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I. INTRODUCTION

Although obesity is already the leading public health crisis in the U.S., with an estimated social cost of approximately $120 billion a year and growing (Rowley, 2004), obesity incidence continues to increase at an alarming rate (Kuhn, 2002). The main culprits are the increase in the consumption of high-calorie foods and beverages and a decrease in exercise (Kuhn, 2002; Allhouse, Frazao, and Tupening, 2002). Paralleling the increase in obesity is the increase in consumption of carbonated soft drinks (Center for Science in the Public Interest, 2005; DiMeglio and Mattes, 2000).

Carbonated soft drinks (CSDs) are a very large part of the American diet. These well-liked drinks account for approximately 30% of all beverages (alcoholic and non-alcoholic) consumed in the U.S. (U.S. Department of Agriculture, 2008). In 2000, Americans spent $61 billion on CSDs (National Soft Drink Association, 2003) and CSDs are among the best-selling products in American grocery stores (Center for Science in the Public Interest, 2005). Also in 2000, more than 15 billion gallons were sold in the United States, which equals every American consuming at least one 12-ounce can per day or an average of 53 gallons per year (Squires, 2001). This article examines consumer CSD choices and their implications for obesity policy. Specifically, it assesses the importance of product and consumer heterogeneity on consumer choices using a random coefficients logit model (Berry, Levinsohn, and Pakes, 1995; hereafter BLP) and a national dataset that includes product and consumer characteristics. The estimated choice parameters are then linked to consumer body mass indexes (BMI) using a second-stage regression, and the effectiveness of tax policies assessed through counterfactual experiments.

II. THE MODEL

Following the BLP model, the consumer, in choosing one unit of a CSD brand among competing products, maximizes utility, driven by the brand characteristics as well as his/her own characteristics. The indirect utility of consumer *i* from buying a unit of brand *j* is:

(1) $$U_{ij} = \underbrace{\beta x_j + \alpha p_j}_{\delta_j} + \underbrace{\phi D_i x_j + \lambda D_i p_j + \sigma_i x_j + \gamma v_i p_j + \varepsilon_{ij}}_{\mu_{ij}},$$

which can be expressed in two components: (1) the mean utility term δ_j, determined solely by brand characteristics, and (2) the deviation from the mean, μ_{ij}, capturing the interactions between consumer and brand characteristics.

In equation (1), x_j is a vector of observed product characteristics of brand *j*; p_j is the price of brand *j*; D_i represents observed consumer characteristics (such as demographics) with a probability density function *h(D)*; v_i represents unobserved consumer characteristics with a probability density function *g(v)*, which is assumed to be normally distributed *N(0,I)*; α, β, δ, and σ are fixed parameters; and ε_{ij} is an error term, which has a probability density function $f(\varepsilon)$. Note that in this framework individual taste parameters with respect to price and brand characteristics are given by $\alpha_i = \alpha + \lambda D_i + \gamma v_i$ and $\beta_i = \beta + \phi D_i + \sigma v_i$, respectively.

In order to define the market and market shares, an outside good is introduced. Let k=0 denote the outside good, which gives the consumer the option not to buy any of the *J* brands included in the choice set as well as excluded CSD brands and substitute beverages. The utility of the outside good is normalized to be constant over time and to equal zero. In this model, consumers choose one unit of a brand in the choice set that is assumed to yield the highest utility or the outside good. Aggregating over consumers, the market share for the j^{th} brand equals the probability that the j^{th} brand is chosen, given by:

$$(2) \qquad s_j(p, x, \theta) = \int I\{(D_i, v_i, \varepsilon_{ij}) : U_{ij} \geq U_{ik} \, \forall \, k = 0,..N\} dH(D) dG(v) dF(\varepsilon),$$

where *H(D), G(v)* and $F(\varepsilon)$ are cumulative density functions for the indicated variables, assumed to be independent of each other, and $\theta = (\alpha, \beta, \lambda, \phi, \gamma, \sigma)$ is a vector of parameters.

The price elasticities of the market shares for individual brands are:

$$(3) \qquad \eta_{ijk} = (\partial s_j / \partial p_k)(p_k / s_j) = \begin{Bmatrix} p_j / s_j \int \alpha_i s_{ij} (1 - s_{ij}) dH(D) dG(v), \; for \; j = k \\ - p_k / s_j \int \alpha_i s_{ij} s_{ik} dH(D) dG(v), \; otherwise \end{Bmatrix},$$

where each consumer has a different price elasticity for each individual brand.

In order to analyze the CSD–obesity link, individual consumers' BMIs are linked to their estimated taste parameters of CSDs.[1] Following Rashad (2004), BMI is a function of caloric intake, exercise, smoking, and socio-demographic variables. Given the interest in policy, the taste parameters for calories and price from the BLP model are included as explanatory variables in the BMI model. A counterfactual experiment of the impact of *ad valorem* taxes for caloric CSDs on BMI was conducted.

III. DATA AND ESTIMATION

To estimate the BLP model, we used sales data on 26 brands of CSDs in 20 cities across the U.S., over 20 quarters (1988 to 1992).[2] Therefore the study consists of 10,400 total product brand observations (26 brands x 20 cities x 20 quarters).

The sales data, from the Information Resources, Inc. (IRI) Infoscan database provided by the Food Marketing Policy Center at the University of Connecticut, consist of dollar sales, volume sold (in 288 ounces/case units), and the percent volume sold with any display promotion. The retail prices (p_j) were computed by dividing the dollar sales of each brand by the number of 12-ounce servings sold. The market size was assumed to be the per capita per day consumption of all CSDs, water, and fruit juices. Other definitions of market size (e.g., including fluid milk) neither significantly altered nor improved the results. Market shares were computed by dividing the number of servings sold by the market size. The outside good market share was defined as the residual between one and the sum of the observed market shares for the J brands in the choice set. The nutritional brand characteristics (x_j) were collected by examining the labels on each CSD brand, for caffeine, calorie, and sodium content per 12-ounce serving.

The observable consumer characteristics, D, consisted of age, income, and a male dummy. They were obtained by 100 random draws per market from the Behavioral Risk Surveillance System (BRFSS).[3] For estimation purposes, a market was defined as each city and quarter combination, resulting in 400 markets (20 cities x 20 quarters). Another 100 random draws per market were obtained from a normal distribution with zero mean and unitary variance. Thus, this sample includes 40,000 consumer observations. All interactions of price and brand nutritional characteristics were considered in the model.

Instrumental variables were used to control for potential endogeneity of prices due to their correlation with brand characteristics. Different sets of instrumental variables (176 in total) were interacted with error terms in the last part of the BLP estimation procedure. The first set of instruments involved 130 interactions between brand dummy variables and input prices, as in Villas-Boas (2007). Input prices included electricity prices (U.S. Department of Energy), wages for the different cities (U.S. Department of Labor), the cost of sugar, (USDA Producer Price Index for Corn Sweeteners and Sugar), the cost of materials (Manufacturing Industry Database), and the Federal Funds Effective rate (Federal Reserve Board). The next set of instrumental variables used the housing price index (National City Corporation) for each city interacted with brand dummy variables. The last set of instruments consisted of 20 city dummy variables (one for each city in the sample) to capture the differences with regard to pricing of the CSD brands among the 20 cities. Finally, this paper follows Berry (1994), relying on formation of a Generalized Method of Moments estimator for estimating a proxy of the integral in equation (2).

To investigate the determinants of consumers' BMIs, data from the BRFSS was used (as in the BLP model). In addition to the demographic variables used in the BLP model (age, income, and gender), marital status, education level, exercise behavior, and smoking behavior were included, with the same 100 random draws per market, or 40,000 observations. The BLP model was estimated using Matlab, the BMI regression was estimated using Shazam, and the tax simulations were done using Excel. The econometric and policy simulation results are presented in the following section.

IV. EMPIRICAL RESULTS

Table 1 presents the estimated taste parameters of the demand for CSDs. The parameter estimates of the mean utility for price, promotion, calories and sodium are all statistically significant at the 5% level. The negative result for price indicates that for the average consumer CSD price creates negative marginal utility, as one would expect. Promotional effects and calorie content are shown to increase mean utility, while the caffeine and sodium content are shown to decrease it. However, the taste parameters and price sensitivity differ with consumer heterogeneity (age, income, gender, and the unobserved characteristics), resulting in a distribution of the parameters rather than just a single point estimate.

As the results in Table 1 show, older consumers, males, and consumers with higher income levels tend to be less price sensitive. The negative response to price becomes more pronounced as income and age decrease, and is so for female consumers. In other words, the average consumer's valuation for calorie and caffeine content is shown to decrease with age and income (although increased for male consumers) indicating that predominantly younger and lower income consumers choose CSDs with more calories and caffeine. Nearly 55% of consumers respond positively toward calorie content. It is clear in Table 1, however, that lower income consumers have a greater tendency toward a positive taste for calorie and caffeine content than higher income consumers, as do younger age groups and males. Flavor seems to dominate nutritional concerns for lower income consumers, younger consumers, and males. Not surprisingly, the results for sodium follow a similar pattern.

Since a large number of cross-price elasticities were computed, Table 2 presents only a sample of cross-price elasticities, averaged over the 20 cities in the sample. The cross-price elasticities are all positive, as expected, implying that the brands are substitutes. Note that the cross-price elasticities are quite low when compared to the own-price elasticities. This confirms that although consumers are sensitive to CSD prices with respect to their chosen brands, they have brand loyalty and will substitute to the outside good rather than choosing another brand of CSD.

Table 3 displays the BMI regression results. All of the estimated coefficients are significantly different from zero at the 1% level. The results confirm that there is a positive association between a consumer's valuation of calories and BMI: consumers with a preference for calorie-containing CSDs are more likely to have a higher BMI. As this type of preference is the cumulative effect of habit formation, likely due to advertising, nutrition education, and childhood habits, this opens up the possibility of addressing obesity through efforts to modify consumer valuation of calories, especially among the most critical groups, the obese and low income consumers.

Given the estimated price elasticities and the partial tax transmission rate, the effect of a 10% *ad valorem* calorie tax on CSDs was estimated at the product brand level.[4] The results are presented in Table 4. Such a tax would have the effect of reducing the quantity of caloric CSDs consumed and increase the consumption of non-caloric (diet) CSD. However, the substitution is imperfect and consumers would also switch to the outside good (water, fruit juices and residual CSDs). Assuming brand loyalty and that consumers reduce their consumption of caloric CSDs to switch to non-caloric soft drinks, the reductions in caloric CSDs would translate to less than a pound of weight loss for the average consumer, or approximately one tenth of their BMIs. This is an upper bound as consumers could also switch to caloric alternatives that are not taxed (e.g., fruit juices), especially among those who are price sensitive such as low income consumers.

The results for the impact of a 10% *ad valorem* tax on changes in BMIs or obesity rates indicate that such a tax would have a very weak effect on reversing the obesity epidemic, just as Kuchler, Tegene and Harris (2005) found. In addition, such a tax, like other nutrition regulation policies, is likely to face stiff political opposition from a well-organized industry lobby (Nestle, 2002). Finally, a 10% tax is greater than most state sales tax rates, which may be interpreted as excessive, given the ongoing food price inflation. In addition, given the choices of low-income consumers, this tax w ould be regressive with respect to income, since low-income consumers spend a larger portion of their income on food. Therefore, any policy that increases the price of food will have the greatest impact on lower-income consumers.

V. CONCLUDING REMARKS

This article examined consumer choices of CSDs using a random coefficients logit demand model (Berry, Levinsohn, and Pakes, 1995) and scanner data and then linked the estimated taste parameters to consumer body mass indexes (BMI) to examine potential policies to address the obesity epidemic.

Empirical demand results indicate that consumer choices of CSDs are driven by both product and consumer characteristics. More specifically, lower income and younger consumers as well as male consumers tend to have a more positive valuation of calories, suggesting that they are less concerned about obesity consequences. Furthermore, higher income and older consumers as well as male consumers are less sensitive to price changes, suggesting they care less about higher prices. The BMI regression results indicate that the likelihood of obesity increases when consumers have a positive valuation of calories and when they are less responsive to price changes. They also indicated that those who exercise, are better educated and smoke are less likely to be obese. Counterfactual experiments show that an *ad valorem* tax on caloric CSDs would be effective in decreasing consumption of CSDs but would have a hardly discernable effect on the incidence of obesity.

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FOOTNOTES

[1]The National Institute of Health adopted BMI as the common public health measure (U.S. Department of Health and Human Services, 2001).The Body Mass Index is the most convenient measure available in assessing overweightness and obesity, taking into account a person's weight and height to gauge total body fat. A BMI under 18.5 is considered underweight, a BMI of 18.5 to 24.9 is considered a healthy weight, a BMI of 25 to 29.9 is considered overweight, and a BMI of 30 and higher is considered obese.

[2] The city market areas are: Atlanta, Baltimore, Chicago, Cincinnati, Hartford, Houston, Indianapolis, Kansas City, Los Angeles, Louisville, Miami, Milwaukee, Minneapolis, Nashville, New York, Omaha, Phoenix, Raleigh, Salt Lake City, and Seattle.

[3]The Behavioral Risk Factor Surveillance System is a yearly telephone health survey consisting of more than 350,000 observations per year. The survey is conducted by each of the 50 state health departments with support from the Centers for Disease Control and Prevention. The BRFSS survey has been successfully used in economic analysis of obesity (Burke and Heiland, 2007; Chou, Grossman and Saffer, 2004).

[4]Simulated calorie tax reductions are based on per capita annual CSD consumption in ounces and calories (U.S. Department of Agriculture, 2007) using 3,500 calories per pound of body weight (American Diabetic Association, 2003).

TABLE 1
Estimates of the BLP Discrete Choice Model

Variable	**Mean Utility**	**Deviations:** Age	Income	Male	Unobservables
Constant	-1.393 (2.911)	-1.667 (6.034)	-1.400 (2.720)	1.469 (4.414)	2.043** (0.442)
Price	-6.096** (1.144)	2.576 (2.30)	3.705** (1.087)	1.395 (1.661)	2.228** (0.139)
Promotion	0.399** (0.020)				
Calories	0.123** (0.058)	-1.407 (1.447)	-1.506* (0.6228)	0.940** (0.353)	-0.964** (0.246)
Caffeine	-0.707 (3.979)	-1.808 (2.888)	-1.129 (1.968)	1.725 (4.130)	-1.261 (1.057)
Sodium	-0.143** (0.571)	1.696 (4.023)	-2.484** (1.232)	1.654* (0.985)	-0.906 (1.053)

Note: Standard errors are given in parenthesis
**significant at the 5% level
* significant at the 10% level

TABLE 2

TABLE 2

Sample of Average Own-and Cross-Price Elasticities

Brands	**7 Up**	**A&W**	**Canada Dry**	**Cherry 7-Up**	**Cherry Coke**	**Coke**	**Coke Classic**	**Diet 7-Up**	**Diet Cherry 7-Up**	**Diet Coke**	**Diet Dr. Pepper**	**Diet Pepsi**
7 Up	-6.328	0.155	0.166	0.112	0.117	0.342	0.206	0.054	0.148	0.085	0.156	0.091
A&W	0.135	-6.945	0.182	0.129	0.145	0.395	0.236	0.043	0.128	0.073	0.124	0.076
Canada Dry	0.112	0.146	-5.963	0.107	0.113	0.333	0.187	0.056	0.156	0.087	0.145	0.098
Cherry 7-Up	0.113	0.153	0.167	-6.279	0.123	0.343	0.196	0.054	0.146	0.080	0.134	0.096
Cherry Coke	0.115	0.163	0.160	0.120	-7.184	0.442	0.260	0.039	0.113	0.087	0.142	0.096
Coke	0.112	0.162	0.156	0.110	0.156	-6.845	0.255	0.035	0.118	0.091	0.152	0.095
Coke Classic	0.110	0.164	0.156	0.103	0.155	0.440	-7.070	0.044	0.129	0.094	0.165	0.101
Diet 7-Up	0.046	0.046	0.081	0.050	0.038	0.121	0.070	-3.607	0.246	0.114	0.201	0.143
Diet Cherry 7-Up	0.044	0.044	0.077	0.049	0.034	0.124	0.065	0.097	-3.530	0.115	0.219	0.144
Diet Coke	0.051	0.056	0.082	0.047	0.054	0.163	0.096	0.087	0.210	-3.996	0.251	0.164
Diet Dr. Pepper	0.051	0.056	0.084	0.051	0.055	0.180	0.103	0.093	0.212	0.157	-4.121	0.166
Diet Pepsi	0.045	0.048	0.079	0.043	0.049	0.152	0.087	0.085	0.213	0.140	0.237	-3.787

Note: These are the average of the elasticities over 20 cities and 20 quarters.

TABLE 3
BMI Regression Results

Independent Variable	**Parameter**	**Dependent Variable**	
		BMI	**Obesity (0,1)**
Taste for Calories	ω_1	0.746*** (0.333)	0.042* (0.024)
Taste for Price	ω_2	0.148*** (0.008)	0.012** (0.006)
Exercise	ω_3	-0.700*** (0.048)	-0.488*** (0.033)
Married	ω_5	0.572*** (0.045)	0.071** (0.032)
Education Level	ω_6	-0.076*** (0.054)	-0.502*** (0.043)
Smoking Behavior	ω_7	-0.715*** (0.044)	-0.427*** (0.037)
Intercept	ω_0	27.222*** (0.807)	-1.460*** (0.056)
Taste-Embodied Effects			
Age	$\omega_1\phi_1^c \overline{D_1} + \omega_2\lambda_1\overline{D_1}$	15.626*** (1.147)	0.030** (0.014)
Income	$\omega_1\phi_2^c \overline{D_2} + \omega_2\lambda_2\overline{D_2}$	-1.411*** (0.047)	-1.463*** (0.038)
Male	$\omega_1\phi_3^c + \omega_2\lambda_3$	0.907*** (0.036)	0.055** (0.025)
Unobserved Consumer Characteristics	$\omega_1\sigma^c\bar{v} + \omega_2\gamma\bar{v}$	-0.961*** (0.032)	-0.964*** (0.233)
City fixed effects		Yes	Yes
Sample Size		40,000	40,000

Note: Standard errors are given in parenthesis
*significant at the 10% level
**significant at the 5% level
***significant at the 1% level

TABLE 4
CSD Changes from a 10% Ad Valorem Calorie Tax

Brand	**Percentage Change in Quantity**	**Change in Ounces Consumed (per capita yearly)**	**Change in Calories Consumed (per capita yearly)**	**Change in Body Weight (pounds) (per capita yearly)**	**Change in average consumer BMI**
7-Up	-4.341	-260.03	-2502.91	-0.72	-0.113
A&W	-3.688	-220.92	-2126.49	-0.61	-0.095
Canada Dry	-4.622	-276.85	-2664.85	-0.76	-0.119
Cherry 7-Up	-4.325	-259.07	-2493.66	-0.71	-0.111
Cherry Coke	-3.476	-208.25	-2004.56	-0.57	-0.089
Coke	-3.878	-232.28	-2235.86	-0.64	-0.100
Coke-Classic	-3.699	-221.58	-2132.88	-0.61	-0.095
Dr. Pepper	-3.318	-198.74	-1912.96	-0.55	-0.103
Minute Maid	-3.995	-239.30	-2303.39	-0.66	-0.081
Mountain Dew	-3.137	-187.94	-1809.01	-0.52	-0.095
Pepsi	-3.692	-221.19	-2129.09	-0.61	-0.111
Pepsi Free	-4.326	-259.17	-2494.70	-0.71	-0.097
R C	-3.739	-224.00	-2156.13	-0.62	-0.122
Schweppes	-4.712	-282.25	-2716.79	-0.78	-0.081
Slice	-3.185	-190.80	-1836.53	-0.52	-0.103
Sprite	-4.020	-240.84	-2318.22	-0.66	-0.069
Sunkist	-2.667	-159.74	-1537.62	-0.44	-0.103
Diet 7-Up	1.545	92.55	0	0	0
Diet Cherry 7-Up	1.521	91.10	0	0	0
Diet Coke	1.973	118.20	0	0	0
Diet Dr. Pepper	2.127	127.43	0	0	0
Diet Pepsi	1.783	106.82	0	0	0
Diet Pepsi Free	1.470	88.08	0	0	0
Diet Rite	1.067	63.91	0	0	0
Diet Slice	6.133	367.38	0	0	0
Diet Sprite	5.005	299.85	0	0	0

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