Evaluating The Impact of Nutritional Label Serving Size Change

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Abstract

This study examines how the change in serving sizes in Nutrition Facts Panel (NFP) affects consumer choices by developing and estimating an equilibrium model of both consumer demand and firms' pricing and nutritional choices decisions, using CSD as a case study. Our study found that larger serving sizes and corresponding nutritional changes negatively impacted consumer demand. Counterfactual simulations explored the effects of different serving size regulations, showing a preference shift towards smaller bottle sizes, and potentially healthier alternatives, and industry adaptations through unnoticed product reformulations. These findings suggest that strategic serving size adjustments policies and product reformulations from food manufacturers may support healthier consumer choices.

*Researcher(s)' own analyses calculated (or derived) based in part on data from Nielsen Consumer LLC and marketing databases provided through the NielsenIQ Datasets at the Kilts Center for Marketing Data Center at The University of Chicago Booth School of Business. The conclusions drawn from the NielsenIQ data are those of the researcher(s) and do not reflect the views of NielsenIQ. NielsenIQ is not responsible for, had no role in, and was not involved in analyzing and preparing the results reported herein.

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1. Introduction

Since 1994, Nutrition Facts Panels (NFP) have become a common feature on packaged foods in the United States, providing detailed information about serving sizes, calorie content, and nutrient breakdowns (FoodDive, 2017). These panels not only make it easier to compare the nutritional value of similar products but also empower consumers to make healthier food choices based on informed comparisons. However, it is important to note that all nutritional data on these labels is relative to the specified serving size, which implicitly recommends a consumption quantity for a single occasion (Caswell & Padberg, 1992). While the total nutritional content of a product remains constant, the manipulation of serving sizes can affect consumer perceptions of healthfulness. For instance, when nutritional information is reported on a 'per serving' basis, it can shape consumers' purchasing decisions depending on how the information is presented (Chernev & Gal, 2010; Levin & Gaeth, 1988). Furthermore, manufacturers may adjust serving sizes as a strategy to alter the reported amounts of calories, saturated fat, and added sugars per serving, influencing consumer perceptions and choices (Mohr et al., 2012). This strategy suggests that while NFPs are designed to guide healthier consumer choices, they can also be used by manufacturers to create a more favorable impression of their products.

In 2016, the Food and Drug Administration (FDA) updated the NFP requirements for prepackaged foods to address several issues, including the display of serving sizes, calories, percent daily values, and other nutrients (FDA, 2021). One important labeling change is the requirement for standardized serving sizes. How much people consume has changed since the previous serving size requirements in 1994. Serving sizes have been updated to better reflect the amount of food that people typically consume at one time, not what they should be eating, which is usually smaller. For instance, the reference amount for one serving of carbonated soft drinks (CSDs) was increased from 8 oz to 12 oz, and for ice cream from 1/2 cup to 2/3 cup.

Nutrition labeling is one of many policies aimed at reducing obesity rates in the United States. Gathering more evidence on the impact of serving sizes on healthy food choices will shed light on cost-effective obesity prevention policies (Kliemann et al., 2018). Previous literature has noted the potential impacts of serving sizes on consumers' purchasing decisions, mainly using consumer surveys and experimental methods. Spanos et al. (2015) found that labeling pizza with a higher number of servings decreased food intake relative to labeling pizza with a lower number of servings. While from another perspective, studies also suggest that a smaller serving size for the same quantity of food has the potential to increase food consumption (Cavanagh et al., 2014; Mohr et al., 2012). Elshiewy et al. (2016) conducted an experiment using yogurt as healthy food and cookies as unhealthy food, the results showed that reduced serving size specification increases sales volumes in the healthier food category (yogurt), but not in the unhealthy food category (e.g., cookies). And this may be explained by how serving size information is framed (Hydock et al., 2016).

In response to growing health concerns, particularly obesity, firms within the food industry have increasingly focused on reformulating products to enhance their nutritional content and promote healthier consumer choices (Onyeaka et al., 2023). Rojas & Jaenicke (2024) offer a thorough review of the trends in the nutritional content of packaged food products in the United States from 2005 to 2021. Their research reveals that manufacturers have made significant strides in adjusting nutrient compositions, notably increasing the presence of beneficial nutrients such as protein, dietary fiber, monounsaturated fats, and polyunsaturated fats. The elimination of trans fats and substantial reductions in sugary product offerings stand out as key improvements. Despite these positive signs, the nutrients that decrease diet quality, such as sodium and sugar contents did not show significant decrease. In a related study, Eyles et al. (2018) observed that while serving sizes of fast food products in New Zealand have increased between 2012 and 2016, this change has paradoxically been accompanied by lower sodium levels in newer and reformulated products. With the updated NFP, the impact of serving size change is unknown.

This study investigates the impact of serving size adjustment in the NFP on consumer choices. We construct and estimate an equilibrium model that incorporates both consumer demand and firms' strategic pricing and nutritional characteristics decisions, with a focus on CSD. On the demand side, we use a random coefficient discrete choice model to analyze consumer preferences for CSDs, revealing a consistent negative valuation of price. We analyze both the direct effects of serving size changes and their broader impact on consumer preferences for other nutritional attributes like calories, sodium, and caffeine. Direct impact from changes in serving sizes and indirect impacts from nutritional change notably negatively affected consumer demand, underscoring the growing influence of health considerations in consumer purchasing behavior. On the supply side, we develop a two stage model where firm choose the nutritional characteristics of their product in the first stage and then play a Nash-Bertrand pricing game and choose the prices in the second stage.

The model are then used to simulate different policy scenarios in labeling to assess potential impacts on consumer behavior, considering the adaptive strategies of firms. Counterfactual simulations underscored potential shifts towards smaller or healthier alternatives, evidenced by decreased market shares for larger servings. Furthermore, industry adaptations through subtle but effective product reformulations aligned with increasing health awareness. These insights highlight the importance of serving size regulations and product reformulation strategies in promoting healthier consumer choices and informing policy within the beverage industry.

2. Data

In this study, we select CSD as a case study based on three primary reasons: First, CSD has been identified as a significant contributor to the rising obesity rates (Bray et al., 2004; Harnack et al., 1999; Pereira, 2006). Second, there is significant variation in serving sizes adjustment across different bottle sizes due to the NFP update, which facilitate the identification for estimation; Third, there are two main changes in the NFP update: serving change and the inclusion of added sugar information. Therefore, isolating these effects could potentially be challenging. However, it is common knowledge that regular CSD primarily consists of added sugars, which allows us to isolate the effects of serving size change from the inclusion of added sugar information. Prior to the implementation of the new policy, the standard serving size was 8 oz. For bottles containing less than two servings, the entire bottle was considered a single serving (FDA, 2023). With the policy update, the standard serving size was increased to 12 oz. However, the 20 oz bottle remained an exception, with its full volume still designated as a single serving. Notably, the largest adjustment was made to the 16.5 oz bottles, and bottles larger than 20 oz experienced a serving size increase of 4 oz.

We use NielsenIQ Retail Scanner data to obtain price and sales information of CSD in the United States from 2014 to 2020, which captures before and after periods of the label change. This data set offers extensive details on product prices, volumes, purchase dates, and geographic information, collected from a point-of-sale system involving over 90 retail chains across the U.S. (NielsenIQ, 2021). Sales data for 20 CSD brands were collected on a monthly basis across 49 states. In addition to the scanner data, we manually collected and digitized nutritional information from various NFP sources, including details on calories, sodium, and caffeine content, as well as serving sizes. Table 1 summarizes the key attributes of selected CSD products, categorized into Regular and Diet categories. Across regular brands, price per ounce varies slightly, with Coca-Cola R priced highest at $0.0453 and Crush R lowest at $0.0387. Nutritional contents also show variation; MTN Dew R contains the highest calorie count at 14.23 Cal/oz and sodium content is highest in Crush R at 5.918 mg/oz. In contrast, diet CSDs consistently show zero calories and varied sodium and caffeine levels, with Canada Dry Diet notably featuring the highest sodium content at 10.1683 mg/oz.

3. Methodology

To analyze the impact of alternative policy designs on the consumption of CSDs, we initially estimated the demand for CSDs. We modeled the firms' decision-making process as a two-stage game: in the first stage, manufacturers determine the nutritional characteristics of their products; in the second stage, they engage in a Nash-Bertrand pricing game to set prices. We then simulated new market equilibria, incorporating prices, nutritional characteristics, and market shares for each brand under various policy scenarios.

Table 1: Product Characteristics by Brand

Brand	Price ($/oz)	Calories (Cal/oz)	Sodium (mg/oz)	Caffeine (mg/oz)
Regular				
Pepsi R	0.0407	12.5325	3.8125	3.1975
Coca-Cola R	0.0453	11.8214	3.7801	2.8349
Sunkist R	0.0417	13.5917	5.4267	1.5817
Dr. Pepper R	0.0421	12.3429	4.6157	3.4057
Canada Dry R	0.0423	11.4533	4.1337	0.0000
Crush R	0.0387	13.3720	5.9180	0.0000
Fanta R	0.0446	13.3120	4.6080	0.0000
MTN Dew R	0.0420	14.2300	5.0538	4.3888
Sprite R	0.0420	11.6650	5.5883	0.0000
Diet				
Dr. Pepper DT	0.0439	0.0000	4.8357	3.4257
Coca-Cola DT	0.0422	0.0000	3.3643	3.8100
MTN Dew DT	0.0422	0.0000	4.1500	4.3913
Pepsi DT	0.0408	0.0000	3.0463	2.9325
Coca-Cola Caffeine Free DT	0.0303	0.0000	3.2450	0.0000
Canada Dry DT	0.0400	0.0000	10.1683	0.0000
Sprite Zero DT	0.0462	0.0000	3.0260	0.0000
Coca-Cola Zero DT	0.0431	0.0000	3.3286	2.8343
Seven Up DT	0.0314	0.0000	3.7080	0.0000
Pepsi Caffeine Free DT	0.0351	0.0000	3.0050	0.0000

DT: diet, R: regular.

3.1 Demand

In this paper, we use a random coefficient discrete choice model following the BLP (Berry et al., 1995). A consumer will choose one of the CSD products from competing products that maximizes his/her per-period utility, which is determined by product characteristics. In our analysis, we define market as the combination of state-year-month level. The indirect utility of consumer i from buying product j in market t can be written as:

$$\begin{aligned} u_{ijt} = \alpha_i P_{jt} + \beta_i X_j + \gamma_{1i}\text{Size}_{jt} + \gamma_{2i}\text{ServChange}_{jt} \\ + \gamma_{3i}\text{ServChange}_{jt} \times X_j + \xi_{jmt} + \varepsilon_{ijt}, \\ i = 1, \ldots, I; j = 1, \ldots, J; t = 1, \ldots, T. \end{aligned} \tag{1}$$

where P_{jt} is the unit price of product j in market t, X_j represents product unit nutritional characteristics including calorie, sodium and caffeine. $Size_{jt}$ is the bottle size of product j at market t. $ServChange_{jt}$ is the change in the serving size of product j due to the new regulation. ξ_{jmt} includes manufacturer, year, seasonal, state and covid fixed effects, it captures the unobserved time-varying product and market factors. ε_{ijt} is the stochastic i.i.d. error term following Type I extreme value distribution.

To capture consumer heterogeneity, the product price, serving size change, and nutritional change because of the serving size change are assumed to have a standard multivariate normal distribution:

$$\begin{pmatrix} \alpha_i \\ \gamma_{2i} \\ \gamma_{3i} \end{pmatrix} = \begin{pmatrix} \alpha \\ \gamma_2 \\ \gamma_3 \end{pmatrix} + \sum v_i, \quad v_i \sim N\left(0, I_{K+1}\right) \tag{2}$$

To allow for category expansion, we define the utility from consuming outside options (bottled water, fruit juice and other CSD options left in the market) as below:

$$U_{i0jt} = \varepsilon_{i0jt} \tag{3}$$

Since the i.i.d error term ε_{ijt} is assumed to be type I extreme value distributed, we have a closed form solution of the probability that consumer i chooses CSD j in market t:

$$Pr_{ijt} = \frac{\exp\left(\delta_{jt} + \mu_{ijt}\right)}{1 + \sum_{j=1}^{J}\left(\delta_{jt} + \mu_{ijt}\right)} \tag{4}$$

where $\delta_{jt} = \alpha P_{jt} + \beta X_j + \gamma_1 \text{ Size }_{jt} + \gamma_2 \text{ ServChange }_{it} + \gamma_3 \text{ServChange}_{it} \times X_j + \xi_{jt}$, it is the mean utility term, and μ_{ijt} is the product-specific and consume specific deviation from the mean. Aggregating over consumers, the market share of product j in market t is given by:

$$s_{jt} = \int Pr_{ijt} d\psi(v) \tag{5}$$

here, $\psi(v)$is the population distribution function. Following the methodology by Berry, Levinsohn, and Pakes (1995), we align the predicted market shares with the observed ones and employ generalized method of moments (GMM) to solve the model parameters.

3.2 Supply

On the supply side, we assume that there are L manufacturers that sell beverage products in market t and each manufacturer holds a set of products $k(l)$. These manufacturers strategically choose product prices and nutritional characteristics to maximize their profits. To estimate the supply side, we use the firms' first-order conditions with respect to prices and nutritional characteristics. Here, we assume all manufacturers choose the nutritional characteristics of their products in the first stage. And firms then play a Nash-Bertrand pricing game and choose the prices in the second stage.

3.2.1 First Stage

Suppose that the fixed cost of choosing a certain combination of nutritional characteristics is given by $fc\,(X_j, \eta_j; \tau)$, and X_j represents the nutritional characteristics, η_j is the unobservable cost shocks, and τ is a vector of parameters. The profit function for the first stage is as below:

$$\Pi_{lt}^{I}(X) = \sum_{j \in k(l)} \Pi_j^{II}(p, X) - fc\,(X_j, \eta_j; \tau) \tag{6}$$

In this equation, $\Pi_j^{II}(p, X)$ is the variable profit from the second stage, and $fc\,(X_j, \eta_j; \tau)$ is the fixed cost of choosing a certain combination of nutritional characteristics. We use a quadratic function to approximate the fixed cost function. Specifically, we assume the slope of the fixed cost function with respect to the hth endogenous characteristics X_{hj} is:

$$\tau_{h0} + \tau_{h1} X_{hj} + \eta_{hj} \tag{7}$$

In the first stage, the firms choose nutritional characteristics. The necessary FOC for the hth characteristic is:

$$\sum_{g \in k(l)} \left(\frac{\partial \Pi_{gt}^{II}}{\partial X_{hjt}} + \sum_{j'} \frac{\partial \Pi_{gt}^{II}}{\partial p_{j't}^{I}} \frac{\partial p_{j't}}{\partial X_{hjt}} \right) = \tau_{h0} + \tau_{h1} X_{hj} + v_{hj} \tag{8}$$

The first term on the left-hand side is the direct impact of increasing the hth characteristic of product j on the variable profit of product g owned by the same manufacturer. The second term is the indirect effect on product g through an impact on the equilibrium prices for all products. The partial derivatives $\left(\frac{\partial \Pi^{II}_{gt}}{\partial X_{hjt}}, \frac{\partial \Pi^{II}_{gt}}{\partial p_{j't}}\right)$ in 8 can be calculated by taking derivatives of the variable profit 6. To identify $\frac{\partial p_{j't}}{\partial X_{hjt}}$ in 8, we assume that the equilibrium pricing function is smooth with respect to characteristics and take an approach similar to Villas-Boas (2007) and Fan (2013). For each characteristic, we need to solve:

$$\begin{aligned} &\textstyle\sum_{k=1}^{N} \underbrace{\left[\frac{\partial s_j}{\partial p_k} + \sum_{i=1}^{N} T(i,j)\frac{\partial^2 s_i}{\partial p_j \partial p_k}(p_i - mc_i) + T(k,j)\frac{\partial s_k}{\partial p_j}\right]}_{g(j,k)} dp_k \\ &+ \textstyle\sum_{h=1}^{H} \underbrace{\left[\frac{\partial s_j}{\partial x_h} + \sum_{i=1}^{N}\left(T(i,j)\frac{\partial^2 s_i}{\partial p_j \partial x_m}(p_i - mc_i)\right)\right]}_{f(j,h)} dx_h = 0 \end{aligned} \tag{9}$$

And we could rewrite this function in a simpler way:

$$G dp + F_h dx_h = 0 \tag{10}$$

$$\frac{dp}{dx_h} = -G^{-1} F_h \tag{11}$$

3.2.2 Second Stage

We first assume that Following Nevo (2001), we assume that the CSD companies have exclusively market power in the marketing channel enabling them to set new retail prices in response to policy changes. Liu et al. (2014) also noted that the CSD market channel as typically comprising national-level companies and local-level retailers. Given policy-makers' interest in consumers' CSD purchases, what we observe are equilibrium retail prices. This approach aligns with previous studies on CSD company pricing strategies (Dhar et al., 2005; Gasmi et al., 1992; Mariuzzo et al., 2003). Consequently, in the second stage, each firm selects a set of prices to maximize its total profits. The total profit for firm l in market t would be:

$$\Pi^{II}_l(p, X) = \sum_{j \in k(l)} (P_{jt} - mc_{jt}) M_t \times S_{jt} \tag{12}$$

Where P_{jt} and mc_{jt} are the price and marginal cost of product j at market t. S_{jt} is the market share of product j, and M_t is total market size. Assume these firms compete in prices and a pure-strategy Bertrand-Nash equilibrium existed. The joint profit maximization in the second stage of firm l with all products leads to the following first order conditions(FOC):

$$S_{jt} + \left[\sum_{g \in k(l)} (P_{gt} - mc_{gt}) \frac{\partial S_{gt}}{\partial P_{jt}} \right] = 0 \tag{13}$$

for any j belonging to product set $k(l)$.

To derive the first-order condition with respect to the price, we define an ownership matrix Δ, and the (k, j) element is as:

$$\Delta_{jl} = \begin{cases} -\frac{\partial q_j}{\partial p_k} & \text{if } j \text{ and } k \text{ have the same manufacturer;} \\ 0 & \text{otherwise.} \end{cases} \tag{14}$$

Therefore, we could write the first order condition with respect to price in a matrix form as:

$$\boldsymbol{p} = \Delta^{-1} \boldsymbol{q} \tag{15}$$

3.3 Instruments

In our analysis, we assume that firms are aware of both the unobservable preferences for nutritional characteristics and the unobservable cost shocks before setting sales prices and nutritional attributes. Consequently, these choices are likely correlated with unobservable factors. We posit that the nutritional characteristics of products, their prices, and the indirect impacts of serving size changes are associated with these unobserved product characteristics or demand shocks. To address this endogeneity, we incorporate several instrumental variables: (1) BLP-type instruments (IV_1, IV_2, IV_3) representing characteristics of competing products in the same market; (2) cost shifters (IV_4, IV_5, IV_6) including interactions between manufacturer and retail wages, electricity prices, and sugar prices, respectively; and (3) market-related instruments similar to Miller & Weinberg (2017) and Barahona et al. (2023) (IV_7 through IV_{12}) which cover the number of new regular and diet products from the same and different manufacturers, as well as the count of products unaffected by policy changes, both from the same and different manufacturers.

4. Results

4.1 Estimation Results

We estimated the parameters using the Generalized Method of Moments (GMM). The results of this estimation are presented in Table 2. As anticipated, consumers have a strong and negative valuation price. However, the standard deviation for the price coefficient is not significant, which suggests that there is no significant heterogeneous preference on price in our study. The changes in serving size, as well as the nutritional changes resulting from it, negatively influence consumer preferences. This suggests that, on average, the serving size change has significant direct and indirect impacts on consumer demand for CSD. The standard deviations for the "Serving Size Change" and its interaction with "Calorie", "Sodium" and "Caffeine" are all significant, revealing the variations in consumer responses to the change in serving size and its indirect influence on nutritional content.

Other nutritional attributes, including bottle size, and content of calorie, sodium and caffeine also significantly impact consumer preferences. A positive coefficient for calorie contents indicates a general favor for energy dense CSD, in other words, regular CSD products. Conversely, the negative coefficient for sodium suggests a consumer preference for CSD with less sodium contents. In addition, consumers also have a positive preference for caffeine.

To better understand how the serving change affects consumer preferences, Table 3 shows the marginal willingness to pay (MWTP) for nutritional characteristics based on changes in serving size. As the serving size change of CSD increases, the MWTP for all three nutritional characteristics decreased, implying consumers value these attributes less as the serving size change increases. This suggests that larger servings may prompt more health-conscious purchasing decisions.

Table 2: Estimation Results

	Parameter	Estimate	SE	Parameter	Estimate	SE
Utility						
Price	α	-48.4021***	0.2588	v_1	5.0738	12.5930
Serving size change	γ_2	-0.6393***	0.0102	v_2	0.6895**	0.4063
Calorie per oz * Serving size change	γ_{31}	-0.1154***	0.0004	v_3	0.1769**	0.0827
Sodium per oz * Serving size change	γ_{32}	-0.7138***	0.0018	v_4	0.3602***	0.0878
Caffeine per oz * Serving size change	γ_{33}	-1.2041***	0.0016	v_5	0.9047***	0.1573
Bottle size	γ_1	0.0053***	0.0003			
Calorie per oz	β_1	0.0355***	0.0009			
Sodium per oz	β_2	-0.0740***	0.0044			
Caffeine per oz	β_3	0.4443***	0.0041			
Marginal cost ($)	mc	0.0214				
Slope of the fixed cost for calorie						
Constant	τ_{10}	0.0004				
Calorie	τ_{11}	-0.000003				
Slope of the fixed cost for sodium						
Constant	τ_{20}	-0.0003				
Sodium	τ_{21}	-0.00001				
Slope of the fixed cost for caffeine						
Constant	τ_{30}	0.0026				
Caffeine	τ_{31}	-0.00008				

*** Significant at the 1 percent level, ** Significant at the 5 percent level, * Significant at the 10 percent level.

Table 3: Marginal Willingness to Pay for Nutritional Contents

	WTP for nutrients ($)		
Serving Size Change (oz)	Calorie	Sodium	Caffeine
0	0.001	-0.002	0.009
1	-0.002	-0.016	-0.016
4	-0.009	-0.061	-0.090
8.5	-0.020	-0.127	-0.202

4.2 Counterfactual Simulations

This section explores counterfactual simulations designed to assess the impact of serving size regulations on both consumer behavior and industry responses.

We develop a full equilibrium simulation considers the potential for product reformulation by manufacturers in response to new regulations. Food reformulation involves altering the processing or composition of a food or beverage product (Scott et al., 2017). In these scenarios, reformulated products would replace existing versions and be marketed in ways that preserve consumer acceptance and liking, maintaining sensory characteristics that consumers are used to. This approach, often described as gradual and 'silent' reformulation, is likely to go unnoticed by consumers in terms of changes in taste or texture (Gressier et al., 2021). Evidence suggests that manufacturers frequently adjust product formulations in response to regulatory changes, aiming to align with consumer health consciousness or to maintain a competitive advantage (Scarborough et al., 2020). These simulations will evaluate how such reformulations might influence consumer choices and market changes, providing insights into the potential effectiveness of policy measures intended to promote healthier eating habits.

4.2.1 Full Equilibrium Simulation

Many nations have adopted food labeling standards and marketing regulations to nudge consumers toward healthier dietary choices and hope to mitigate diet-related illnesses, such as obesity. These measures frequently lead to significant industry-wide product reformulations. For instance, the United Kingdom introduced a sodium-reduction campaign in 2005, complemented by initiatives encouraging voluntary sodium reduction by food manufacturers. It is estimated that these product reformulations accounted for approximately 75% of the reduction in sodium levels observed in the national food supply (Griffith et al., 2017). Subsequently, the implementation of a soft drink levy in the UK led to a 34-percentage-point decrease in the proportion of beverages subject to the higher tax rate (those with sugar content exceeding 5 g per 100 mL) (Scarborough et al., 2020), indicating that the tax effectively incentivized manufacturers to reformulate their products. Moreover, from 2015 to 2019, there was a 43.7% reduction in the average sugar content per 100 mL of these beverages. The total sugar purchased per household from taxed drinks also declined markedly across all socioeconomic groups, with decreases ranging from 32.7% to 38.5% (Public Health England, 2021). In the United States, the mandated disclosure of trans fat content on product packaging precipitated a substantial elimination of trans fats from the food supply (Otite et al., 2013). Similarly, Chile's 2016 mandate for warning labels on products high in calories, sugars, salt, or saturated fats led to significant changes within six months of implementation: the proportion of products high in sugars dropped from 80% to 60%, and those high in sodium from 74% to 27% (Paraje et al., 2021; Reyes et al., 2020).

In light of the substantial impacts of food labeling and taxation policies on product reformulation, we propose to extend our analysis through the simulation of alternative policy designs that vary serving sizes—specifically, increasing them to 16 oz, 20 oz, and 24 oz, specifically, we allow firms to adjust their prices, and reformulate CSDs' nutritional contents: calorie, sodium and caffeine. This simulation will allow us to assess the responsiveness of firms in adjusting their product formulations within these parameters. Additionally, it will enable the simulation of potential shifts in market shares resulting from these changes. To ensure that these modifications do not significantly alter consumer perceptions of taste and product quality, we will impose a constraint that any nutritional content adjustments, which in terms of calorie, sodium, and caffeine content, must not exceed a 15% increase or decrease from current levels. The effectiveness of each policy variation will be compared, focusing on their capacity to maintain consumer satisfaction while achieving desired health outcomes. This approach will provide valuable insights into the optimal balance between regulatory objectives and market changes, informing future

Table 4: Simulated Percent Change of CSD Attributes by Brand

	Price Change (%)			Calorie Change (%)			Sodium Change (%)			Caffeine Change (%)		
Brand	16 oz	20 oz	24 oz	16 oz	20 oz	24 oz	16 oz	20 oz	24 oz	16 oz	20 oz	24 oz
Canada Dry DT	0.23	0.01	-0.03	-	-	-	-12.73	-14.56	-11.86	-	-	-
Canada Dry R	-0.08	-0.08	-0.02	-12.44	-14.50	-11.51	-12.74	-14.32	-14.90	-	-	-
Coca-Cola Caffeine Free DT	0.01	-0.12	0.04	-	-	-	-12.38	-7.63	-4.90	-	-	-
Coca-Cola DT	0.16	-0.05	-0.03	-	-	-	5.72	-12.37	-4.04	-14.35	-6.91	-13.27
Coca-Cola R	-0.19	0.07	-0.14	-11.94	-13.01	-13.16	0.00	-12.23	9.75	-12.18	-5.72	-0.09
Coca-Cola Zero DT	0.00	0.14	0.06	-	-	-	10.39	-10.64	5.19	-9.66	-0.70	-10.24
Crush R	0.04	-0.01	-0.03	-14.96	-14.98	-14.88	-12.03	-7.86	-13.11	-	-	-
Dr Pepper DT	-0.06	-0.22	-0.04	-	-	-	-2.19	-14.97	-7.71	-7.13	-14.60	-1.12
Dr Pepper R	-0.15	-0.16	0.01	-14.19	-15.00	-13.53	-7.39	-14.33	2.65	-7.88	-10.19	9.83
Fanta R	0.03	0.08	0.13	-12.74	-14.75	-12.53	0.29	-14.89	0.21	-	-	-
MTN Dew DT	0.01	0.24	-0.08	-	-	-	14.60	-10.03	2.97	-15.00	-15.00	-15.00
MTN Dew R	0.02	-0.15	-0.08	-14.85	-14.40	-14.95	-7.15	-7.40	6.01	-15.00	-11.08	-15.00
Pepsi Caffeine Free DT	-0.20	0.07	0.04	-	-	-	-5.02	-2.19	14.48	-	-	-
Pepsi DT	0.08	0.08	-0.05	-	-	-	-3.80	-3.07	-11.94	-0.38	-12.40	-9.63
Pepsi R	-0.08	0.12	-0.15	-13.61	-14.97	-13.92	-7.94	-5.26	4.91	-2.10	-12.88	-4.80
Seven Up DT	0.28	-0.08	0.21	-	-	-	1.11	-4.84	9.67	-	-	-
Seven Up R	-0.31	0.01	-0.11	-5.69	-11.61	-5.49	7.98	-7.32	1.99	-	-	-
Sprite R	0.00	-0.50	0.10	-12.37	-14.99	-11.90	-10.23	-15.00	-12.45	-	-	-
Sprite Zero DT	-0.22	0.24	0.00	-	-	-	-3.86	-12.57	-2.64	-	-	-
Sunkist R	-0.26	-0.26	0.08	-13.82	-12.53	-10.89	-14.54	-8.18	-14.04	-14.86	-1.42	-9.90

policy development in the public health domain.

Table 4 provides the adjustments in key product attributes—price, calories, sodium, and caffeine—across various brands under three distinct serving size mandates: 16 oz, 20 oz, and 24 oz. The results show a prevalent trend of product reformulation among brands, likely in response to regulatory demands and consumer preferences for healthier options. Significant reductions in sodium and caffeine content across multiple brands emphasize how the serving size change causes CSD industry to cater to health-conscious trends. Notably, brands such as 'Coca-Cola regular' and 'Dr Pepper regular' exhibit consistent reductions in both calories and sodium across all serving sizes, indicative of a comprehensive strategic reformulation. Despite these nutritional modifications, the data reveal that price adjustments have been minimal, suggesting that consumer costs have remained relatively stable. This stability may reflect firms' strategies to balance compliance with health regulations against maintaining market competitiveness.

Table 5 presents simulated percentage change in market shares under alternative policy scenarios with varying serving sizes. Our findings indicate that when firms are allowed to adjust their nutritional contents, diet versions CSDs, which usually have 0 calorie, generally see an increase in market share, reflecting successful adaptation to consumer demands for healthier options. In contrast, regular versions which high in calorie, often experience declines in market share under the same conditions, suggesting challenges in these product while new NFP increases health-conscious shopping behaviors. The differential impact observed between diet and regular beverages underscores consumer preferences that favor lower-calorie or lower-sugar options, particularly in environments influenced by regulatory changes. This pattern highlights the strategic necessity for firms to anticipate and respond to shifts in consumer behavior and regulatory policies, ensuring that they could strategically maintain market power.

Table 6 shows the simulated percent change in market shares by bottle size. Smaller bottle sizes (8 oz and 16.5 oz) show an increase in market share across all scenarios, suggesting consumer preference for relatively smaller bottle size CSDs. In contrast, larger bottles (24 oz, 33 oz, 42 oz) consistently show a decrease in market shares, indicating a potential consumer shift away from larger bottle sizes, possibly due to health-conscious

Table 5: Simulated Percentage Change in Market Shares under Alternative Policy Scenarios by Brand while Allowing Firms Reformulation

Brand	S1: Serving Size = 16 oz	S2: Serving Size = 20 oz	S3: Serving Size = 24 oz
Canada Dry DT	-2.69	-4.57	-5.29
Canada Dry R	-3.27	-5.95	-6.61
Coca-Cola Caffeine Free DT	1.52	1.03	1.19
Coca-Cola DT	0.49	1.20	-0.28
Coca-Cola R	-4.06	-5.25	-5.92
Coca-Cola Zero DT	2.18	3.98	2.82
Crush R	2.85	1.84	2.08
Dr Pepper DT	0.98	0.87	2.13
Dr Pepper R	-1.72	-2.12	-0.95
Fanta R	3.94	3.05	1.70
MTN Dew DT	-2.98	-3.08	-3.29
MTN Dew R	-2.05	-1.66	-2.83
Pepsi Caffeine Free DT	-4.33	-5.37	-6.49
Pepsi DT	-3.00	-5.34	-5.02
Pepsi R	-3.52	-6.19	-6.28
Seven Up DT	-1.58	-3.03	-4.11
Seven Up R	2.24	1.79	1.71
Sprite R	-5.52	-7.88	-8.55
Sprite Zero DT	1.80	1.43	1.78
Sunkist R	0.85	1.10	1.21

Table 6: Simulated Percentage Change in Market Shares under Alternative Policy Scenarios by Bottle Size while Allowing Firms Reformulation

Bottle Size (oz)	S1: Serving Size = 16 oz	S2: Serving Size = 20 oz	S3: Serving Size = 24 oz
8	8.35	8.47	8.73
12	-1.78	-1.56	-1.59
16.5	8.84	9.08	9.29
20	-4.22	-4.13	-4.14
24	-14.98	-16.46	18.66
33	-5.60	-7.61	-8.11
42	-17.56	-24.62	-29.11
67	-2.83	-3.15	-3.72

Table 7: Simulated Percentage Change in Nutrition Intake under Different Scenarios while Firms Reformulation

Serving Size (oz)	Calorie	Sodium	Caffeine
16	-3.56	-2.78	-2.78
20	-5.07	-4.04	-3.79
24	-5.88	-4.76	-4.46

behaviors or regulatory influence. However, since firms can reformulate, these drops are smaller compared to scenarios without reformulation.

Tables 7 and 8 further clarify the impact of these scenarios on nutrition intake and volume consumption, respectively. Table 7 highlights a uniform decrease in calorie, sodium, and caffeine intake as the serving size increases, reflecting effective reformulation strategies that align with public health objectives to reduce these constituents. Similarly, Table 8 shows a decrease in total volume consumption with an increase in serving size, with diet CSDs experiencing a less severe decline compared to regular CSDs. This trend suggests that consumers are responding not only to serving size but also to the improved nutritional profiles of diet beverages. Together, these tables shows us a market where regulatory scenarios and firm reformulations drive significant shifts in consumer behavior, aligning consumption patterns with healthier dietary preferences.

5. Conclusion

Our research estimate the factors affecting consumer preferences for CSDs using random coefficient discrete choice model. We found a significant negative valuation of price by

Table 8: Simulated Percentage Change in Volume Consumption under Different Scenarios while Firms Reformulation

Serving Size (oz)	Total	Regular CSD	Diet CSD
16	-2.87	-3.64	-1.20
20	-2.78	-3.60	-0.97
24	-4.93	-6.05	-2.43

consumers, although the variance in price sensitivity was not significant, suggesting homogeneity in price preferences across our study sample. Our findings also underscored significant negative impacts of changes in serving size and corresponding nutritional modifications on consumer demand, indicating both direct and indirect effects on the market for CSDs. Specifically, significant variations in consumer responses were noted to changes in serving size and related nutritional attributes such as calories, sodium, and caffeine. We further delved into the implications of serving size adjustments on MWTP. With increasing serving sizes, there was a clear decline in MWTP for calories, sodium, and caffeine, suggesting that larger servings may lead consumers to prioritize health considerations more strongly in their purchasing decisions.

In our counterfactual simulations, we explored the potential impacts of serving size regulations on consumer behavior and industry responses, categorized into demand-side and supply-side effects. Our results indicated a general decrease in market shares across most CSD brands as serving sizes increased, suggesting a shift in consumer preferences towards smaller servings or potentially healthier alternatives. This was further corroborated by significant market share declines in larger bottle sizes, and reductions in calorie, sodium, and caffeine intakes with larger serving sizes, highlighting consumer choice changes.

On the supply side, our simulations assessed industry adaptations to regulatory changes through product reformulation. These adjustments often remained unnoticed by consumers in terms of taste and texture but were crucial in aligning products with increased health consciousness and regulatory standards, thus maintaining competitive market positions. The effectiveness of these reformulations was evident from the sustained or improved market shares of diet CSDs versus regular CSDs, reflecting successful strategic adaptations by firms facing new regulatory landscapes.

In conclusion, our findings provide compelling evidence that increasing serving sizes, coupled with effective product reformulation, could lead to decreased market shares for larger bottle sizes and encourage relatively healthier consumer choices. This insight is crucial for policymakers and industry stakeholders aiming to forge strategies that promote healthier dietary patterns while considering the economic dynamics of the beverage industry.

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