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A Composite Demand Analysis for the Beverage Market

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Introduction

The sales of nonalcoholic beverages in the U.S., including milk, juice, soft drinks, bottled water, energy drinks, coffee, and tea, have increased moderately in the past five years, reaching \$131 billion in 2013, and are expected to continue growing to \$164 billion by 2018 (Mintel, 2014). While the overall beverage market is growing, different types of beverage products have had different growth rates. According to the Beverage Marketing Corporation (2015), bottled water, ready-to-drink coffee/tea, and energy drinks grew rapidly in 2014, while the traditional beverage carbonated soft drinks continued to lose both volume and market share, and fruit beverages lost the most in volume (2.8%) compared to 2013. Given the ongoing changes in the sector, analysis of consumer demand and price competition among beverage products will provide useful information for both private and public sectors associated with this industry.

Scanner data has been considered as a reliable data source for demand analysis, and it reflects consumers' real purchase choices in the markets, thus is able to capture consumers' dynamic behavior by recording their purchases over time. However, using scanner data is not without a cost, and one issue is data aggregation in demand analysis. As disaggregated data used in demand analysis would lead to difficulties such as degrees of freedom and computational limitations, aggregation over food products is important for demand analysis. However, to aggregate groups, appropriate tests are needed to determine if the products should be aggregated. Two most common justifications for aggregation are separable preferences and Hicks-Leontief Composite Commodity Theorem (CCT). Separable preferences restrict the patterns of expenditures and test how consumers allocate their expenditures over groups of products, while CCT restricts price movements and requires relative prices within a group to be constant over time. Previous studies have showed that both conditions tend to be violated in empirical work

(Eales and Unnevehr, 1988; Nayga and Capps, 1994, Reed, Levedahl, and Hallahan, 2005; Schulz, Schroeder, and Xia, 2012). A more recent substitute approach for justifying data aggregation is the Generalized Composite Commodity Theorem (GCCT), proposed by Lewbel (1996), which showed that aggregation can be justified by relaxing the strict conditions of the CCT. The GCCT only requires that relative prices be statistically independent of the group prices, instead of constant over time. This approach has been applied in various studies investigating the valid aggregation of both consumer goods and agricultural supplies (Lewbel, 1996; Davis, Lin, and Shumway, 2000; Reed, Levedahl, and Hallahan, 2005; Schulz, Schroeder, and Xia, 2012). To our knowledge, this study is the first application of GCCT in the beverage market.

Several authors have studied the beverage market using scanner data, and demand and price analysis is always implemented at some level of aggregation (Zheng and Kaiser, 2008; Smith, Lin, and Lee, 2010; Yen et al., 2004), mostly based on traditional groupings or research purposes rather than empirical tests. For example, aggregating 100% fruit juice and fruit drinks into fruit beverages, and aggregating regular and diet carbonated soft drinks into soft drink are commonly used in studies. However, as consumers' lifestyles and perceptions have been dramatically changed, questions can be raised regarding the validation of such traditional aggregations. One factor that drives current beverage sales is health consideration, and consumers' perceptions towards various types of beverages. For example, as consumers are increasingly concerned about overweight and obesity, many consumers are avoiding regular soft drinks to reduce sugar and calorie intake from consuming beverages, while trends in diet soft drinks consumption might be different because of the lack of sugar content, indicating regular and diet soft drinks could be two separate categories. Similarly, although fruit juices are 100%

juice and naturally sweet, fruit drinks contain less than 100% fruit juice and have extra sugar added. Therefore, one interest of this study is to test for valid aggregation based on the GCCT. Moreover, if the aggregation is valid, we further estimate price elasticities of demand and investigate the price competition among these beverage composites.

The objectives of our study are: (1) to apply GCCT to the beverage market data and determine valid aggregation strategies, and (2) to estimate price elasticities of demand for proposed composites in beverage demand. We used nationwide scanner data of beverage sales for April 2013 - April 2015. Fifteen beverage products are used in this study, including ready-to-drink (RTD) coffee, ready-to-drink (RTD) tea, milk, flavored milk, refrigerated orange juice, shelf stable orange juice, refrigerated apple juice, shelf stable apple juice, refrigerated other fruit juice, shelf stable other fruit juice, fruit drinks, regular soft drinks, diet soft drinks, and bottled water. A Rotterdam model is used to estimate price and expenditure elasticities. Our study provides useful and timely information to understand current consumers' demand for various beverage products and the price competition among composites in the market.

Methods and Data

This section describes the empirical procedure as follows. First, 15 beverage products are tested for valid demand composites based on the GCCT. Second, if the aggregation is valid, we conduct demand analysis for composites using a Rotterdam model.

Testing

Following Lewbel (1996) and Reed, Levedahl, and Hallahan (2005), we define p_i is the price of good i and P_I is the Laspeyres price index of group I that contains good i . Let $\gamma_i = \ln(p_i)$ and $R_I = \ln(P_I)$, the i th relative price is can be presented as:

$$\rho_i = \gamma_i - R_I \quad (1)$$

According to Lewbel (1996), a valid aggregation requires that ρ_i is independent of R_I . Therefore, testing whether GCCT holds or not is equivalent to testing whether ρ_i and R_I are independent of each other. Following Lewbel (1996), tests depend on time series properties of the data. The procedure can be described as two steps: (1) determine the stationarity of each ρ_i and R_I using unit root tests; (2) based on the results of step 1, test the independences between ρ_i and R_I . Three possible results can be specified from the first step: if both ρ_i and R_I are stationary, a correlation test will be conducted to test independence; if ρ_i and R_I are both nonstationary, a cointegration test will be conducted to test independence; if ρ_i is stationary and R_I is nonstationary, or R_I is stationary and ρ_i is nonstationary, then no test is required because two series cannot be cointegrated when one is stationary and the other is not.

Rotterdam model

The Rotterdam model is used to estimate the composite demand systems implied by the GCCT tests. The Rotterdam model was introduced by Theil (1965) and has been widely used in demand system estimation using scanner data. The absolute value version of the Rotterdam model is specified as follows:

$$w_{it}\Delta \ln(q_{it}) = \alpha_i + \beta_i\Delta \ln(Q_t) + \sum_{j=1}^n c_{ij} \Delta \ln(p_{jt}) + \sum_{k=1}^3 d_{ik} D_k + v_i, \quad i, j = 1, \dots, n \quad (2)$$

where w_{it} is the budget share of the i th product in time t ; Δ is the first difference operator; q_{it} is consumption of i th product in time t ; $\Delta \ln(Q_t)$ is the Divisia volume index $\Delta \ln(Q_t) = \sum_{j=1}^n w_{jt}\Delta \ln(q_{jt})$; p_{jt} is the price of the j th product in time t ; D_k is a quarterly dummy variable to capture seasonality; v_i is a random error term; and α_i , β_i , c_{ij} , and d_{ik} are coefficients to be

estimated. The intercept α_i is used to capture any structure changes or trends that not captured by other variables (Taylor and Tonsor, 2013)

The adding-up, homogeneity, and symmetry restrictions are imposed to ensure the demand model is consistent with economic theory. The adding-up restrictions are

$$\sum_{i=1}^n \beta_i = 1; \sum_{i=1}^n c_{ij} = 0 \quad (3)$$

The homogeneity and symmetry restrictions are

$$\sum_{j=1}^n c_{ij} = 0; c_{ij} = c_{ji} \quad (4)$$

To avoid singularity of the covariance matrix, the j th equation needs to be dropped, and the coefficients of the dropped equation can be recovered by imposed restrictions. In our estimation, the equation for bottled water was dropped.

The own- and cross-price compensated demand elasticities and the expenditure elasticity can be calculated by:

$$e_{ij} = \frac{c_{ij}}{w_i}; e_i = \frac{\beta_i}{w_i} \quad (5)$$

A delta method is used to estimate the variance of each elasticity, and t-values are computed to test for statistical significance.

Data

The nationwide aggregated weekly sales on beverage products from April 2013 through April 2015 were provided by ACNielsen. For each product, ACNielsen recorded information on dollar sales, unit, and equivalent unit from stores earning \$2 million or more in annual sales and

Walmart. To be able to compare products of different package sizes, we use equivalent unit. The unit price is computed by dividing the dollar sales by the equivalent unit. For simplification purposes, beverages were aggregated into 15 categories: RTD coffee, RTD tea, milk, flavored milk, refrigerated fruit drinks, shelf-stable fruit drinks, refrigerated apple juice, shelf-stable apple juice, refrigerated orange juice, shelf-stable orange juice, refrigerated other juice, shelf-stable other juice, regular soft drinks, diet soft drinks, and bottled water.

Percentage shares of quantity and sales for each product are calculated and reported in Table 1. In this dataset, the sales of milk accounts for the largest share of sales dollar with nearly 24%, followed by regular soft drinks with about 23% share of sales. Diet soft drinks and bottled water have share of sales of 12.3% and 11.6%, respectively. Refrigerated apple juice and shelf stable orange juice have the lowest percentage shares of sales dollar with less than 1% (0.08% and 0.19%).

Results

The tested GCCT results for the valid aggregation are summarized in Table 2 and Table 3. The stochastic nature of the GCCT may support numerous aggregation schemes (Reed, Levedahl, and Hallahan, 2005), and we have tested several conventional groupings that were not supported. For example, tests results do not support aggregation of regular soft drinks with diet soft drinks, refrigerated fruit drink with fruit juice, and shelf-stable fruit drink with fruit juice, as well as refrigerated fruit juice and shelf-stable juice. Such results indicate that aggregations need to be tested to obtain reliable information from demand system. We propose to aggregate the 15 beverage products into eight composites. The coffee and tea composite includes RTD coffee and RTD tea; the dairy composite includes milk and flavored milk; the fruit drinks composite includes refrigerated fruit drinks and shelf stable fruit drinks; the refrigerated juice composite

includes refrigerated apple juice, refrigerated orange juice, and refrigerated other juice; the shelf stable juice composite includes shelf stable apple juice, shelf stable orange juice, and shelf stable other juice; regular soft drinks, diet soft drinks, and bottled water are treated as valid composites.

Table 2 reports the unit root tests on 12 relative prices and 8 composite prices. Following Reed, Levedahl, and Hallahan (2005) and Schulz, Schroeder, and Xia (2012), both the Augmented Dickey-Fuller (ADF; Dickey and Fuller, 1979) test and Kwiatkowski, Phillips, Schmidt, and Shin (KPSS; Kwiatkowski et al., 1992) test were conducted for relative prices and composite group price indices. The ADF test is with a null hypothesis of nonstationarity, while the KPSS test is with a null hypothesis of stationarity. When results from two tests are conflicted, inferences based on the joint confirmation hypothesis (JCH) of a unit root were used (Carrion-i-Silvestre et al., 2001). Results show that the composite price index for coffee and tea, dairy, refrigerated juice, shelf stable juice, and bottled water follow unit root, while the composite price index for fruit drink, soft drinks, and diet soft drinks are stationary. Relative prices of both products within the dairy composite (milk and flavored milk), both products within the fruit drink composite (refrigerated and shelf stable fruit drink), and all products within the refrigerated juice composite (refrigerated apple juice, orange juice, and other juice) are nonstationary, while relative prices of coffee and tea, and products within the shelf stable juice composite, including shelf stable apple juice, orange juice, and other juice, are considered to be stationary. The Engle-Granger tests were used to test for cointegration when both the composite price index (R_t) and relative price (p_i) are nonstationary, and the results are summarized in Table 3. As the tests failed to reject the null of a spurious regression for individual comparisons, the series are independent of each other, indicating the GCCT holds and the proposed aggregation is valid.

The price and expenditure elasticities were estimated with the Rotterdam model using SAS 9.4 software, and estimated results are presented in Table 4. The own-price elasticities are all negative and statistically significant at the 5% level. Estimated price elasticities range from -0.643 to -2.068. The dairy composite is the least price elastic, while the diet soft drink is the most price sensitive. While using different products and time spans could affect estimated elasticities, our estimation is comparable with previous studies. For example, Andreyeva, Long, and Brownell (2010) reviewed previously estimated price elasticity of demand for major food categories, and they reported the value of price elasticity for soft drinks ranged between 0.13 and 3.18, juice price elasticity ranged between 0.33 and 1.77, and milk price elasticity ranged between 0.02 and 1.68.

Estimated cross-price elasticities provide the demand relationship among composites. The composite for coffee and tea is a substitute for regular soft drinks and diet soft drinks. This could be because these products are caffeinated drinks. The composite for dairy is a substitute for diet soft drinks and bottle water. The composite for refrigerated juice is a substitute for shelf stable juice, diet soft drinks, and water while the composite for shelf stable juice is a substitute for refrigerated juice, regular soft drinks and diet soft drinks. Such results might indicate that consumers perceive dairy, refrigerated juice, diet soft drinks, and water as healthier beverage products, while shelf stable juice might not be considered as healthy as water and can substitute with regular soft drinks, although the magnitude is small. Also, more consumers would switch to refrigerated juice when price of shelf stable juice increases than those who would switch to shelf stable juice when refrigerated juice price increases, which could also indicate that consumers perceive refrigerated juice as higher quality than shelf stable juice. The fruit drinks composite is a substitute for regular soft drinks and diet soft drinks. The substitution effect between fruit

drinks and regular soft drinks are much bigger than other pairs, which implies that when regular soft drinks become more expensive, a large portion of consumers would substitute with fruit drinks, which is also a sugary beverage. Meanwhile, fruit drinks is not a statistically significant substitute for juice products, which could be because that consumers do not consider fruit drinks as a healthy beverage as fruit juice. Regular soft drinks is a substitute for coffee and tea, shelf stable juice, fruit drinks, and water. Diet soft drinks could substitute with all beverage composites except regular soft drinks, indicating consumers who purchase regular soft drinks and those purchase diet soft drinks are two different consumer segments. Bottled water can substitute with dairy, refrigerated juice, regular soft drinks, and diet soft drinks. This might be because these beverages are water-based and good for hydration.

All expenditure elasticities are statistically significant and ranged from 0.487 for dairy to 1.904 for soft drinks. Soft drinks has the largest expenditure share, perhaps indicating that a large share of the recorded purchases in our data are represented by low-income consumers. Yen et al. (2004) also found an expenditure elasticity of soft drinks greater than one in their samples.

Conclusion

As consumers' lifestyles and health perceptions have dramatically changed in recent years, the nonalcoholic beverages market of the U.S. is also undergoing changes. Given these changes, our analysis of consumer demand and price competition among beverage products with recent data can provide information for both private and public sectors associated with this industry.

We apply the GCCT to nationwide scanner data to test for valid commodity aggregation in order to obtain reliable information from price and demand analysis. The empirical results show that some conventional aggregations are not supported by the GCCT, such as aggregation

of fruit drinks and juice, and aggregation of regular and diet soft drinks. This confirms that aggregations need to be justified before implementation. Our results support aggregation of coffee and tea, milk products, refrigerated juice, shelf stable juice, fruit drinks, regular soft drinks, diet soft drinks, and bottled water.

A Rotterdam model was used to estimate composite demand elasticities based on the results of the GCCT. Results indicate that consumers substitute coffee and tea with regular and diet soft drinks. This could be explained if consumers are seeking a beverage with caffeine content. Dairy and refrigerated juice can be substituted with diet soft drinks and water, which might indicate that consumers perceive these products as a group of healthier beverages that are substitutable. Fruit drinks is a closer substitute with regular soft drinks, indicating a large proportion of consumers would switch to another sugary beverage even regular soft drinks become more expensive. Our results also show that consumers for regular soft drinks and diet soft drinks are two separate groups, though they have often been aggregated in the past.

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Table 1. Average Percentage Share of Quantity and Sales

Product	Quantity (%)	Sales (%)
Ready-to-Drink coffee	0.331	1.130
Ready-to-Drink tea	5.365	4.425
Milk	27.779	23.834
Flavored milk	1.036	1.240
Refrigerated fruit drink	2.304	2.266
Shelf stable fruit drink	11.197	9.158
Refrigerated apple juice	0.045	0.085
Shelf stable apple juice	1.329	1.367
Refrigerated orange juice	3.949	5.440
Shelf stable orange juice	0.182	0.194
Refrigerated other juice	0.721	1.731
Shelf stable other juice	1.380	2.346
Regular soft drinks	4.382	22.911
Diet soft drinks	0.893	12.246
Bottled water	39.107	11.626

Table 2. Unit Root Test Results

	ADF Test H0:I(1) ^a	KPSS Test H0:I(0) ^b	I(1) or I(0) ^c
R (coffee and tea)	-2.471 (3)	0.109 (4)	I(1) (JCH)
ρ (coffee)	-3.619 (2)*	0.091 (4)	I(0)
ρ (tea)	-3.647 (2)*	0.091 (4)	I(0)
R (dairy)	1.039 (1)	0.413 (4)*	I(1)
ρ (milk)	-2.733 (4)	0.292 (4)*	I(1)
ρ (flavored milk)	-2.765 (4)	0.290 (4)*	I(1)
R (fruit drink)	-3.695 (2)*	0.130 (4)	I(0)
ρ (refrigerated fruit drink)	-3.411 (9)*	0.200 (4)*	I(1) (JCH)
ρ (shelf stable fruit drink)	-3.262 (9)*	0.193 (4)*	I(1) (JCH)
R (refrigerated juice)	-3.250 (1)*	0.277 (4)*	I(1) (JCH)
ρ (refrigerated apple juice)	-1.733 (3)	0.196 (4)*	I(1)
ρ (refrigerated orange juice)	-1.300 (3)	0.201 (4)*	I(1)
ρ (refrigerated other juice)	-1.041 (3)	0.216 (4)*	I(1)
R (shelf stable juice)	1.133 (1)	0.396 (4)*	I(1)
ρ (shelf stable apple juice)	-4.740 (1)*	0.047 (4)	I(0)
ρ (shelf stable orange juice)	-3.201 (3)*	0.108 (4)	I(0)
ρ (shelf stable other juice)	-5.872 (1)*	0.035 (4)	I(0)
R (soft drinks)	-3.500 (4)*	0.072 (4)	I(0)
R (diet soft drinks)	-4.121 (5)*	0.056 (4)	I(0)
R (water)	-3.226 (1)*	0.190 (4)*	I(1) (JCH)
10% critical values	-3.13	0.119	(-3.479, 0.082)

Note: * denotes rejection of the null at 10% significant level

^aThe test statistics of the null hypothesis of I(1) are the ADF t-statistics of the lagged level variable in the regression of the first-differences on a constant, a time trend, the lagged level and lagged-differences of variables appended to the regression. The number of lags of first differences is reported in parentheses and determined by R statistical software.

^bThe test statistics of the null hypothesis of I(0) are the KPSS t-statistics. The t-statistics are the sum of the squared partial sums of residuals divided by an error variance estimator. The residuals are computed from a model in which the series is regressed on a constant and a time trend. For the correction of the error term a Bartlett window with four lags was used to ensure the variance matrix was well behaved.

^cInferences based on the joint confirmation hypothesis (JCH) of a unit root are used when the ADF and KPSS tests conflict. The joint critical values of (-3.479, 0.082) represent the mid-point of critical values for 100 and 150 observations for the ADF and KPSS tests with trend. They are interpreted as follows. If the value of DF statistic is less (greater) than -3.479 and the value of the KPSS statistic is less (greater) than 0.114 then the series is considered (at the 10% level) stationary (nonstationary). Otherwise, the series cannot be confirmed to be a unit root and is therefore considered stationary.

Table 3. Generalized Composite Commodity Test Results

	Test	Results (T_k) ^a	MacKinnon p-value ^b	GCCT
R (coffee and tea)				
ρ (coffee)	Not necessary			yes
ρ (tea)	Not necessary			yes
R (dairy)				
ρ (milk)	Cointegration	-0.296	0.923	yes
ρ (flavored milk)	Cointegration	-0.332	0.918	yes
R (fruit drink)				
ρ (refrigerated fruit drink)	Not necessary			yes
ρ (shelf stable fruit drink)	Not necessary			yes
R (refrigerated juice)				
ρ (refrigerated apple juice)	Cointegration	-1.779	0.391	yes
ρ (refrigerated orange juice)	Cointegration	-1.557	0.504	yes
ρ (refrigerated other juice)	Cointegration	-1.329	0.619	yes
R (shelf stable juice)				
ρ (shelf stable apple juice)	Not necessary			yes
ρ (shelf stable orange juice)	Not necessary			yes
ρ (shelf stable other juice)	Not necessary			yes

^aThe test statistics are the Engel-Granger tests of the null hypothesis that the k th relative price and the vector of composite group prices are not cointegrated. The entries are ADF tests of $I(1)$ residuals formed from regressing the k th relative price on each of the integrated group price indices.

^bThe p-values are based on MacKinnon's t-statistics (with a constant in the cointegrating vector) and 104 observations (MacKinnon, 1996).

Table 4. Estimated Composite Compensated Price and Expenditure Elasticities

Elasticity of the quantity of	with respect to the price of								with respect to expenditure
	Coffee & Tea	Dairy	Refrig. juice	Shelf stable juice	Fruit drink	Soft drinks	Diet soft drinks	Water	
Coffee & Tea	-1.317 *	-0.008	-0.097	0.066	0.139	0.633 *	0.450 *	0.133	0.887 *
Dairy	-0.002	-0.643 *	0.058	0.024	-0.075	0.185	0.214 *	0.239 *	0.487 *
Refrigerated juice	-0.074	0.202	-1.756 *	0.220 *	0.130	0.246	0.683 *	0.350 *	0.873 *
Shelf stable juice	0.094	0.151	0.408 *	-1.700 *	0.095	0.278 *	0.438 *	0.235	0.959 *
Fruit drink	0.068	-0.165	0.082	0.032	-2.005 *	1.183 *	0.667 *	0.138	0.911 *
Soft drinks	0.154 *	0.203	0.078	0.047 *	0.590 *	-1.324 *	0.013	0.240 *	1.904 *
Diet soft drinks	0.204 *	0.438 *	0.405 *	0.140 *	0.622 *	0.024	-2.068 *	0.236 *	0.926 *
Water	0.064	0.516 *	0.219 *	0.079	0.135	0.474 *	0.248 *	-1.930 *	0.637 *

Note: * denotes statistically significance at 5% level.