_i + \sum_j \gamma_{ij} \log(p_k) + \beta_i \log\left(\frac{X}{P}\right)_t + s_i sin_t + c_i cos_t + z_i t_t + \rho\left\{w_{it} - \left(\alpha_i + \sum_j \gamma_{ij} \log(p_{t-1}) + \beta_i \log\left(\frac{X}{P}\right)_{t-1} + s_i sin_{t-1} + c_i cos_{t-1} + z_i t_{t-1}\right)\right\}$$

where i and j represent any two commodities; w_i is the expenditure share for the i^{th} commodity; p_j is the price of the j^{th} commodity; X is total expenditures on all goods included in the model; α_i, γ_{ij}, β_i, ci, s_i, and z_i are the parameters estimated by the model; P is a nonlinear price index; $sin_t = f(t, SL)$ and $cos_t = g(t, SL)$ are trigonometric functions capturing seasonality; t represents a trend variable; ρ is the first-order autoregressive coefficient; and ε_i is an error term.

RESULTS

Parameter Estimates. The AIDS parameters estimates are reported in Table 4. Of the70 parameters estimated, 32 were significant at the 0.01 probability level; and an additional ten and two parameter estimates were significant at the 0.05 and 0.10 significant probability levels respectively while 26 parameters were not statistically significant. Several of the parameter estimates corresponding to the trigonometric variables were not statistically significant, which is evidence against a strong presence of seasonal patterns in the data. However, there were strong trending patterns as evidence by all but one of the parameter estimates associated with the trend variable being statistically significant at the 0.01 probability level. In addition, following Attfield (1985), the statistical significance of the parameter estimates from equation (16) is evidence towards allowing for the assumption of endogeneity in the model.

Table 5 reports the coefficient of determinations (R^2), the Durbin Watson (DW) statistics, and the first order autoregressive coefficient (ρ). The R^2 values ranging from 77% to 96% suggest that overall the system of equations are a good fit for the data while DW statistics close to 2 and the statistical significance of the coefficient ρ indicates that the serial correlation was effectively addressed in the model.

Table 4. AIDS Parameter Estimates.

Parameter Estimates from Equation (18):

			γ_{i1}	γ_{i2}	γ_{i3}	γ_{i4}	γ_{i5}	γ_{i6}	γ_{i7}
α_1	-0.113‡	γ_{1j}	-0.078*	0.074*	-0.015‡	0.002	0.003‡	0.021	-0.008*
α_2	0.267*	γ_{2j}		-0.140*	-0.009‡	-0.001	-0.001	0.072*	0.005*
α_3	-0.100*	γ_{3j}			-0.006	0.005†	-0.002	0.021*	0.005
α_4	0.038*	γ_{4j}				-0.009*	0.002‡	-0.005	0.006*
α_5	0.012*	γ_{5j}					-0.006*	0.000	0.004*
α_6	0.864*	γ_{6j}						-0.110*	0.000
α_7	0.032	γ_{7j}							-0.013‡

		i	s_i	c_i	z_i
β_1	0.039*	1	0.002‡	0.000	0.000*
β_2	-0.060*	2	-0.002	-0.000	0.000*
β_3	0.027*	3	-0.000	-0.000	0.000*
β_4	-0.006*	4	-0.000†	0.000	-0.000†
β_5	-0.001	5	-0.000	-0.000	-0.000*
β_6	-0.002	6	0.002	-0.001	-0.001*

Additional Parameter Estimates from Equation (16):

Par.	v_0	v_1	v_2	v_3	v_4	v_5	v_6	v_7	g
Par. Est.	-4.401	0.331*	0.036	-0.337‡	-0.319*	0.053	0.922*	-0.419‡	1.267*

Note: Daggers (†), double daggers (‡) and asterisks (*) denote statistical significant at p = 0.10, p = 0.05, and p = 0.01 respectively.

Table 5. Coefficients of Determination (R^2), Durbin-Watson Statistics (*DW*), and First-Order Autoregressive Coefficient (ρ).

i	R^2	*DW*
Orange Juice Drink	0.77	2.33
Orange Juice Blend Drink	0.97	1.87
Orange Juice Blend	0.91	1.80
Grapefruit Juice Cocktail	0.73	2.99
Grapefruit Juice Blend	0.77	2.42
100 % Orange Juice	0.96	1.41
100 % Grapefruit Juice	0.94	1.83
Parameter	Estimate	p-value
ρ	0.763	0.000

Demand elasticities. The compensated cross- and own-price elasticity estimates are reported in Table 6. Of the 49 elasticity estimates, 23 were significant at the 0.01 probability level, an additional eight were significant at the 0.05 probability level and 18 were not significant.

Table 6. Uncompensated Own-Price and Compensated Cross-Price Elasticities of Demand.

i	1	2	3	4	5	6	7
1	**-2.192****	1.200**	-0.120	0.039	0.042*	1.017**	-0.088*
2	0.462**	**-1.716****	-0.039	0.016*	-0.002	1.122**	0.054**
3	-0.140	-0.119	**-1.090****	0.094	-0.032	1.073**	0.134
4	0.164	0.169*	0.336	**-1.559****	0.140*	0.336	0.405**
5	1.184*	-0.160	-0.759	0.938*	**-3.621****	0.780	1.637**
6	0.094**	0.269**	0.084**	0.007	0.003	**-1.160****	0.027**
7	-0.210*	0.335**	0.272	0.230**	0.139**	0.690**	**-1.485****

Note: i = 1,2, … 7; where 1 = Orange Juice Drink, 2 = Orange Juice Blend Drink, 3 = Orange Juice Blend, 4 = Grapefruit Juice Cocktail, 5 = Grapefruit Juice Blend, 6 = 100 % Orange Juice and 7 = 100 % Grapefruit Juice. Statistical significance at the 0.05 and 0.01 probability levels are indicated by single (*) and double asterisks (**) respectively.

Own-price elasticities. Own-price elasticity measures the percentage change in the quantity demanded of a commodity resulting from a percentage change in the price of that same commodity. The own-price elasticity estimates are the diagonal coefficients reported in Table 6. All the uncompensated own-price elasticities were negative and statistically significant at the 0.01 probability level. In addition, our estimates suggest all the selected citrus beverages are price elastic; that is, price sensitive. Our elastic results are consistent with Brown et al. (1994) who reported an own-price elasticity estimate for grapefruit juice of -1.8791. However, most previous studies report the own-price elasticities of demand for orange juice to be price inelastic (Table 2). Our elastic own-price elasticity of demand for orange juice may be attributed in part to the variety of similar substitute products considered in our study, also referred in the literature as analyses using narrowly defined categories. As the price for 100% natural orange juice and grapefruit juice increase, the consumers have the option to switch to similar substitute products, making the market of 100% orange and grapefruit juices more sensitive to price changes. Our elastic own-price elasticity estimates may also be attributed to the sharp increases in the prices of orange and grapefruit juices (Figure 3). The orange juice price increased from $4.30/gallon in 2004 to $6.80/gallon in 2018 while the grapefruit juice price increased from $5.06/gallon in 2004 to $7.62/gallon in 2018. In general, sharp price increases may influence consumers to consider the product more as a luxury product than as a necessity. Last, there are more additional choices and close substitutes in the breakfast beverage market today (such as cold coffee drinks, flavored milk, soft drinks, artificially flavored drinks like Tang, etc.) that make the market more competitive and influence consumers to be more price sensitive.

Cross-price elasticities. Cross-price elasticities of demand measure the effect of a price change of one good on the quantity demand of another good. Positive cross-price elasticities indicate substitute relationship between two goods, while negatives indicate complementary relationships. Our compensated cross-price elasticity estimates are the off-diagonal coefficients reported in Table 6. Of the 42 cross-price elasticity estimates, 16 were significant at the 0.01 probability level while an additional eight were significant at the 0.05 probability level. Among the statistically significant coefficients, all were positives, meaning the citrus beverages categories examined are mostly substitute products for each other, except for 100% grapefruit and orange juice drinks (and vice versa) that were complements.

According to the results, 100% natural orange juice can be substituted with orange juice drinks, orange juice blend drinks, orange juice blends, and grapefruit juice. The cross-price elasticity of 100% natural orange juice and 100% natural grapefruit juice is 0.027, meaning that if the price for 100% natural orange juice increases by 1%, the quantity demanded of 100% natural grapefruit juice is expected to increase by 0.027%, holding everything else constant. This finding is consistent and similar in magnitude to the cross-price elasticity of 100% grapefruit and orange juice products of 0.0231 reported by Lee and Brown (2009), also suggesting that 100% grapefruit and orange juice products are substitutes. The cross-price elasticity of orange juice drinks and orange juice blend drinks is 1.2, meaning that if the if the price for orange juice drinks increases by 1%, the quantity demanded of orange juice blend drinks is expected to increase by 1.2%, holding everything else constant.

Expenditure elasticities. Our expenditure elasticity estimates of demand are reported in Table 7.

The expenditure elasticities indicate the relationship between the change in total expenditure on the selected categories of citrus beverages and the quantity demanded of the same commodities. All the estimated expenditure elasticities were positive and statistically significant at 0.01 probability level, except for grapefruit juice blend (Table 7). Total orange blend drinks, total grapefruit juice cocktails, and total orange juice were found to be necessary goods since their elasticity coefficients were less than one, indicating that one percent change in total expenditure on citrus beverages is expected to have less than one percent impact on the quantity of these citrus juices demanded. Total orange juice drinks, total orange juice blend 100% juice, and total grapefruit juice were found to be luxury goods since their elasticities were greater than one, indicating that one percent change in total expenditure on citrus beverages is expected to cause more than one percent change in quantity demanded of these products. These results are consistent with most previous studies (Table 2).

Table 7. Expenditure Elasticities of Demand.

i	Expenditure Elasticity	Std. Error
Orange Juice Drink	1.618**	0.1753
Orange Juice Blend Drink	0.633**	0.0907
Orange Juice Blend	1.504**	0.0851
Grapefruit Juice Cocktail	0.615**	0.1105
Grapefruit Juice Blend	0.375	0.4131
100 % Orange Juice	0.997**	0.0253
100 % Grapefruit Juice	1.114**	0.0743

Note: Statistical significance at the 0.05 and 0.01 probability levels are indicated by single (*) and double asterisks (**) respectively.

CONCLUSION AND DISCUSSION

This study used Homescan and scan track data from The Nielsen Company on household purchases from October 2004 to June 2018 to estimate an AIDS model and analyze the impact of price changes on the quantity demanded of seven citrus beverage types. Our empirical findings suggest that the selected citrus beverage categories are highly sensitive to price changes, with own-price elasticities being elastic, indicating consumers being very responsive to selected citrus beverage price fluctuations. The own-price elasticity of 100% orange juice was found to be -1.16, indicating that 1% increase in the price of 100% orange juice is expected to cause a decrease in quantity demanded of 100% orange juice by 1.16%, holding everything else constant. The own-price elasticity of 100% grapefruit juice was found to be -1.48, indicating that 1% increase in the price of 100% grapefruit juice is expected to cause a decrease in quantity demanded of the same juice by 1.48%, holding everything else constant. This suggests juice processors and marketers can increase revenues by decreasing prices of these products. Cross-price elasticities mainly indicated substitutability relationships between the selected beverage types. The cross-price elasticity of 100% natural orange juice and 100% natural grapefruit juice is 0.027, meaning that if the price for 100% natural orange juice increases by 1%, the quantity demanded of 100% natural grapefruit juice is expected to increase by 0.027%, holding everything else constant. Positive expenditure elasticities indicate that selected commodities are normal goods and suggest that an increase in the expenditure budget leads to an increase in the quantity demanded of selected beverages. Three citrus beverage types (orange juice drink, orange juice blend and 100% grapefruit juice) obtained expenditure elasticity coefficients greater than unity, suggesting luxury goods, while the other four beverage types (orange juice blend drink, grapefruit juice cocktail, grapefruit juice blend and 100% orange juice blend) were less than one, indicating that these beverages are necessary goods. The expenditure elasticity of 100% natural orange juice was 0.99, which suggests that as household expenditures on citrus beverages increase by 1%, the quantity demanded of natural orange juice increases by 0.99%. Expenditure elasticity of 100% natural grapefruit juice is calculated to be 1.11, which suggests that as household expenditures on citrus beverages increase by 1%, the quantity demanded of natural grapefruit juice increases by 1.11%.

The results obtained can assist citrus beverage manufacturers in developing revenue maximizing and risk-avoiding strategies. The elasticities suggested by this study can be used to forecast the demand for these citrus beverages, helping the manufacturers to make important decisions about input, inventory, supply, and marketing strategies. Finally, the estimation results can help policymakers in decisions of market targeting and market segmenting.

Future research would benefit from adding more individual characteristics about the consumers to the data such as their gender, age, education, how they value their health, etc. Similarly, the study could be enhanced if more detailed geographic data were included in the analysis, which could assist manufacturers and marketers in targeting specific markets.

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