A Demand Analysis for Fresh Tomatoes in the Dallas/Fort Worth Grocery Market.

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Abstract

Tomato consumption and production have been rapidly increasing. With most of the U.S. tomatoes produced being processed, tomato imports for the fresh market are significantly greater than tomato imports for the processed market. Consequently, it is critical and increasingly valuable for fresh-market producers who sell directly to grocery chains, farmers' markets, and food service providers to analyze emerging consumption trends as well as the substitution patterns among different types of tomatoes and vegetables. This study uses the Almost Ideal Demand System (AIDS) to estimate the demand parameters for fresh tomatoes in the Dallas/Fort Worth grocery market using AC Nielsen Homescan data for the year 2012. Unlike previous fresh fruit and vegetable studies, the study reports disaggregated tomato elasticities, including Hicksian and Marshallian price elasticities and expenditure elasticities. The analysis identifies tomato types that are highly marketable in the Dallas/Fort Worth metropolitan area and provides insight on tomato varieties that could be grown for the region.

Key words: Disaggregated tomato elaticities, scanner data, tomato types, demand system

JEL codes: Q11, R21

Introduction

The demand for food, especially fresh vegetables, has increased steadily over the last several years (EPA, 2012). Tomatoes are the fourth most consumed vegetable in the nation (USDA-ERS, 2012) and its production has also increased steadily for the last 20 years (Lucier, Lin, Allshouse, and Kantor, 2000). From 1960 to 2010 the production of tomatoes per planted acre increased more than 40%, making the tomato the second highest ranking fresh vegetables in terms of farm value (Borris and Brunke, 2005). In 2000, tomato consumption increased approximately 30% over the previous decade (Lucier et al., 2000).

Tomatoes are generally produced for processing or for consumption at the fresh market level. Processed tomatoes are harvested by mechanical equipment, while fresh tomatoes are handpicked to preserve a certain quality of the fruit, which is why machinery may be detrimental to tomatoes being sent to the fresh market. The use of automatic equipment generally increases the amount that is harvested; and results in more tomatoes being sent to processing. For example, approximately 89% of the total tomatoes produced in the U.S. were processed in 2008 (USDA-ERS, 2012). The majority of processed-tomato producers contract with firms who process vegetables into items such as, soups, condiments, juices, etc. However, the majority of fresh-market producers sell at the open market (USDA-ERS, 2012). In general the fresh tomato industry is considered vertically integrated, with companies controlling production, packing, and shipping of the produce. As a result, it is common for fresh-market producers to sell directly to local grocery chains, farmers' markets, and food service providers (Strange et al., 2000).

Since 2006, tomato production in the U.S. has remained above 12 million tons per year reaching a peak of 14 million tons in 2009 (FAOSTAT 2014). From 1960 to 2010 U. S. tomato yields increased from 118,000 to 277,000 lbs. per planted acre respectively (Boriss and Brunke, 2005). In 2010, the tomato was the highest selling fresh market vegetable with revenues of 1.4 billion dollars (Borris and Brunke, 2005). Most tomatoes are produced in California and Florida (Jung et. al, 2005). California leads the tomato production during warm months while Florida leads during the winter (Girapunthong et al., 2003). Surplus production often causes tomatoes from California to sell at prices lower than winter (Boriss and Brunke, 2011). During the winter season, Florida producers receive higher prices due to producing outside of the regular season (Boriss and Brunke, 2011).

In 2007, the U.S. exported approximately 180,000 metric tons of processed tomatoes with Canada, Mexico, Japan, Italy, and Korea accounting for majority of the export market (Lynch and McCarty, 2008). In 2007, U.S. imports of processed tomatoes totaled $37.7 million or 49,993 metric tons (Lynch and McCarty, 2008). Mexico, China, Canada, Israel, and Chile are the top leading sources of imports of processed tomatoes into the U.S. (Lynch and McCarty, 2008). Imports of processed tomatoes are significantly lower than fresh market tomatoes because California produces most processed tomatoes consumed in the U.S. (Lynch and McCarty, 2008).

Consumption patterns have changed over the years. In 1981, the average annual per capita consumption of fresh tomatoes was 12.3 pounds (Boriss and Brunke, 2011). In 2008, this number has increased to 18.5 pounds (Boriss and Brunke, 2011). This is in part due to increasing cultural diversity within the nation. The immigration of Hispanic and Asian immigrants into the U.S. has led to higher vegetable consumption (Nzaku and Houston, 2009). According to Lucier et al. (2000), Hispanics are the nation's largest consumer of fresh tomatoes. Studies also suggest that NAFTA's opening of free trade agreements have led to an increase in tomato consumption (Grant and Foster, 2005; Huang and Huang, 2007). Studies have also emphasized the positive benefits of eating fresh produce (Deghan et al., 2011). More Americans across the nation have a desire to maintain healthy lifestyles. An average medium-sized tomato can provide up to 40% of the recommended dietary intake of Vitamin C. Tomatoes also contain folate, potassium, flavonoids, and phytosterol (Beecher, 1998). Lycopene, a compound found in tomatoes, has also been found to help with immune responses and decrease risk of various diseases, such as cancer (Agarwal and Rao, 2000). The compound has also been found to reduce the risks of cardiovascular disease and to be inversely related to breast and prostate cancer (Agarwal and Rao, 2000). The amount of fresh tomatoes consumed has also been found to positively correlated with income and age (Lucier et al., 2000).

Given the upward trending consumption and production patterns for tomatoes, an understanding of the substitution patterns among different types of tomatoes and vegetables becomes increasingly valuable for producers and distributors. The main objective of this study is to appropriately estimate Hicksian and Marshallian price elasticities and expenditure elasticities for fresh tomatoes at the retail level using AC Nielsen Homescan consumption data and a demand system approach. Unlike previous fresh fruit and vegetable studies (Brandow, 1961; George and King, 1971; Brumfield et al., 1993; You et al., 1996; Henneberry et al., 1999; Agarwal and Rao, 2000; Thompson, 2003; Grant and Foster, 2005; Jung et al. 2005; Nzaku and Houston, 2009; Padilla and Acharya, 2009; Deghan et al., 2011; Naanwaab and Yeboah, 2012; Niu and Wohlegenaut, 2012; Seale et al., 2013), this study reports disaggregated tomato elasticity estimates which were previously not available.

Methods and Procedures

Various demand systems have been used to analyze demand for fresh fruits and vegetables, including the Rotterdam model (e.g., Seale et al., 2013), the AIDS (e.g., Thompson, 2003), the linear approximation of the AIDS (e.g., Padilla and Acharya, 2009; Naanwaab and Yeboah, 2012), the quadratic AIDS (e.g., Thompson, 2003), first difference version of the AIDS (e.g., Jung et al., 2005), and the inverse AIDS (e.g., Grant and Foster, 2005). Results from misspecification tests showed that the Rotterdam functional form was not an appropriate representation of the fruit and vegetable demand systems that Henneberry et al. (1999) considered. This study will use Deaton and Mullbauer's (1980) Almost Ideal Demand System (AIDS) to estimate how fresh tomatoes perform at the retail level.

Deaton and Muelbauer's (1980) AIDS model is considered an arbitrary first order approximation of any demand system. It satisfies the axioms of choice and aggregates perfectly over consumers up to a market demand function without invoking parallel linear Engel curves. The functional form is consistent with household-budget data, can be used to test the properties of homogeneity and symmetry through linear restrictions on fixed parameters, and is not difficult to estimate. In the AIDS model, the Marshallian demand function for commodity *i* in share form is specified as:

$$(1) \qquad w_{it} = \alpha_i + \sum_j \gamma_{ij} \log(p_{jt}) + \beta_i \log[X_t/P_t] + \varepsilon_{it},$$

where w_{it} is the budget share for commodity i at time t; p_{jt} is the price of commodity j at time t; X_t is total household expenditure on the commodities being analyzed; α_i, β_i and γ_{ij} are parameters, and ε_i is a random term of disturbances, and P_t is a price index.

In a nonlinear approximation, the price index P_t is defined as:

$$(2) \qquad \log(P_t) = \alpha_0 + \sum_k \alpha_k \log(p_{kh}) + \frac{1}{2} \sum_k \sum_j \gamma_{kj} \log(p_{kh}) \log(p_{jh}).$$

The demand theory properties of adding-up, homogeneity and symmetry are imposed on the system of equations by restricting parameters in the model as follows:

(3) Adding-up: $\sum_i \alpha_i = 1$, $\sum_j \gamma_{ij} = 0$, and $\sum_i \beta_i = 0$;

(4) Homogeneity: $\sum_i \gamma_{ij} = 0$;

(5) Symmetry: $\gamma_{ij} = \gamma_{ji}$.

The parameter estimates and the mean expenditure shares are used to estimate the Marshallian (uncompensated) and the Hicksian (compensated) price elasticities as well as the expenditure elasticities. Following Green and Alston (1990), the elasticities are estimated as:

(6) Marshallian Price Elasticity: $e_{ij} = \frac{\gamma_{ij}}{w_i} - \frac{\beta_i}{w_i}\left(\alpha_i + \sum_k \gamma_{kj} \log(p_k)\right) - \delta_{ij}$

(7) Hicksian Price Elasticity: $e_{ij}^c = e_{ij} + w_j e_i$

(8) Expenditure Elasticity: $e_i = 1 + \frac{\beta_i}{w_i}$

where δ_{ij} is the Kronecker delta, which is equal to 1 if $i = j$ and equal to 0 if otherwise.

One equation is omitted in the estimation of this system, but the parameters of that equation will be recovered by making use of the theoretical classical properties. Usually the equation excluded is the one holding the smallest budget share.

Data and Procedures

Scanner data allow researchers for quick access to data for many products at both the consumer and retail level. Data on sales in dollars and units, average unit prices, and unit sizes from January 1st through December 28th, 2012 for various types of tomatoes was obtained from The Nielsen Company. The data acquired from The Nielsen Company represents random purchases at the retail level, is reported in four week cycles, and covers the Dallas/Fort Worth grocery market. There were a total of 1,031 tomato purchases in the random sample of groceries collected in 2012.[1]

Table 1 reports the twenty eight types of tomatoes that were reported in the sample. This study groups these twenty eight types of tomatoes in four categories: cherry tomatoes (cherry and cherry mixed tomatoes), grape tomatoes (grape, grape cherry, grape hydroponic, and grape sweet), regular tomatoes, and other types of tomatoes (baby, baby Roma sweet, beefsteak, Campari, Campari sweet hydroponic, cherry, cherry mixed, cocktail, HVSM-GRH, mandarin sweet, medley, mixed, Roma, salad, scarlet pearl grape, sugar plum grape, sweet, sweet greenhouse tricolor, sweetheart, tear drop, tesoro, vine ripe, and yellow sweet). Table 2 reports the quantities sold and average prices for these four categories. According to the sample of random purchases, regular tomatoes at $1.22/lb. sold the most followed by grape tomatoes at $2.09/lb., and cherry tomatoes at $2.86/lb. As reported in Table 2, grapes tomatoes generated the highest revenues ($1.47 million), but they are closely followed by regular tomatoes ($1.44 million).

Results

The full AIDS model was estimated using an iterated seemingly unrelated regression (ITSUR) procedure in SAS version 9.3. The parameters were estimated imposing the theoretical neoclassical restrictions and excluding the other tomato category. Figure 1 depicts the budget shares used in the estimation of the demand system.

[1] One random purchase of Medley tomatoes was eliminated from the analysis given that the unit size was considerable different from the other tomato unit sizes. It was considered an outlier likely resulting from reporting an incorrect unit size.

Table 3 reports the AIDS model parameter estimates. Of the seventeen parameter estimated (α_i, i = 1, …, 4; γ_{1j}, j = 1, …, 4; γ_{2j}, j = 2, …, 4; γ_{3j}, j = 3, 4; γ_{4j}, j = 4; and β_i, i = 1, …, 3), five were significant at 5% probability level, two at the 10% probability level, four were significant at the 20% probability level, and six were not significant. The independent variables in the cherry tomato equation explains 66.50% of the total variation in the cherry tomato budget share, while the independent variables in the grape tomato and the regular tomato equations explain 61.86% and 83.07% of the total variation in their corresponding budget share.

Tables 4 and 5 report the Marshallian (uncompensated) and Hicksian (compensated) price elasticities. All own-price elasticities have the expected negative sign. There were generally more negative price elasticities (10 Marshallians and 10 Hicksians) than positive (6 Marshallians and 6 Hicksians). Negative cross-price elasticities suggest cases of complement types of tomatoes while positives suggest cases of substitute types of tomatoes. For instance, cherry and grape tomatoes as well as grape and regular tomatoes are (gross and net) substitutes (and vice versa) while cherry and regular tomatoes as well as cherry and other types tomatoes are (gross and net) complements (and vice versa). Moreover, the sign of each Marshallian price elasticity (Table 4) is the same as its corresponding Hicksian price elasticity (Table 5).

Disaggregated tomato elasticity estimates are currently not available in the U.S. Consequently, only an indirect comparison with previous aggregated elasticity estimates is possible. When comparing elasticities, it's important to remember that differences in model functional forms, sample sizes, and time period under consideration, among other things, tend to make elasticity estimates different from one study to another.

The magnitude of the own-price elasticity estimate of grape tomatoes was the greatest. However, large own-price elasticity magnitudes are not unusual in demand studies at the disaggregated level (Lopez et al., 2012; Chidmi and Lopez, 2007; Nevo, 2001). It suggests that grape tomato consumers are very responsive to changes in prices of the grape tomatoes.

Table 6 reports the expenditure elasticities. In addition, notice that all expenditure elasticities have the expected positive sign, which means all types of tomatoes considered in the study are "normal" goods. A 1% increase in the consumers' budget for tomatoes increases the consumption of each tomato by the percentages reported in Table 6. In addition, notice that all, but one, expenditure elasticities are less than one. When the expenditure elasticity of a good is greater than one, the good is considered a "luxury"; in the sense that consumers are very responsive to changes in their budget for tomatoes. That is, slight changes in the consumers' budget for tomatoes will result in consumers adjusting their consumption significantly. For example, 1% increase in the consumers' budget for tomatoes is expected to increase grape tomato consumption by 2.44%. Similarly, the closer the expenditure elasticity of a good is to zero, the more the good is considered a "necessity"; in the sense that consumers are irresponsive to changes in their budget for tomatoes. That is, regardless of the consumers' tomato budget increasing or decreasing, the consumers will not adjust much their tomato consumption.

Conclusion

The consumption of tomatoes has been rapidly increasing. In 2000, tomato consumption increased approximately 30% over the previous decade (Lucier et al., 2000). This increasing trend in consumption is partly due to the increasing Hispanic and Asian population in the U.S. (Nzaku and Houston, 2009), the NAFTA's opening of free trade agreements (Grant and Foster, 2005; Huang and Huang, 2007), the growth of the U.S. economy, trends in healthy lifestyles (Beecher, 1998), and the increasing popularity of the positive benefits of eating fresh tomatoes

(Deghan et al., 2011) including helping with immune responses, and decreasing risk of breast and prostate cancer and cardiovascular diseases (Agarwal and Rao, 2000).

In 2008, about 89% of the tomatoes produced were processed and about 11% were sent to the fresh market (USDA-ERS, 2012). With most of the U.S. tomatoes produced being processed, tomato imports for the fresh market are significantly greater than tomato imports for the processed market. Consequently, it is critical and increasingly valuable for fresh-market producers who sell directly to grocery chains, farmers' markets, and food service providers to analyze any emerging consumption trend as well as the substitution patterns among different types of tomatoes and vegetables. The main objective of this study was to estimate the demand elasticities for fresh tomatoes at the retail level to contribute to a better understanding of the market of fresh tomatoes in the Dallas/Fort Worth area. Unlike previous fresh fruit and vegetable studies (Brandow, 1961; George and King, 1971; Brumfield et al., 1993; You et al., 1996; Henneberry et al., 1999; Agarwal and Rao, 2000; Thompson, 2003; Grant and Foster, 2005; Jung et al. 2005; Nzaku and Houston, 2009; Padilla and Acharya, 2009; Deghan et al., 2011; Naanwaab and Yeboah, 2012; Niu and Wohlegenaut, 2012; Seale et al., 2013), this study reports disaggregated tomato elasticity estimates which were not previously available. The analysis identifies tomato types that are highly marketable in the Dallas/Fort Worth metropolitan area and may provide insight on tomato varieties that could be grown locally.

All own-price elasticities obtained the expected negative sign. Negative cross-price elasticities suggest cases of complement types of tomatoes. Cherry and regular tomatoes as well as cherry and other types of tomatoes were found to be (gross and net) complements. Positive cross-price elasticities suggest cases of substitute types of tomatoes. Cherry and grape tomatoes as well as grape and regular tomatoes were found to be (gross and net) substitutes. Excluding own-price elasticities, there are as many negative cross-price elasticities as there are positive cross-price elasticities (6 Marshallians and 6 Hicksians), which suggests that both case of complements and substitutes are likely among types of tomatoes. In addition, the Marshallian price elasticities had the same sign as the corresponding Hicksian price elasticities.

All expenditure elasticities also obtained the expected positive sign, which means all types of tomatoes considered in the study are “normal” goods. All but one expenditure elasticities were less than one. When the expenditure elasticity of a good is greater than one, the good is considered a “luxury; while the closer to zero it is, the more the good is considered a “necessity”. Cherry tomatoes, regular tomatoes and other types of tomatoes were found to have expenditure elasticities lower than one while grape tomatoes were found to have an expenditure elasticity greater than one.

This study used a demand system approach to estimate price and expenditure elasticities for four categories of fresh tomatoes using AC Nielsen Homescan consumption data from the Dallas/Fort Worth grocery market in 2012. Due to financial constraints, only one year of data from AC Nielsen Homescan data was purchased. The study could be easily expanded to include more years, provided additional funds were available. The study could also be expanded to include more vegetables such as carrots, cauliflower, celery, lettuce, onions, radishes, spinach, and other remaining vegetables. The study could also explore including fresh-salad mixes in the analysis. A separate study could also analyze the processed-tomato market. Finally, the study could use the estimated elasticities to generate a sensitivity analysis of likely tomato prices for fresh tomato producers in the Dallas/Fort Worth area and combine it with data from local production practices to conduct a profitability analysis.

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Tables

Table 1. Random Sample of Fresh Tomato Purchases from the Dallas/Fort Worth Grocery Market in 2012.

Tomato Type	Quantity (lbs)	Price ($/lb)	Volume Share
Baby	33,841	3.23	1.2072%
Baby Roma Sweet	1,618	3.24	0.0577%
Beefsteak	4,128	0.21	0.1473%
Campari	26,385	2.13	0.9412%
Campari Sweet Hydroponic	95,215	3.50	3.3964%
Cherry	342,867	2.86	12.2305%
Cherry Mixed	22	1.69	0.0008%
Cocktail	19,894	1.53	0.7096%
Grape	658,628	2.05	23.4940%
Grape Cherry	15	0.61	0.0005%
Grape Hydroponic	42,476	2.65	1.5152%
Grape Sweet	496	2.19	0.0177%
HVSM-GRH	7,107	2.45	0.2535%
Mandarin Sweet	17	0.61	0.0006%
Medley	947	5.56	0.0338%
Mixed	14	1.43	0.0005%
Regular	1,180,285	1.22	42.1021%
Roma	49,890	1.76	1.7796%
Salad	10,419	6.18	0.3717%
Scarlet Pearl Grape	305	0.26	0.0109%
Sugar Plum Grape	1	0.27	0.0000%
Sweet	72,450	1.06	2.5844%
Sweet Greenhouse Tricolor	56	2.46	0.0020%
Sweetheart	33,698	4.89	1.2020%
Tear Drop	378	10.21	0.0135%
Tesoro	22,703	1.14	0.8098%
Vine Ripe	29,189	3.37	1.0412%
Yellow Sweet	170,345	2.44	6.0764%
Total	2,803,388		100.0000%

Table 2. Random Sample of Fresh Tomato Purchases by Category from the Dallas/Fort Worth Grocery Market in 2012.

Tomato Type	Quantity (lbs)	Price ($/lb)	Volume Share
Cherry	342,889	2.8560	12.23%
Grape	701,615	2.0902	25.03%
Regular	1,180,285	1.2163	42.10%
Other	578,598	3.0028	20.64%
Total	2,803,388		100.00%

Table 3. AIDS Model Parameter Estimates.

Coefficient	Cherry Tomatoes Coefficient Estimate	Cherry Tomatoes Approx Std Err	Grape Tomatoes Coefficient Estimate	Grape Tomatoes Approx Std Err	Regular Tomatoes Coefficient Estimate	Regular Tomatoes Approx Std Err	Other Tomatoes Coefficient Estimate	Other Tomatoes Approx Std Err
α_i	2.6965*	1.0460	-5.3738*	1.3426	1.8463‡	0.8165	1.8310	n.a.
γ_{i1}	-0.1710	0.3302	0.8320*	0.3289	-0.2378†	0.1564	-0.4232†	0.2426
γ_{i2}	0.8320*	0.3289	-1.8617‡	0.9093	0.4537	0.3380	0.5760	0.8881
γ_{i3}	-0.2378†	0.1564	0.4537	0.3380	0.0710	0.1489	-0.2868†	0.1836
γ_{i4}	-0.4232†	0.2426	0.5760	0.8881	-0.2868†	0.1836	0.1340	n.a.
β_i	-0.1684*	0.0685	0.3734*	0.0885	-0.0946†	0.0533	-0.1104	n.a.
Goodness of Fit								
	R-Square	Adj. R-Sq	R-Square	Adj. R-Sq	R-Square	Adj. R-Sq	R-Square	Adj. R-Sq
	0.6650	0.5533	0.6186	0.4914	0.8307	0.7742	n.a.	n.a.

Note: Significant at the 0.05, 0.10, and 0.20 probability levels are indicated by asterisks (*), double daggers (‡), and daggers (†) respectively, except for the parameter coefficient estimates whose standard errors are not available (n.a.) because they correspond to the omitted equation in the system.

Table 4. Marshallian Price Elasticities by Types of Tomatoes.

i\j	Cherry	Grape	Regular	Other
Cherry	-1.8822	4.5195	-1.2874	-2.3199
Grape	2.9609	-7.6939	1.5956	2.0407
Regular	-0.8744	1.6642	-0.6813	-1.0845
Other	-1.2791	1.6871	-0.8721	-0.5018

Table 5. Hicksian Price Elasticities by Types of Tomatoes.

i\j	Cherry	Grape	Regular	Other
Cherry	-1.8726	4.5335	-1.2737	-2.3032
Grape	3.3957	-7.0616	2.2154	2.7960
Regular	-0.7627	1.8266	-0.5221	-0.8905
Other	-1.1646	1.8536	-0.7089	-0.3028

Table 6. Expenditure Elasticities by Types of Tomatoes.

i	Expenditure Elasticities (η_i)
cherry	0.0540
grape	2.4421
regular	0.6272
other	0.6432

Figures

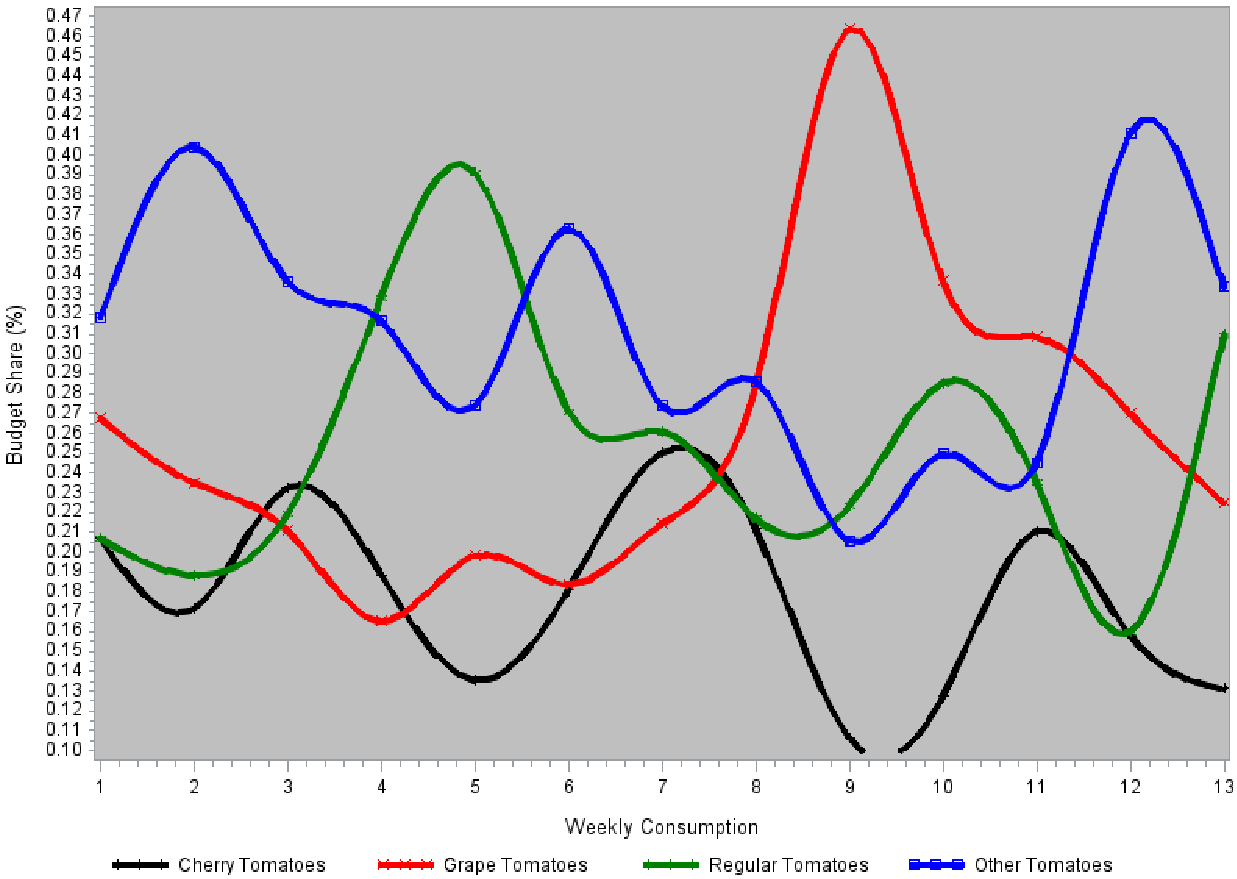

Figure 1. Budget Shares by Type of Tomatoes.