A DEMAND ANALYSIS OF CITRUS BEVERAGES IN THE UNITED STATES

A Thesis

by

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ABSTRACT

A DEMAND ANALYSIS OF CITRUS BEVERAGES IN THE UNITED STATES

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In 2017, the United States was the second largest producer of fresh and processed citrus with 711,000 bearing acreages and a production of 7.77 million metric tons (National Agricultural Statistics Service-USDA [NASS-USDA], 2018). Over 70% of the oranges produced in the U.S. are processed, while the remaining 30 % is sold as fresh fruits. Despite the U.S. annual orange juice production decreasing to 215,000 metric tons in 2017, per-capita domestic consumption increased to 41.75 pounds or remained at above 41.75 pounds (Economic Research Service-USDA [ERS-USDA], 2018). With record low production levels and record high import levels over the last 17 years, it is important to empirically estimate the U.S. household demand for citrus beverages. An effective approach is the estimation of household elasticities of demand. This study estimates an almost ideal demand system (AIDS) using AC-Nielsen monthly data for the period of 2004-2018. The parameter estimates of the AIDS model were employed to estimate the elasticities of demand for orange juice, grapefruit juice, orange juice drink, orange juice blend drink, orange juice blend, grapefruit juice cocktail, and grapefruit juice blend. Our results revealed that all Marshallian own-price elasticities had the expected negative signs and in absolute terms were greater than 1 indicating that the U.S. demand for the given citrus beverages was price-elastic. The Hicksian cross-price elasticities revealed both complementary relationships and substitutability between the selected citrus beverages types. The expenditure elasticities indicated that the selected citrus beverages are mostly normal goods.

The findings of this study improve an understanding of the citrus beverages market structure and provide insight into consumer demand behavior. Particularly, the estimated elasticities will be useful in the measurement of the U.S. consumers responsiveness to the price changes in the citrus beverages market. The findings also can be a foundation for policy-making, market segmentation, and marketing decisions.

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INTRODUCTION

Annual production of citrus fruits is over 93.3 million metric tons, covering nearly 18.7 million acres globally (National Agricultural Statistics Service-USDA [NASS-USDA], 2018). Brazil is the major producer with 17.34 million metric tons of production in 2017 (NASS-USDA, 2018). The United States is the second largest producer, with 0.7 million bearing acreages and 7.77 million metric tons of fresh and processed citrus production in 2017 (NASS-USDA, 2018). California and Florida are the major citrus-producing states in the U.S with production shares of about 51% and 45%, respectively, in the 2016/2017 crop year (NASS-USDA, 2018). With over 70% of the oranges produced in the U.S. and 30% sold as fresh fruits, per-capita consumption of fresh oranges is estimated to be about 15.07 pounds. Per-capita domestic consumption of processed oranges totaled 41.75 pounds in 2015. (Economic Research Service-USDA [ERS-USDA], 2018).

Orange Juice and Grapefruit Juice Consumption and Production

Orange juice is the most consumed citrus juice in the U.S., followed by grapefruit juice (Foreign Agricultural Service-USDA [FAS-USDA], 2018). Worldwide annual orange juice production for 2017 decreased by 16.02% to 1.73 million metric tons as production by the leading producers, Brazil, European Union (EU), and the U.S., fell by 16%, 9%, and 32%, respectively, compared to production in 2016 (FAS-USDA, 2018). Global consumption for 2017 was down by 5.78% to 1.63 million metric tons, led by the U.S. and EU with a decrease of 10.53% and 2.74%, respectively, compared to the 2016 market year (FAS-USDA, 2018). Figure 1 displays global citrus juice production and consumption from the year 2000 to 2017.

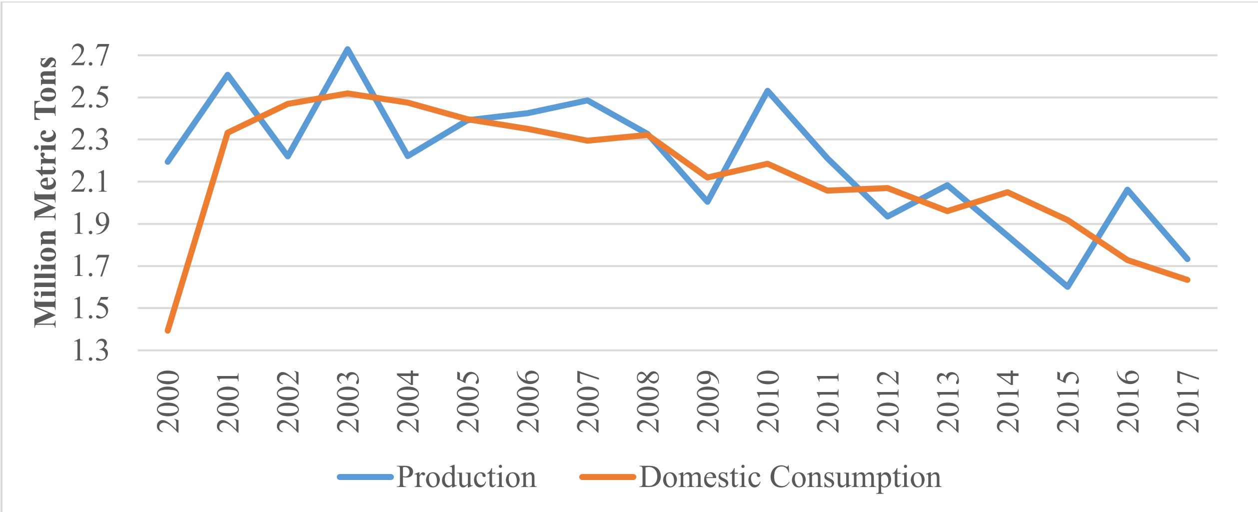

Figure 1. Global citrus juice production and consumption.
Source: FAS-USDA (2018)

In 2017, Brazil, the U.S., and the EU were the world's largest producers of oranges globally (Fruit and Tree Nuts Outlook, 2018). U.S. orange juice production decreased by 97,000 metric tons to 215,000 metric tons because fewer oranges were available for processing (Fruit and Tree Nuts Outlook, 2018). According to Figure 1, orange juice and grapefruit juice per capita consumption has declined drastically since the 2000s, to 2.87 gallons and 0.15 gallons, respectively, in 2015 (Fruit and Tree Nuts Outlook, 2018). According to Figure 2, 2017 was the most unfavorable year with the lowest production and highest import of orange juice over the past 17 years.

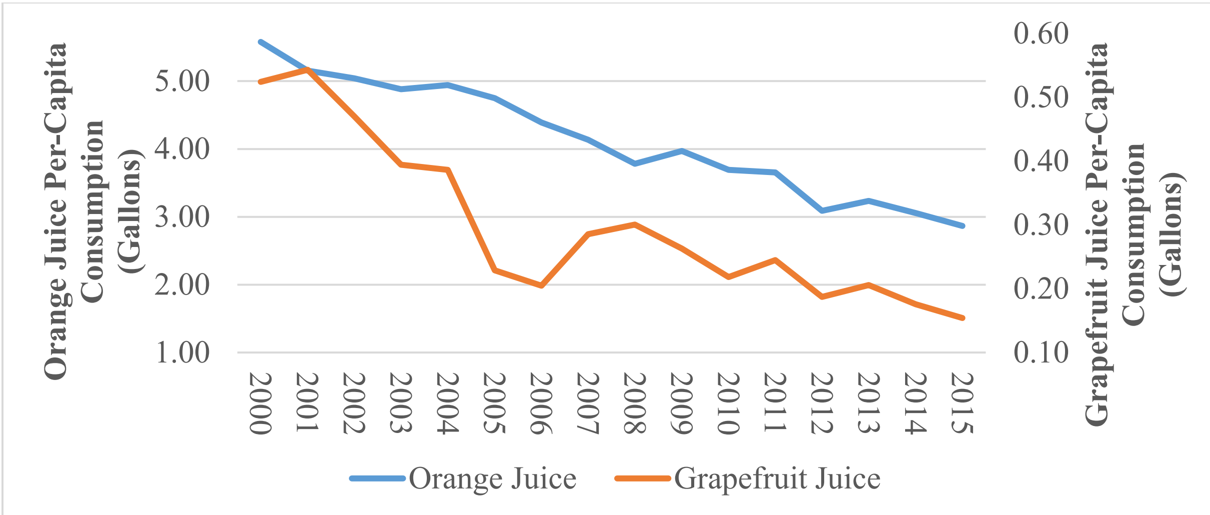

Figure 2. Per-capita consumption of orange juice and grapefruit juice in the U.S.
Source: FAS-USDA (2018)

Table 1
U.S. Orange Juice Supply and Utilization, 2000-2017, Metric Tons

Year	Beginning Stocks	Domestic Consumption	Ending Stocks	Exports	Imports	Production	Total Distribution	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 3 shows the average orange juice and average grapefruit juice price ($) per gallon trends for the period of 2004 to 2018 reported by the United States Department of Agriculture (USDA). According to the USDA, the average price for 1 gallon of orange juice increased by $2.46 becoming $6.80 per gallon in 2018, being only $4.30 per gallon in 2004. Average grapefruit juice prices increased proportionately with the average orange juice prices. Grapefruit juice price increased by $2.57 per gallon from the period of 2004 to 2018, being $5.06 per gallon in 2004 and $7.62 per gallon in 2018.

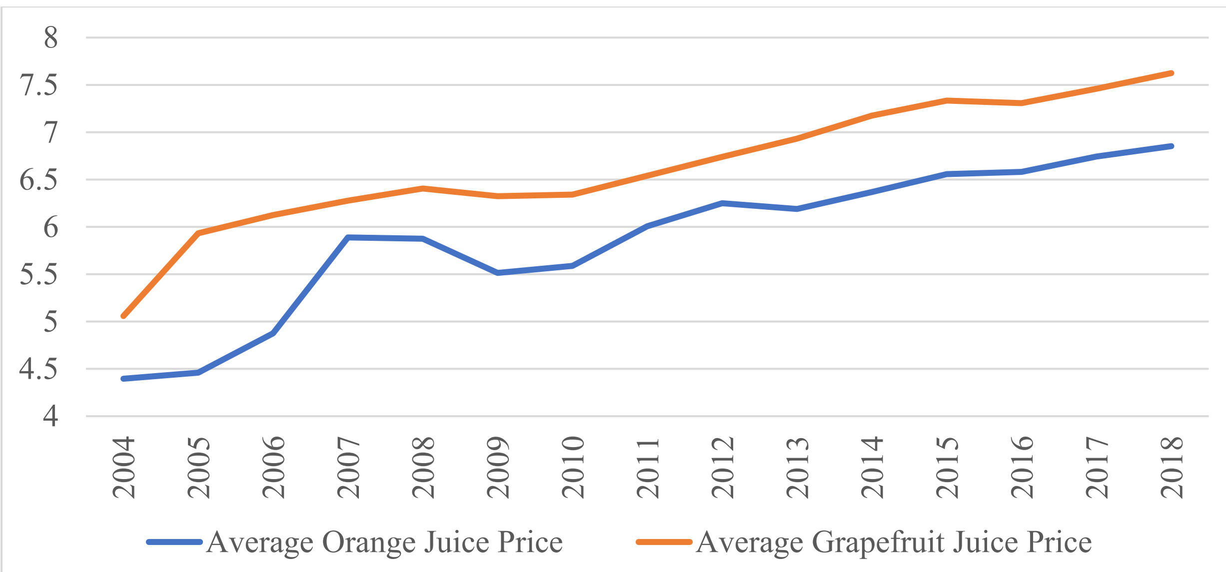

Figure 3. Average orange juice and average grapefruit juice prices in the U.S., 2004-2018, $ per gallon. Source: FAS-USDA (2018)

Orange Juice and Grapefruit Juice Trade

U.S. 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 SSE brix (the percentage of solids present in the juice of a plant) level for that specific item. Orange juice imports and the average import price increased compared to 2016, by 5% and 20%, respectively (Figure 4), while orange juice exports 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.

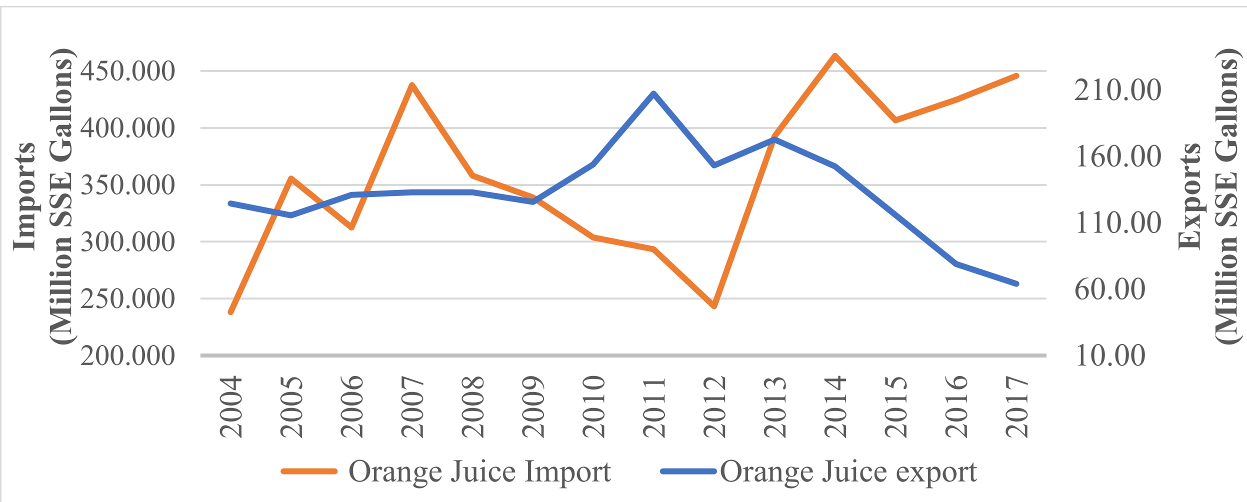

Figure 4. U.S. import and export of orange juice.
Source: FAS-USDA (2018)

The U.S. imports of grapefruit juice totaled 5,6 million SSE gallons (Figure 4) 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). U.S. 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).

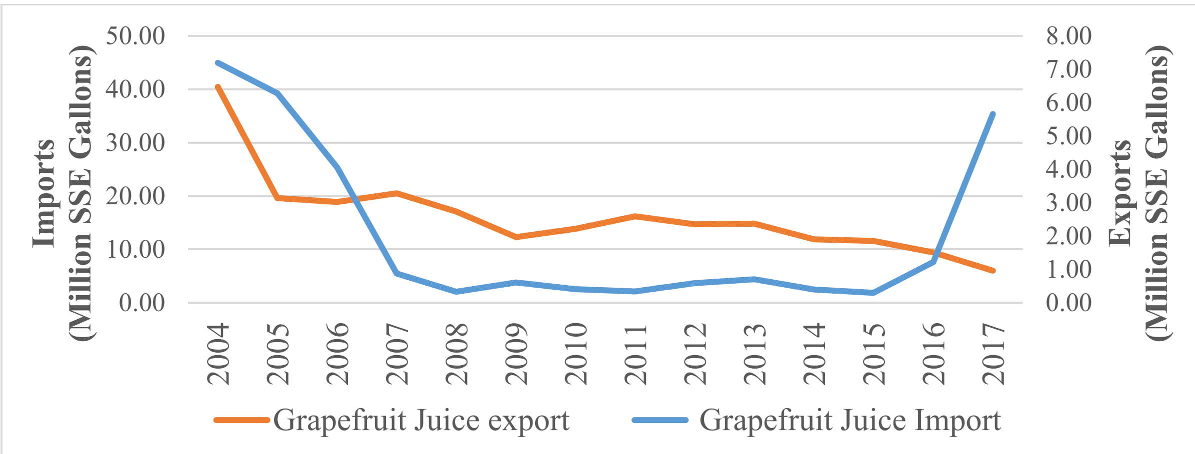

Figure 5. U.S. grapefruit juice imports and exports.
Source: FAS-USDA (2018)

The decrease in the U.S. citrus production and exports in 2017, increasing trends in orange and grapefruit juice imports, and a decrease in exports in 2017, can be the consequence of Hurricane Irma, which hit Florida in September 2017. The hurricane considerably reduced the amount of fruit going into processing and severely damaged many citrus trees (ERS-USDA, 2018).

Statement of the Problem

Due to recent declining trends in U.S. orange and grapefruit juice production and consumption accompanied by increasing trends in import dependency, an economic analysis explaining the change of the household demand, its significance, and imminence becomes increasingly important. Although household demand for orange and grapefruit juice is the focus for many studies, many of them are outdated and/or do not focus on recent changes in the market, which may be due to such events as hurricanes or bacterial diseases. Several researchers have examined the factors affecting the retail demand for citrus juices, such as flu/cold season (Lee & Brown, 2009), promotion, and advertisement (Capps, Bessler, & Williams, 2004), the import demand for fresh citrus including the seasonality aspects (Baldwin & Jones, 2012). However, no studies were found that focused on the U.S. orange and grapefruit juice retail demand analysis. In this study, an almost ideal demand system model was developed to estimate retail demand for orange and grapefruit beverages.

Objectives and Purpose of the Study

The main purpose of this study is to examine the United States household demand for orange and grapefruit beverages.

The specific objectives of the study are to:

1. Provide an overview of the U.S. processed citrus market, consumption, and trade.
2. Estimate Marshallian own-price and expenditure elasticities of retail demand for orange and grapefruit juice and discuss their responsiveness to price changes.
3. Estimate Hicksian cross-price and expenditure elasticities of retail demand for orange and grapefruit juice and discuss the possible economic connection between them.

Significance and Hypothesis of the Study

The study shows estimates of the U.S. household demand for orange and grapefruit beverages. Most prior studies are outdated and have primarily focused on different factors impacting the U.S. retail demand for citrus beverages, such as advertisement or flu/cold season. The aim of this study differs from prior studies by focusing on specific orange and grapefruit beverage categories and up-to-date data, filling the gap in the existing literature.

This information included in this study helps to develop a better understanding of the U.S. citrus beverages market and explains the sensitivity of consumers to the price and changes in total expenditure. The information provided can be useful for citrus beverages manufacturing companies for determining citrus juice prices, and for policy-makers in evaluating potential policies regulating the market.

The key hypothesis of the proposed study is that the prices and total expenditure affect the quantity of the orange and grapefruit beverages demanded, own prices, prices of substitute, and complement products.

Organization of Thesis Chapters

Chapter 1 provides an outlook of the U.S. citrus beverages industries, including a discussion of the citrus beverages production, consumption, and trade. Chapter 1 also includes the study's objectives and significance. Chapter 2 includes prior research conducted and highlights the major findings. Chapter 3 includes the theoretical specification and development of the almost ideal demand system as well as the procedures of deriving the compensated and uncompensated price and expenditure elasticities of demand. The major characteristics of data used in the study are discussed in Chapter 3. The estimation procedures, interpretations, and the results are summarized in Chapter 4. Last, Chapter 5 includes the conclusion and the summary of the study.

Chapter 2

REVIEW OF THE LITERATURE

Remarkable research efforts have been committed to estimate the U.S. retail demand for citrus beverages, as well as to estimate the U.S. 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 almost ideal demand system (AIDS) model (Deaton & Muellbauer, 1980). AIDS is one of the most widely used for demand estimations. With linear Engel curves for all commodities and system of budget share equations, the model enables the researcher to calculate own-price elasticity of demand, cross-price elasticity of demand, and expenditure elasticity of demand. This chapter presents studies in which researchers examined both import and retail demands for citrus beverages and fresh fruits using one of the most popular and widely used models in the estimation of a system of demand equations.

Brown (1986) analyzed the single-flavor fruit juice market including four juice types - grapefruit juice, orange juice, grape juice, and apple juice. The study used NPD Research Inc. (formerly National Purchase Diary Panel Inc.) reported information on the number of households purchasing fruit juice, the quantity purchased, and total price and quantity of sales from December 1977 to April 1985. U.S. personal income, Consumer Price Index and the U.S. population data provided by the Survey of Current Business were used in the study for the same period. The method of seemingly unrelated regressions was employed to the research to estimate two equations for each juice type: one is for a number of households purchasing fruit juice and one for the average quantity of fruit juice purchased per household. The SSE gallons per household estimates indicated that income elasticities for orange juice and grapefruit juice were

0.76 and -0.029, respectively, and were statistically significant. The own-price elasticities for all juice types were negative and significant. The own-price elasticity for orange juice was -0.728, meaning that 1% increase in the price of orange juice is expected to result in a decrease of 0.728% in quantity demanded orange juice, holding everything else constant. The own-price elasticity for grapefruit juice was -0.304, meaning that 1% increase in the price of grapefruit juice is expected to result in a decrease of 0.304% in quantity demanded of grapefruit juice, holding everything else constant. The cross-price elasticities results revealed a substitute relationship between orange juice and grapefruit juice (Brown, 1986).

Brown, Lee, and Seale (1994) analyzed the influence of income and price on U.S. juice beverages demand. Brown et al. (1994) analyzed AC Nielsen weekly sales data for the U.S. stores with total sales higher than four million dollars yearly for the period from December 1988 to November 1992. Seven juice groups were selected, including juices of grapefruit, orange, apple, blended juices, juice drinks, juice cocktails, and remaining juices. Alternative differential demand models combining the features of the Rotterdam model and AIDS were employed. According to their results, orange juice was found to be a necessity good with an expenditure elasticity of 0.8518 and own-price elasticity of -0.8816, both being the lowest among the seven juice types included in the study. 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 in 1992 and low demand elasticities for orange juice indicated that orange juice can be considered as a staple juice among the juices studied (juices of grapefruit, orange, apple, juice drinks, blended juices, juice cocktails, and remaining juices). 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 among orange juice and grapefruit juice. Expenditure elasticities and own-price elasticities of demand were also divided into four seasons. According to the results, expenditure elasticity estimates for orange juice decreased from 0.86 in 1988-89 to 084 in 1991-92, while the own-price elasticity increased for the same period from -0.82 to -0.94 in absolute terms. This can be explained by the decrease in expenditure share of orange juice over the same period from 0.37 to 0.33. Orange juice had an average expenditure share of 0.3487 for the period from 1988 to 1992. Grapefruit juice had an average expenditure share of 0.0274 for the period from 1988 to 1992. Expenditure elasticity estimates for grapefruit juice indicated that it becomes more sensitive to expenditure changes. Last, Brown, Lee, and Seale found the own-price elasticity estimates had increased from -1.69 in 1988-89 to -1.87 in 1991-92 in absolute terms, becoming more elastic over the period analyzed.

Capps, Bessler, and Williams, (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 AC Nielsen data for several orange juice 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 have 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, meaning that 1 % increase in the price of orange juice is expected to decrease the quantity demanded by 0.684 %, holding everything else constant. The study also revealed a substitute relationship between orange juice and grapefruit juice. The cross-price elasticity of orange juice with grapefruit juice was found to be 0.388, meaning that 1 % increase in the price of grapefruit juice is expected to increase the quantity demanded of orange juice by 0.388 %.

Lee and Brown (2009) examined the impact of promotions and flu/cold incidences on the demand for orange juice. The cross-section time-series pooling technique was used to estimate the demand parameters. AC Nielsen reported weekly grocery stores' orange juice sales and the flu/cold incidences information reported by 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, suggesting a quantity demanded decrease of 0.5741% in case of 1% increase in orange juice price, holding everything else constant. Cross-price elasticities suggested that 100% grapefruit juice and orange juice products are substitutes with the elasticity of 0.0231, while orange juice blends, grapefruit juice blends, and orange juice blend drinks are complements of orange juice (Lee & Brown, 2009).

Baldwin and Jones (2012) analyzed the U.S. import demand for citrus using quarterly import data for the period of 1989 to 2010 for the major six citrus imported products (oranges, grapefruit, limes, mandarins, lemons, and “other,” an aggregate group for any remaining imported citrus products). A nonlinear AIDS was employed in the study. The estimated expenditure elasticities for oranges, grapefruit, mandarins, and lemons were greater than one (1.442, 1.479, 1.360, and 1.164, respectively). Limes and other citrus had expenditure elasticities of less than a unity, 0.518 and 0.262 respectively. The findings show that as income increases, consumers tend to spend more of their total income on imported citrus such as oranges, grapefruit, lemons, and mandarins and less on limes and other citrus. Consistent with economic theory, the own-price elasticities had the expected negative sign and were statistically significant, except for oranges, meaning that an increase in the import price is expected to reduce the quantity demanded. Oranges, mandarins, lemons, and limes had inelastic own-price elasticities, -0.050, -0.359, -0.742, and -0.126, respectively. The results of the study indicate the supplying countries can increase their revenues by decreasing the quantity supplied to the U.S., and an increase in the price of these imported products will lead to a proportional reduction in the amount imported. The compensated cross-price elasticities indicate that none of the fruits is a statistically significant natural 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 in 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 & Jones, 2012).

Elasticity estimates from prior studies are summarized in Table 2. The own-price elasticity estimates for orange juice indicate an inelastic elasticity of demand, which shows consumption of orange juice is generally irresponsive to changes in the price of orange juice.

Own-price elasticity of oranges is negative, meaning that as the price for oranges increases, quantity demanded is expected to decrease, holding everything else constant. Recent studies show that grapefruit juice has an inelastic own-price elasticity of demand, meaning that changes in prices of grapefruit juice have an impact on quantity demanded.

Table 2

Summary of Demand Elasticities Obtained by Prior Studies

Study	Commodity	Own-price elasticity	Expenditure elasticity
Brown (1986)		-0.7280	0.7620
Brown, Lee, and Seale (1994)		-0.8816	0.8518
Capps, Bessler, and Williams (2004)		-0.6840	
Lee and Brown (2009)	Orange Juice	-0.5741	
Baldwin and Jones (2012)	Oranges	-0.0500	1.442
Brown (1986)		-0.3040	-0.029
Brown, Lee, and Seale (1994)	Grapefruit Juice	-1.8791	1.007
Baldwin and Jones (2012)	Grapefruits	-1.1360	1.479

According to the expenditure elasticities estimates in Table 2, people tend to purchase more citrus beverages as income increases. In addition, orange juice has been found to have an expenditure elasticity coefficient smaller than one, making it a necessity good. On the contrary, recent studies have found grapefruit juice to have an expenditure elasticity coefficient greater than one, making it a luxury commodity. Last, both fresh oranges and grapefruits were found to be luxury commodities, according to their expenditure elasticities of demand (Table 2).

Chapter 3

DATA AND ESTIMATION PROCEDURES

Data

The Florida Department of Citrus (2018) reported the AC Nielsen four-week data for orange and grapefruit beverages that were used in this study for the period October 2004 to June 2018, which includes sales in gallons and price per gallon for all the U.S. for several orange and grapefruit beverage types. Homescan and scan track (point of sale) data were collected in drug stores with $1 million and greater sales, in grocery stores with $2 million and greater sales, mass merchandisers like Walmart, dollar stores such as Dollar General, Family Dollar, clubs like Sam's, and military/Defense Commissary Agency. The Walmart data were homescan, the remaining data were scan track data. The beverages types include seven categories including 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. This study also uses the Consumer Price Index reported by the U.S. Bureau of Labor Statistics to adjust the beverage prices for inflation. Household income data reported by The U.S. Census Bureau were used to address the issue of possible endogeneity. All the data used are publicly available. Table 3 reports the names and the descriptions of the seven citrus beverages reported by the Florida Department of Citrus and selected for this study.

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

Model

The AIDS was first introduced by Deaton and Muellbauer in 1980, after which it has gained wide popularity and has become more flexible and applicable. 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 derive the given utility (Deaton, & Muellbauer, 1980).

The expenditure function, *c*, has the following form in the AIDS model.

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

The cost function looks like the following

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

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 the good *i,* using the following relation:

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

Therefore, the differentiation of cost function with respect to $\log(p_i)$ yields the budget shares

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

where

P is a nonlinear price index defined as

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

The following are the AIDS model restrictions:

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

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

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

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

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

where:

- δ_{ij} 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 ware calculated as

$$\varepsilon_{ix} = 1 + \frac{\beta_i}{w_i}. \tag{10}$$

Compensated (Hicksian) price elasticities were calculated using the Slutsky equation as

$$e_{ij} = \varepsilon_{ij} + w_i * \varepsilon_{ix}. \tag{11}$$

Seasonal variations are very common in agriculture. Before estimating the AIDS model, the data was tested and treated for seasonality if necessary. In theory, there are several ways to capture and treat for seasonality, such as using harmonic regression and/or dummy variables. The dummy variable method introduces binary variables that take the value of 1 if the given season and 0 otherwise. The method of harmonic regression adds to the model two trigonometric variables, *sine,* and *cosine*. The sine and cosine variables have the following format:

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

and

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

where:

- t_i is the corresponding trend variable taking up the value of 1 for the first observation and the value n for the n^{th} 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. The sums of coefficients of trigonometric variables were limited to zero:

$$\sum_i s_i = 0 \tag{14}$$

$$\sum_i c_i = 0 \tag{15}$$

where i is the index of each beverage slip; c_i and s_i are the coefficients for the sine and cosine functions measuring their contribution to the model (Arnade & Gehlhar, 2005).This study employs the harmonic regression model to deal with the issue of seasonality.

Endogeneity of the 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. The log of total expenditure was modeled as a function of the real household income and the real prices used to calculate the total expenditure to solve the issue of endogeneity.

That is:

$$\log(X) = \alpha_0 + \sum_i \vartheta_i \log(p_i) + g\log(HI) + +\varepsilon_i \tag{16}$$

where:

- *log(X)* is the total expenditure logarithm,
- p_i is the price of the i^{th} commodity,
- *HI* is the household income,
- α_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 to assess serial autocorrelation (Durbin & Watson, 1951):

$$d = \frac{\sum(\widehat{e_t} - \widehat{e_{t-1}})^2}{\sum \widehat{e_t}^2} \quad (17)$$

In this study the AIDS model is estimated as:

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

where:

- *i* and *j* represent any two commodities,
- w_i is the expenditure share for i^{th} the commodity,
- p_j is the price of j^{th} the commodity,
- *X* is total expenditures on all goods included in the model,
- α_i, γ_{ij}, β_i c_i s_i and z_i are the parameters that are 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.

Chapter 4

ESTIMATION RESULTS

Durbin-Watson statistics close to two indicates that the serial correlation issue was effectively addressed in the model. Table 4 shows the coefficients of determination, first-order autoregressive coefficient, and Durbin Watson statistics. The coefficient of determinations ranges from 77% to 96%, suggesting that overall the system equations are a good fit for the data.

Table 4

R^2, Durbin Watson Statistics, and First-Order Autoregressive Coefficient (ρ)

i	R^2	Durbin Watson
1	0.77	2.33
2	0.97	1.87
3	0.91	1.80
4	0.73	2.99
5	0.77	2.42
6	0.96	1.41
7	0.94	1.83
	Estimate	Standard Error
ρ	0.763	0.019

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, 7 = 100 % Grapefruit Juice.

Demand Elasticities

The compensated cross-price elasticities and uncompensated own-price elasticities of demand calculated are reported in Table 5.

Table 5

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*	-0.16	-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****

* Significant at p=0.05; ** significant at p=0.01.
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, 7 = 100 % Grapefruit Juice.

Own-Price Elasticities

Own-price elasticity measures the percentage change in the quantity demanded of a commodity from a percentage change in the price of that same commodity. Table 6 includes own-price elasticities. All the uncompensated own-price elasticities were negative and statistically significant at 1% significance level. All the selected citrus beverages were found to be price elastic, as their own-price elasticities were greater than one in absolute terms, meaning that these beverages are price sensitive. The own-price elasticities of demand for orange juice and grapefruit juice in the prior studies reviewed appeared to be price inelastic, except for grapefruit juice in the study of Brown., Lee, and Seale (1994) with the elasticity of -1.8791. The explanation for the own-price elasticity being price elastic in this study can be the wide variety of substitute products present in the market today. As the price for 100% natural orange juice and grapefruit juice increase, the consumers switch to other substitute products, making the market of 100% orange and grapefruit juice price sensitive.

Table 6

Own-Price Elasticities of Demand

	Own-Price Elasticity	Standard Error
Orange Juice Drink	-2.192**	0.2115
Orange Juice Blend Drink	-1.716**	0.0677
Orange Juice Blend	-1.090**	0.0840
Grapefruit Juice Cocktail	-1.559**	0.1246
Grapefruit Juice Blend	-3.621**	0.2953
100 % Orange Juice	-1.160**	0.0367
100 % Grapefruit Juice	-1.485**	0.2113

* Significant at p=0.05; ** Significant at p=0.01

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 negative cross-price elasticities of demand mean complementary relationship between the two goods observed. All the compensated cross-price elasticities of demand are reported in Table 7.

Table 7

Cross-Price Elasticities

i	Orange Juice Drink	Orange Juice Blend Drink	Orange Juice Blend	Grapefruit Juice Cocktail	Grapefruit Juice Blend	100 % Orange Juice	100 % Grapefruit Juice
Orange Juice Drink		1.200**			0.0420*	1.0170**	-0.0880*
		(0.1258)			(0.0173)	(0.2267)	(0.0421)
Orange Juice Blend Drink	0.4620**			0.0160*		1.1220**	0.0540**
	(0.0484)			(0.0074)		(0.0752)	(0.0752)
Orange Juice Blend						1.0730**	
						(0.1399)	
Grapefruit Juice Cocktail		0.1690*			0.1400*		0.4050**
		(0.0799)			(0.0555)		(0.1460)
Grapefruit Juice Blend	1.1840*			0.9380*			1.6370**
	(0.4873)			(0.3719)			(0.6111)
100 % Orange Juice	0.0940**	0.2690**	0.0840**				0.0270**
	(0.0209)	(0.0180)	(0.011)				(0.0062)
100 % Grapefruit Juice	-0.2100*	0.3350**		0.2300**	0.13900**	0.6900**	
	(0.1002)	(0.0615)		(0.0829)	(0.0518)	(0.1609)	

* Significant at p=0.05; ** Significant at p=0.01

Note: Standard Errors are reported in the parenthesis

All the cross-price elasticities reported are positive, meaning that the seven citrus beverages categories examined are mainly substitute products for each other, only 100% grapefruit juice and orange juice drinks being complements. All the cross-price elasticities reported are statistically significant at 1% either at a 5% significance level.

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 the influence of everything else constant. The cross-price elasticity of orange juice drinks and orange juice blend drinks is 1.2, meaning that 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 the influence of everything else constant. The findings are consistent with the findings of Lee and Brown's (2009) study, suggesting that 100% grapefruit juice and orange juice products are substitutes with the elasticity of 0.0231.

Expenditure Elasticities

The expenditure elasticities of demand are reported in Table 8.

Table 8

Expenditure Elasticities of Demand

i	Expenditure Elasticity	Standard 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

* Significant at p=0.05; ** Significant at p=0.01

The expenditure elasticities indicate the relationship between the change in expenditure on the selected categories of citrus beverages and the quantity demanded of the same commodities. All the estimated expenditure elasticities were positive. All the elasticities were statistically significant at 1% significance level except for grapefruit juice blend. Total orange blend drinks, total grapefruit juice cocktails, and total orange juice revealed to be necessity goods, as their elasticities were less than 1 indicating that 1% change in total expenditure on citrus beverages is expected to have less than 1% impact on the quantity of these citrus juices demanded. Total orange juice drinks, total orange juice blend 100% juice, and total grapefruit juice were considered as luxury goods, as their elasticities were greater than 1 indicating that 1% change in total expenditure on citrus beverages is expected to cause more than 1% change in quantity demanded of these products.

Chapter 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS FOR FUTURE RESEARCH

In this study, AC Nielsen homescan and scan track data on household purchases from October 2004 to June 2018, were used to estimate an AIDS model and analyze the impact of price changes on the quantity demanded of seven citrus beverage types. The empirical findings of this study show that the selected citrus beverage categories are highly price change sensitive, with own-price elasticities being elastic, indicating consumers are 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 gallons, holding the influence of 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 the influence of everything else constant. This suggests juice processors and marketers can increase revenues by decreasing the prices for these products. Cross-price elasticities revealed mainly substitutability relationship 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 the influence of everything else constant. Positive income elasticities indicate that selected commodities are normal goods and suggest that an increase in income leads to an increase in the quantity demanded of selected beverages. Three citrus beverage types had a value greater than unity, being luxury goods, while the income elasticities for the other four types were less than one, indicating that these beverages are necessity goods. Expenditure elasticity of 100%

natural orange juice is calculated to be 0.99, which suggests that as household income increases by 1%, the quantity demanded of natural orange juice increases by 0.9. Expenditure elasticity of 100% natural grapefruit juice is calculated to be 1.11, which suggests that as household income increases by 1%, the quantity demanded of natural grapefruit juice increases by 1.11.

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

A few recommendations for future research need to be highlighted. Future research would benefit from adding more individual characteristics about the consumers to the data, such as gender, age, education, how they value their health, and so forth. Similarly, since this study is at the national level, it 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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APPENDIX

APPENDIX

PARAMETER ESTIMATES, UNCOMPENSATED AND COMPENSATED ELASTICITIES OF DEMAND, AND CORRESPONDING STANDARD ERRORS, P-VALUES, AND STATISTICS FOR THE FIRST SYSTEM OF DEMAND EQUATIONS

PARAMETER ESTIMATES, UNCOMPENSATED AND COMPENSATED ELASTICITIES OF DEMAND, AND CORRESPONDING STANDARD ERRORS, P-VALUES, AND STATISTICS FOR THE FIRST SYSTEM OF DEMAND EQUATIONS

Table A.1. Estimates of the Demand System

Parameter	Estimate	Standard Error	*t* Value	Approximate Pr > |*t*|
g11	-0.0781	0.0143	-5.44	<0.0001
g12	0.0740	0.0096	7.69	<0.0001
g13	-0.0149	0.0058	-2.58	0.0107
g14	0.0023	0.0020	1.19	0.2363
g15	0.0027	0.0011	2.37	0.0187
g16	0.0214	0.0149	1.44	0.1507
g17	-0.0076	0.0027	-2.78	0.0060
g22	-0.1400	0.0143	-9.81	<0.0001
g23	-0.0086	0.0035	-2.40	0.0173
g24	-0.0012	0.0013	-0.92	0.3580
g25	-0.0010	0.0007	-1.43	0.1548
g26	0.0716	0.0132	5.41	<0.0001
g27	0.0052	0.0017	3.03	0.0028
g33	-0.0062	0.0043	-1.43	0.1539
g34	0.0048	0.0028	1.71	0.0900
g35	-0.0016	0.0016	-1.01	0.3137
g36	0.0212	0.0077	2.74	0.0068
g37	0.0054	0.0042	1.27	0.2057
g44	-0.0085	0.0018	-4.52	<0.0001
g45	0.0020	0.0008	2.43	0.0163
g46	-0.0051	0.0031	-1.63	0.1042
g47	0.0057	0.0021	2.61	0.0097
g55	-0.0058	0.0006	-8.87	<0.0001
g56	0.0002	0.0017	0.12	0.9024
g57	0.0036	0.0013	2.65	0.0089
g66	-0.1097	0.0227	-4.84	<0.0001
g67	0.0003	0.0042	0.08	0.9384
g77	-0.0127	0.0055	-2.29	0.0234
a1	-0.1134	0.0494	-2.30	0.0228
a2	0.2673	0.0642	4.16	<0.0001
a3	-0.1000	0.0279	-3.59	0.0004
a4	0.0378	0.0075	4.99	<0.0001
a5	0.0122	0.0042	2.89	0.0043
a6	0.8638	0.0759	11.38	<0.0001
a7	0.0321	0.0216	1.49	0.1388
v0	-4.4007	10.482	-0.42	0.6752

rho1	0.9978	0.0146	68.57	<0.0001
v1	0.3310	0.0767	4.31	<0.0001
v2	0.0355	0.0556	0.65	0.5193
v3	-0.3368	0.1513	-2.23	0.0273
v4	-0.3186	0.0735	-4.36	<0.0001
v5	0.0533	0.0437	1.22	0.2237
v6	0.9220	0.1992	4.63	<0.0001
v7	-0.4186	0.1659	-2.52	0.0127
v8	1.2668	0.3627	3.49	0.0006
rho	0.7631	0.0193	39.49	<0.0001
b1	0.0386	0.0114	3.53	0.0005
a1sin	0.0023	0.0010	2.19	0.0301
a1cos	0.0004	0.0010	0.45	0.6543
z1	0.0004	0.0001	5.57	<0.0001
b2	-0.0595	0.0147	-4.04	<0.0001
a2sin	-0.0024	0.0015	-1.63	0.1047
a2cos	-0.0001	0.0015	-0.1	0.9187
z2	0.0002	0.0001	3.12	0.0021
b3	0.0268	0.0045	5.92	<0.0001
a3sin	-0.0002	0.0004	-0.53	0.5959
a3cos	-0.0000	0.0000	-0.12	0.9062
z3	0.0001	0.0000	4.79	<0.0001
b4	-0.0057	0.0016	-3.48	0.0006
a4sin	-0.0002	0.0001	-1.86	0.0651
a4cos	0.0002	0.0001	1.57	0.1185
z4	-0.0000	0.0000	-2.03	0.0439
b5	-0.0013	0.0009	-1.51	0.1322
a5sin	-0.0000	0.0000	-0.98	0.3301
a5cos	-0.0003	0.0002	-0.09	0.9267
z5	-0.0000	0.0001	-5.31	<0.0001
b6	-0.0018	0.0172	-0.10	0.9165
a6sin	0.000707	0.0017	0.41	0.6830
a6cos	-0.00084	0.0017	-0.48	0.6294
z6	-0.00073	0.0002	-7.89	<0.0001

Table A.2.

Estimated Uncompensated Elasticities of Demand

Parameter	Estimate	Standard Error	*t*-statistic	*p*-value
e_11	-2.1920	0.2115	-10.36	<0.0001
e_22	-1.7157	0.0677	-25.33	<0.0001
e_33	-1.0904	0.0840	-12.98	<0.0001
e_44	-1.5588	0.1246	-12.51	<0.0001
e_55	-3.6208	0.2953	-12.26	<0.0001
e_66	-1.1601	0.0367	-31.64	<0.0001
e_77	-1.4850	0.2113	-7.03	<0.0001

Table A.3.

Estimated Compensated Elasticities of Demand

Parameter	Estimate	Standard Error	*t*-statistic	*p*-value
ec_11	-2.0908	0.2082	-10.04	<0.0001
ec_12	1.1999	0.1258	9.54	<0.0001
ec_13	-0.1196	0.0883	-1.36	0.1771
ec_14	0.0391	0.0301	1.30	0.1952
ec_15	0.0421	0.0173	2.43	0.0162
ec_16	1.0172	0.2267	4.49	0.0000
ec_17	-0.088	0.0421	-2.09	0.0381
ec_21	0.4621	0.0484	9.54	<0.0001
ec_22	-1.6128	0.0687	-23.47	<0.00010
ec_23	-0.039	0.0198	-1.97	0.0503
ec_24	0.0155	0.0073	2.11	0.0362
ec_25	-0.0022	0.0041	-0.53	0.5963
ec_26	1.1222	0.0752	14.93	<0.0001
ec_27	0.0541	0.0099	5.44	<0.0001
ec_31	-0.1403	0.1035	-1.36	0.1771
ec_32	-0.1189	0.0603	-1.97	0.0503
ec_33	-1.0102	0.0851	-11.87	<0.0001
ec_34	0.0941	0.0527	1.79	0.0754
ec_35	-0.0317	0.0307	-1.03	0.3028
ec_36	1.0727	0.1399	7.67	0.0000
ec_37	0.1340	0.0798	1.68	0.0950
ec_41	0.1638	0.1264	1.30	0.1952

ec_42	0.1687	0.0799	2.11	0.0362
ec_43	0.3364	0.1881	1.79	0.0754
ec_44	-1.5496	0.1251	-12.38	0.0000
ec_45	0.1398	0.0555	2.52	0.0126
ec_46	0.3356	0.2087	1.61	0.1096
ec_47	0.4051	0.1464	2.77	0.0061
ec_51	1.1838	0.4873	2.43	0.0162
ec_52	-0.1599	0.3013	-0.53	0.5963
ec_53	-0.7587	0.7341	-1.03	0.3028
ec_54	0.9377	0.3719	2.52	0.0126
ec_55	-3.62	0.2954	-12.25	<0.0001
ec_56	0.7802	0.7913	0.99	0.3255
ec_57	1.6367	0.6111	2.68	0.0081
ec_61	0.0938	0.0209	4.49	<0.0001
ec_62	0.2687	0.0183	14.93	<0.0001
ec_63	0.0843	0.0111	7.67	<0.0001
ec_64	0.0073	0.0046	1.61	0.1096
ec_65	0.0025	0.0026	0.99	0.3255
ec_66	-0.4836	0.0334	-14.46	<0.0001
ec_67	0.0267	0.0062	4.29	<0.0001
ec_71	-0.2095	0.1002	-2.09	0.0381
ec_72	0.3345	0.0615	5.44	<0.0001
ec_73	0.2719	0.1624	1.68	0.0950
ec_74	0.2301	0.0829	2.77	0.0061
ec_75	0.1386	0.0518	2.68	0.0081
ec_76	0.6899	0.1609	4.29	<0.0001
ec_77	-1.455	0.2113	-6.89	<0.0001

VITA

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