Promoting Healthy Diets Through Food Reformulation: The Demand for "Better for You" Beverage

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Selected Paper prepared for presentation at the 2023 Agricultural & Applied Economics Association Annual Meeting, Washington DC; July 23-25, 2023

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Abstract

This paper explores how nutrients, new ingredients, and health claims from product reformulation influence consumer decisions, dietary intake, and population health in the beverage market. We focus on the beverage market in the U.S. as a case study because of the emerging health demand for "better-for-you" beverage options. We formulate a random coefficient discrete choice model to evaluate consumer preference for reformulated products in the non-alcoholic beverages market. We find that new ingredients that provide functionality such as energy ingredients, carbonation, or no artificial flavors have a significant positive impact on consumer choices. Further, the use of health claims can significantly increase consumer demand for beverages. Results from simulations suggest that the use of "no/low sugar", "no/low sodium", and "no artificial sweetener" health claims will increase the net sugar and sodium intakes from SSB, leading to an increase in BMI and the incidence of coronary heart disease (CHD) and diabetes. The nutrient reformulation by cutting sugar and sodium content by 10%, on the other hand, will result in a decrease in sugar and sodium consumption, and further lower the incidence of CHD and stroke. However, the policy aimed at lowering the intake of one single nutrient may have an unintended spillover effect on other nutrient intakes, and policymakers should take a comprehensive approach and consider the broader nutrient impact of any policy aimed at reducing a specific nutrient.

[1] Statements: a. 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. b. 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.

1. Introduction

Consuming a healthy diet can help prevent malnutrition and noncommunicable diseases (NCDs). However, the development of globalization and urbanization over the last decades has witnessed a rise in ultra-processed and convenience food and beverages, which are often unhealthy and high in calories, fats, salt, and sugar, and low in good nutrients (Moodie et al., 2013). According to the World Health Organization (WHO), about 1.9 billion adults worldwide are overweight or obese, which is the fifth leading risk of death globally.[2] One of the most straightforward measures to address the increasing health concerns is to create a healthy food environment and nutritious food supply.

Food and beverage reformulation is considered cost-effective by the WHO as one of the recommended interventions to promote healthy diets and reduce NCDs.[3] If successful, food reformulation strategies will improve dietary intake by changing the composition of foods without having to change consumers' eating habits. The idea that reformulation efforts can potentially improve nutritional quality has been gradually developing in the public health policy debate (Gressier et al. 2020). A key aim of policies designed to incentivize food reformulation is to improve the nutrient composition of foods available to consumers while not detracting from other product characteristics that are known to drive consumer choices, such as taste, convenience, or affordability (Buttriss, 2013). Many governments have adopted obesity prevention policies to protect the population against NCDs, among them labeling policies and taxes, which indirectly induced reformulations. Direct measures being taken include food fortification by adding nutrients lost in the manufacturing process, the reduction in trans-fatty acids (TFA) in foods, and more recently, sodium, added sugar, and energy reduction.

[2] https://www.who.int/news-room/fact-sheets/detail/healthy-diet.
[3] https://ncdalliance.org/why-ncds/risk-factors-prevention/unhealthy-diets-and-malnutrition.

In response to consumer priorities for health and sustainability and government regulations aimed at changing nutrient intakes, food manufacturers invest in product reformulation by launching new products with improved nutrient formulations and reformulating existing products (Mancino et al., 2008; Magnusson and Reeve, 2015). While the reformulation of existing food products does not change the range of choice options available to consumers, as reformulated products replace previous versions, introducing new products with improved nutrient composition extends the range of choice options, leaving both old and new products in the market (Gressier et al., 2020). Some previous literature discussed the potential effect of industry-level food reformulation on health outcomes by using nutrient profile analysis to achieve target diet requirements (Leroy et al., 2016; Gressier et al., 2017). These studies had assumed that consumers do not change their diets, and their overall diet quality will improve with a better food supply. Other studies focus on the trend or changes in the average levels of nutrients over time that is potentially related to reformulation (Mancino et al., 2008; Muth et al. 2019). For example, Mancino et al. (2008) analyzed the trend in sales and find an increase in retail sales and consumption of whole-grain food products after the release of the 2005 Dietary Guidelines, largely through reformulation of existing products, induced by competition among food suppliers.

However, the net impact of food reformulation might be complicated due to consumer choices. Some consumers might not be willing to switch to the reformulated, nutritionally balanced options. When the original products remain available, consumers may not change their food choices to avoid the "taste cost" of changing habits. When the original products are replaced, they may switch to other less healthy products similar to the original products. Chen and Chen (2022) evaluate the impact of sodium reduction in instant noodles and find that voluntary sodium reduction by a single firm results in its sales loss to its competitors. Other consumers may even

increase their consumption of the reformulated alternatives because it is perceived to be healthier. This “halo effect” may result in overconsumption of certain nutrients intakes with more net intakes of sugar, sodium, fat, carbs, etc. (Sorqvist et al., 2013, 2015; Lim, Hu, and Nayga, 2021).

Food reformulation has the potential for generating major public health impacts but realizing this potential will require a better understanding of mechanisms through which reformulation can have an impact on people’s diet and health (Gressier, et al., 2020). Given the research gap in the absence of the impact of food reformulation on the healthfulness of consumer purchases, to better inform public policies designed to promote a healthier diet, it is important to understand factors that influence consumer decisions over reformulated products.

This paper explores how nutrients, new ingredients, and health claims from product reformulation influence consumer decisions, dietary intake, and population health in the beverage market. We focus on the beverage market in the U.S. as a case study because of the emerging health demand for “better-for-you” beverage options. Manufacturers are meeting the demand of health-conscious consumers with cleaner formulations, which are advocated as healthy, convenient, functional, and clearer labeling. 83% of beverage manufacturers stated they are actively altering ingredients specifically to meet consumer health demands and even successful offerings have been reformulated into new health-conscious varieties by adjusting ingredient formulations (Lacy-Nichols, et al., 2020; PMMI, 2021). Manufacturers are also reformulating the ingredients of beverages and developing hybrid or fusion drinks, which combine two or more drink categories, blending flavors and functionality. To effectively communicate new formulation health advantages to consumers, manufacturers are turning to clean and clear labeling as well. Research has shown that consumers are willing to pay a price premium for clean labels and the new food technology used (Grant et al, 2021).

Using Nielsen Retail Scanner data from 2015 to 2019, we formulate a random coefficient discrete choice model to evaluate consumer preference for reformulated products in the non-alcoholic beverages market. Specifically, we assume consumers make beverage choices based on three categories of factors: (1) nutrients such as sugar, sodium, and caffeine content, (2) new functionality that promote health and wellness such as energy ingredient, natural flavor, etc., and (3) marketing strategies such as price, health and wellness labels and claims, and product line expansion.

We find that new ingredients that provide functionality such as energy ingredients, carbonation, and no artificial flavors have a significant positive impact on consumer choices. Further, the use of health claims can significantly increase consumer demand for beverages. We further compare alternative practices of beverage reformulation and assess the impact on consumers' net nutrient intake and health outcomes through a series of simulations. Results from simulations suggest that the use of "no/low sugar", "no/low sodium", and "no artificial sweetener" health claims will increase the net sugar and sodium intake from soft drinks, leading to an increase in BMI and the incidence of CHD and diabetes. The nutrient reformulation by cutting sugar and sodium content by 10%, on the other hand, will result in a decrease in sugar and sodium consumption, and further lower the incidence of CHD and stroke. Given the impact of these health claims on consumer choices, to ensure accuracy and transparency, the government could establish regulations for the use of certain claims, such as "no/low sugar", "no/low sodium", and "no artificial sweeteners". Policymakers should also adopt a comprehensive approach and consider the broader nutrient impact of any policy aimed at reducing a specific nutrient, as such a policy may have unintended consequences for other nutrient intakes. Considering the potential spillover

effects on other nutrients can help ensure that the overall nutritional quality of the diet is maintained while reducing the intake of a specific nutrient.

The rest of the paper is organized as follows. Section 2 describes the data and summary statistics for the main variables. Section 3 describes the method for demand estimation. Section 4 presents the estimation results, the design of the counterfactual analysis and the simulation results. Section 5 concludes.

2. Data

This analysis combines multiple types of brand-level data. The main data used in this study is the Nielsen Retail Scanner Data from 2015 to 2019, which covers more than half of the total sales volume of U.S. grocery and drug stores and more than 30 percent of all U.S. mass merchandiser sales volume.[4] The data includes dollar sales, volume sales, prices, and detailed information on product characteristics (e.g. brand names, container sizes, package sizes, etc.), marketing (e.g. price and in-store displays), location, and time of sales. To capture the impacts of the new ingredients and functionalities of the reformulated beverages, we include a total of 141 beverage brands in multiple categories. In addition to traditional soda, we include categories like sparkling water, energy drinks, sports drinks, and other flavored water, where newer and reformulated products are usually introduced.

We use brand-level data on beverages across the contiguous United States and data for market shares and prices are aggregated at the brand-month-state level. The total market is defined as a general refreshment beverage market (Lopez and Fantuzzi, 2012; Liu and Lopez, 2016). With consumers having the outside option of not purchasing the beverage products in our selected

[4] See https://www.chicagobooth.edu/research/kilts/datasets/nielsenIQ-nielsen.

categories, the market size in each state is the total volume consumption of all soft drinks,[5] calculated as per capita consumption times population. Market shares are then calculated by the total volume sold.

The nutrition content, ingredients, health claims, and labeling information are collected from multiple sources including product labels, media coverage, and firms' own websites.[6] By looking into the pictures of the package, we collected information for health claims and labeling, such as if there are sugar claim, sodium claim, artificial sweetener claim, vitamin claim, antioxidants claim, electrolytes claim, and real juice claim. Nutrition contents that are mandatory by labeling regulations, such as sugar and sodium content, can be found in nutrition facts tables. In addition, we collected information on the caffeine content, other functionality and ingredients including if the beverages contain carbonated water, energy ingredients (such as caffeine, green tea extract, Taurine), preservatives (such as potassium benzoate, sodium benzoate and potassium citrate) and artificial flavors, from the description on the packages.

Table 1 shows the summary statistics of the main variables. We can see from the table that regular soda contains the most sugar, while diet soda, sparkling water and other flavored beverages typically have no or very little sugar. There are more sodium and caffeine in energy drinks. In addition to the standard nutrition content, such as sugar, sodium, and caffeine, we include some other ingredients that are related to the health features such as carbonated water, no artificial flavor, energy ingredient, etc. In general, more than half of all beverages are carbonated and have energy

[5] Including carbonated soft drinks, energy drinks, sports drinks, sparkling water, flavored water, liquid tea, fruit juice, milk, and bottled water, etc.

[6] To ensure consistency, we primarily collected product information from Walmart's website, but for items that were not available there, we sourced information from other third-party websites like Amazon, as well as the official websites of some products such as Ripe It, Hal's New York, and Keurig Dr Pepper. While we were unable to track functional ingredients or health claims over time due to the lack of reliable data, we were able to capture cross-sectional variation in nutritional ingredients and health claims across products. Additionally, we were able to identify when products entered or exited the market.

ingredients, but no artificial flavors. Among those, sparkling water is less likely to contain energy ingredients and preservatives, while a larger percentage of energy drinks use artificial flavors.

Many food manufacturers regularly introduce new products to expand their product line because it is generally believed that consumers love variety, and it can keep current consumers engaged while enticing new consumers to try the new reformulated beverages. In this analysis, we capture the product variety by counting the number of available products offered by a brand each month. As can be seen in Table 1, regular soda brand (such as Coca-Cola and Pepsi) has the highest average number of product lines for each brand, which provides consumers with the most choices. This is consistent with the market share in our dataset, with regular soda taking the top spot in the beverage market.

In addition, we include some popular health claims or labels shown on the reformulated beverages such as “no artificial sweetener”, “no sugar”, “no sodium”, etc. The summary statistics are also presented in Table 1. In general, there are more brands that have a no/low sugar claim on their packages (49%) than those with a no/low sodium claim (19%). While all diet soda has a no/low sugar claim, only 75% for sparking water brands, 71% for other flavored beverages, and 39% for sports drinks. Regular soda and sparkling water brands have a slightly higher probability to show a no/low sodium claim. Compared to soda, brands in sparkling water, flavored beverage brands and sports drinks are more likely to label the vitamin claim, antioxidants claim, electrolytes claim, and real juice claim.

3. Empirical Framework

3.1 Model

We estimate the demand for reformulated drinks following the approach of Berry et al. (1995; hereafter BLP). Assume consumer *i* chooses a beverage product *j* among all available alternatives

{1, …, *J*} or does not purchase {*J*=0} in market *m* to maximize utility driven by product characteristics as well as the consumers' specific tastes. The indirect utility is given by:

$$U_{ijm} = \alpha_i p_{jm} + \beta_1 N_{jm} + \beta_2 H_{jm} + \beta_3 M_{jm} + \xi_j + \rho_m + \pi_{m,} + \eta_j + \kappa_j + \varepsilon_{ijm} \quad (1)$$

where p_{jm} is the sales-weighted price of beverage product *j* in market *t* and a market is defined as a state-month combination in this analysis. N_{jm} is a vector of nutrients such as sugar, sodium, and caffeine. H_{jm} is a vector of functionality that promotes health and wellness such as energy ingredients, natural flavor, etc. M_{jm} is a vector of other marketing strategies that also help promote the newly reformulated beverage products, such as health and wellness labels and claims, and product line extension. ξ_{jm} is unobserved product characteristics and $\rho_m, \pi_{m,} \eta_j$ and κ_j are year, state, product category, and brand fixed effects. ε_{ijm} is a stochastic term with a mean zero that is distributed independently and identically as a Type I extreme value distribution.

Consumers may exhibit heterogeneous preferences. To capture the heterogeneity, we use individual-specific coefficients in our model. Let $\theta_i = (\alpha_i, \beta_i)$ denotes the vector of consumer-specific taste parameters for product characteristics, which is distributed as multivariate normal. Therefore,

$$\theta_i = \theta + \mathbf{\Sigma} v_i \quad (2)$$

where $\mathbf{\Sigma}$ is a scaling matrix and the unobserved consumer characteristics, v_i, follows a standard multivariate normal distribution.[7] Then the indirect utility can be decomposed as:

$$U_{ijm} = \delta_{jm} + \mu_{ijm} + \varepsilon_{ijm}, \quad (3)$$

$$\delta_{jm} = \alpha_i p_{jm} + \beta_1 N_{jm} + \beta_2 H_{jm} + \beta_3 M_{jm} + \rho_m + \pi_{m,} + \eta_j + \kappa_j + \xi_j, \quad (4)$$

$$\mu_{ijm} = (p_{jm}, N_j, H_j, M_j) \times \mathbf{\Sigma} v_i \quad (5)$$

[7] We choose the multivariate normal distribution for random parameters following Nevo (2001).

In Equation (4), δ_{jm} is the mean utility term, μ_{ijm} is the deviations from the mean utility generated by the interactions between consumer and product characteristics, and ε_{ijm} is the stochastic term. Therefore, the probability that consumer *i* choose product *j* in market *m* is

$$s_{ijm} = \frac{\exp(\delta_{jm}+\mu_{ijm})}{1+\sum_{r=1}^{J}\exp(\delta_{rm}+\mu_{irm})} \quad (6)$$

Aggregated over consumers, the market share of product *j* in market *m* corresponds to the probability of product *j* being chosen in market *m*, which is

$$s_{jm} = \int \frac{\exp(\delta_{jm}+\mu_{ijm})}{1+\sum_{r=1}^{J}\exp(\delta_{rm}+\mu_{irm})} dP_v(v) \quad (7)$$

Following BLP, we match the predicted market share with observed shares and solve the model using the generalized moment method (GMM). The estimated coefficients can reveal the consumer's preferences towards energy drinks.

3.2 Identification Strategies, Endogeneity and Instruments

The identification in the generalized moment method (GMM) requires a set of exogenous variables that are not correlated with the error term, the unobservable product characteristics (ξ). Price is potentially endogenous because producers may know the value of the unobservable product characteristics (ξ), but it is unknown to researchers. To control for this endogeneity issue, we use the average prices of the product in other states (excluding the state being instrumented) as instruments for the prices following Hausman (1996) and Nevo (2001). By controlling for brand fixed effect, category fixed effect and state fixed effect, the state-specific valuations of the product are independent across states but are allowed to be correlated within a state. Given the assumption, the prices of the product in other states are valid instruments for the price in a state. Prices of product *j* in different states will be correlated due to the common marginal costs, but they will not

be correlated with the market-specific price variations of the product. We further perform the first stage test and the Durbin-Wu-Hausman test to check the validity of our instrument. And the p-values for both tests are 0.0000, supporting the validation of our instruments.

4. Results

4.1 Demand Estimation

Results from the demand estimation are presented in Table 2. The coefficient of the price is negative and significant, with significant heterogeneity across consumers. As for nutritional characteristics, the coefficient of sugar is positive and significant, suggesting that consumers have a positive valuation for sugar in soft drinks on average. The coefficients for sodium and caffeine are all negative and significant, implying that consumers generally dislike sodium and caffeine in soft drinks on average.

Among other functionality and ingredients, consumers have a strong positive and significant preference for energy ingredients, which have been formulated into drinks to boost performance or highlight supposed health benefits. The coefficient for carbonated beverages is positive and significant, implying that consumers have shown a strong preference for carbonated beverages or sparkling beverages. This is consistent with carbonation being on trend in recent years. Sparkling drinks have seen steady growth and have been reformulated and blended with other beverage categories with innovation around flavors, functionality, and formats. In addition, consumers prefer beverages with no artificial flavors and no preservatives, which are perceived to be healthier and cleaner by many consumers.

Manufacturers use health claims or labels to inform consumers about the health benefits associated with the consumption of reformulated, functional beverages. Previous experiments have

shown that the use of health claims can significantly improve acceptance of functional foods and understanding of their health benefits (Chrysochou & Grunert, 2014; Huang & Lu, 2016). In this analysis, we evaluate the impact of some popular health claims or labels shown on the reformulated beverages on consumer choices. We find that most of the claims have a positive and significant impact on consumer preference, indicating that consumers prefer a beverage product with the no/low sugar claim, the no/low sodium claim, the no artificial sweetener claim, the vitamin claim, and the electrolytes claim.

Consumers generally have a negative preference for products with antioxidant and real juice claims. This may be due to several factors. Firstly, some studies have shown that there is a misunderstanding among consumers regarding the role of antioxidants in the human body, leading to a perception of risk associated with such purchases (Fatkullin et al., 2021). Secondly, while consumers generally view the use of natural antioxidants favorably (Mitterer-Daltoé et al., 2020; Lungu et al., 2020), industrial food processing relies on a wide range of technical and chemically synthesized additives that can be used as antioxidants for food preservation. Some of these technologies or additives may raise health concerns among consumers (Gutiérrez-del-Río et al., 2021). Finally, the real juice claim may be viewed skeptically by consumers due to past lawsuits related to fruit juice labeling. Some companies use less expensive, less nutritious juices, such as apple and white grape, and then label these blends with names other than the primary juices they contain. Major brands, including Tropicana[8] and Naked[9], have also faced lawsuits related to juice claims, which may erode consumer confidence in these claims.

[8] See https://www.foodnavigator-usa.com/Article/2012/01/10/Tropicana-sued-over-100-pure-and-natural-orange-juice-claim, https://topclassactions.com/lawsuit-settlements/consumer-products/beverages/tropicana-dodges-pure-orange-juice-class-action/.
[9] See https://www.foodnavigator-usa.com/Article/2012/01/10/Tropicana-sued-over-100-pure-and-natural-orange-juice-claim, https://topclassactions.com/lawsuit-settlements/consumer-products/beverages/tropicana-dodges-pure-orange-juice-class-action/.

4.2 Counterfactual Analysis

Using the estimated structural parameters from the demand model, we then conduct a series of counterfactual analyses to simulate the market outcomes of several market scenarios. For each scenario, we first calculate the new market sales for all beverage products and evaluate the effects of reformulation on beverage demand. We then translate the changes in sales of beverage products to the overall consumption of several nutrients and population health outcomes.

4.2.1 Counterfactual 1: Health Claims and Labels

Many beverage brands use labels and claims to communicate the new formulation's health advantages to consumers, such as "no sugar", "no sodium", "no calorie", "no artificial sweeteners" etc. However, there are also products that contain no or low content of certain nutrients but do not have a claim or label on their package. In this section, we conduct a set of simulations by labeling all products that are eligible for the "No/Low Sugar Claim", "No/Low Sodium Claim", or "No Artificial Sweeteners Claim" but do not label them.[10] Specifically, we simulate the following scenarios to quantify the effect of health claims on consumer demand.

S1.1: Add a "No/Low Sugar Claim" to products that are eligible for the claim but do not label it.

S1.2: Add a "No/Low Sodium Claim" to products that are eligible for the claim but do not label it.

[10] "No or low sugar claim" is highly correlated with "no/low calorie claim". The "No/Low Sugar Claim" includes products that have at least one of the two claims. We use the definition of "very low sodium" from the FDA to determine eligibility for a no/low sodium claim. Please see https://www.fda.gov/food/nutrition-education-resources-materials/sodium-your-diet. Given the absence of a legal definition of "low" sugar, we use the products in our dataset to define a no/low sugar product. The maximum sugar content for products that have a no/low sugar claim is 0.25 g/oz, and the maximum calorie content for products that have a no/low-calorie claim is 3.14 per oz. So we define a product with sugar content lower or equal to 0.25g/oz and calorie content lower or equal to 3.14 per oz as eligible for a no/low sugar claim.

S1.3: Add a "No Artificial Sweeteners Claim" to products that are eligible for the claim but do not label it.

S1.4: Add all three claims to products that are eligible but do not label them.

The top panel in Table 3 presents the simulated percentage changes in market shares, broken down by categories. We find that all beverage categories benefit from all health claims with increases in sales. Comparing the three claims, the no/low Sodium claim (S1.2) has the largest impact on average, resulting in the large sales increase in sparkling water (20.511%), other flavored beverages (18.088%), and diet soda (8.676%). With the no/low Sugar claim, the sales of sports drinks will benefit the most (13.507% increase) because they typically have lower sugar content but do not label it. According to the summary statistics in Table 1, the average sugar content in sports drinks is 0.75 g per oz, which is around half of the market average. However, only 39% of sports drinks label it. The no artificial sweetener claim, on the other hand, will have the largest impact on sparkling water with a 17.165% increase in sales, followed by other flavored beverages and sports drinks. Finally, when we add all three claims to eligible beverage products, sparkling water will experience the largest increase in sales (41.008%), followed by other flavored beverages (32.886%) and sports drinks (22.481%). In general, the newer beverage markets benefit the most from the health claims.

4.2.2 Counterfactual 2: Reformulation on Nutrient Content

Reformulating the nutrient content in beverages has been considered an important mechanism to promote a healthier diet. To help achieve voluntary, gradual, achievable, and meaningful industry reformulation nationwide, the U.S. National Salt and Sugar Reduction Initiative (NSSRI)[11]

[11] The NSSRI is a partnership of >100 local, state, and national health organizations convened by the New York City Department of Health and Mental Hygiene.

developed and released the draft sugar reduction targets in 2018 and finalized the sugar reduction targets after incorporating the industry's feedback in 2021 (NYC Health, 2021). For sugary beverages, the short-term target in 2023 is to reduce the sales-weighted average sugar content by around 10% (from 8.9 g/100 ml to 8.0 g/100ml), and the long-term target in 2026 is to reduce the sales-weighted average sugar content by around 40% (from 8.9 g/100 ml to 5.4 g/100ml).

In this analysis, using the NSSRI targets as a guideline, we simulate three different scenarios to quantify the effect of nutrient reformulation on consumer demand[12]:

S2.1: Reduce only sugar content by 10% for all products.

S2.2: Reduce only sodium content by 10% for all products.

S2.3: Reduce both sugar and sodium content by 10% for all products.

The simulated impact on market share is presented in the bottom panel of Table 3. With a 10% reduction in sugar content, regular soda sales will be dropped by 0.004%, while all other beverage sales increase. Among those, other flavored beverages increased the most, followed by diet soda, sports drinks, sparkling water, and energy drinks. When we reduce the sodium content by 10%, all beverage sales increase, which is consistent with our demand estimate: consumers dislike sodium in the category of beverages overall. Combining the sugar and sodium reduction, we expect an increase in sales in all beverage categories, with the highest impact on sports drinks and other flavored beverages.

[12] When performing the simulations, we assume that prices of the underlying products and competing products are not changed. Ideally, we would love to estimate a full equilibrium model with both demand and supply sides, where firms will endogenize both pricing decisions and product nutrition content decision. However, full supply side decisions, although a very interesting topic, are beyond the scope of the present study. Modelling firm responses of price, attributes, and product offering would require a structural dynamic game. Further, although our current analysis does not consider the potential changes in prices due to reformulation, we do not think it will have a major impact on our results due to the cost structure of the beverage market. Take Coca-Cola for example, the production cost (e.g., raw materials, packages, etc.) is very low, about 5%. The majority of the costs are spent on overhead (e.g., distribution, marketing, etc.), which are not affected directly by the reformulation process itself. Therefore, the price change caused by the reformulation should be very small.

4.2.3 Impact on Nutrient Intakes

The impact of providing health claims or healthier, reformulated products on nutrient intakes may be complicated by multiple factors. On one hand, the total nutrient intake might be reduced because some consumers may substitute away from sugary drinks and choose the no/low sugar/sodium version of the beverages. On the other hand, consumers may overconsume certain beverages that are perceived to be healthier, and some non-consumers now start to buy the healthier version of the beverages, which can both lead to an increase in certain nutrient intakes. We now calculate the change in nutrient intake for sugar, sodium and caffeine under different scenarios and the results are presented in Table 4.

The top panel of Table 4 shows the results from the health claim scenarios. Among all three types of claims, the "no/low sodium claim" still has the largest overall impact, resulting in a 2.219% increase in total sugar consumption, followed by a 1.511% increase from a "no/low sugar claim", and a 1.133% increase from the "no artificial sweetener claim". The net sodium consumption will also increase due to the health claims, with the largest impact of 2.433% from the "no/low sodium claim". Similar results are shown in caffeine consumption, where the sugar, sodium, and artificial sweetener claim will increase its total consumption by 1.081%, 4.35%, and 1.109%, respectively.

Results from the nutrient reformulations are presented in the bottom panel of Table 4. Although the sugar and sodium reduction increases the sales of most beverage products, the net nutrient intakes are still lower than before the reformulation. When reducing both sugar and sodium content by 10%, the total consumption of sugar will decrease by 9.514% and the sodium consumption will decrease by 8.98%. The total consumption of caffeine, however, will increase by 0.896%. What is worth noting here is that the policy aimed at lowering the intake of one single nutrient may have an unintended spillover effect on other nutrient intakes. When there is a 10%

reduction in sugar content, the intake of sodium and caffeine increases by 0.614% and 0.570% respectively, although there is a decrease in sugar intake. Similarly, when there is a 10% reduction in sodium content, the intake of sugar and caffeine increases by 1.649% and 1.615%, although there is a decrease in sugar and sodium intake.

4.2.4. Impact on Health Outcomes

Based on the simulated changes in nutrient intakes, we further assess the impact of beverage product reformulation on health outcomes. We focus on sugar first. High intake of added sugar is linked to weight gain and cardiometabolic risk. We incorporate the well-established associations: the associations of added sugar with BMI; and the associations of added sugar from sugar-sweetened beverages with coronary heart disease (CHD) and diabetes. Using the etiologic effects of added sugar from the sugar-sweetened beverage and food on cardiometabolic diseases (Micha et al, 2017; Shangguan et al. 2021),[13] we report the effects on the health outcomes in Table 5.

In scenario 1 with the health claims, when adding all three claims ("no/low sugar claim", "no/low sodium claim", and "no artificial sweetener claim"), due to the net increase in sugar consumption (2.393% from Table 4), the average increase in BMI is 0.011 for those with BMI <25 and 0.025 for those with BMI>=25. The three health claims will also increase the incidence of CHD by 2.031% and the incidence of diabetes by 2.259%. In scenario 2 with nutrient reformulation, when reducing both sugar and sodium content by 10%, the associated reduction in net sugar intakes will lead to a decrease in BMI by 0.051 for BMI<25 and 0.113 for BMI >= 25.

[13] A reduction in 1g of added sugar per day, which is equivalent to 0.93% of sugar intake per day, will reduce BMI by 0.005 for BMI <25 and 0.011 for BMI >=25. It will also reduce the incidence of CHD by 0.89% and reduce the incidence of diabetes by 0.99%. During the period from 2017 through 2018, the average adult over 20 years old in the United States is estimated to have consumed 71.35 grams of added sugar per day (USDA-ARS, 2018).

Further, the incidence of CHD will be lowered by 9.105% and the incidence of diabetes will be lowered by 10.128%.

We now turn to sodium. Reducing dietary salt lowers blood pressure and the risk of cardiovascular disease. We used the Coronary Heart Disease Policy Model to quantify the benefits of reductions in sodium (Bibbins-Domingo, et al. 2012).[14] The impact on health outcome due to changes in sodium intake are presented in Table 6. In scenario 1, when adding all three claims, the incidence of CHD will be increased by 0.19% and the incidence of stroke will be increased by 0.16%. However, in scenario 2 when reducing both sugar and sodium content by 10%, the incidence of CHD and stroke will be lowered by 0.53% and 0.45%, respectively. In general, the impact on health outcomes due to changes in sodium intake is smaller than that in sugar intake.

5. Conclusion

This paper evaluates how nutrients, new ingredients, and health claims from product reformulation influence consumer decisions, dietary intake, and population health in the beverage market. We find that new ingredients that provide functionality such as energy ingredients, carbonation, and no artificial flavors have a significant positive impact on consumer choices. Further, the use of health claims can significantly increase consumer demand for beverages. Results from simulations suggest that the "no/low sugar", "no/low sodium", and "no artificial sweetener" health claims will increase the net sugar and sodium intakes, which will lead to an increase in BMI and the incidence of CHD and diabetes. The nutrient reformulation by cutting sugar and sodium content by 10%, on

[14] A reduction in dietary salt of 1g per day (1200mg of sodium per day), which is equivalent to 33.98% of sodium intake per day, is projected to reduce the incident of CHD by 2% to 3.3%, reduce the incidence of Strok by 1.7% to 2.7%, and the death from any cause by 0.9% to 1.4%. During the period from 2017 through 2018, the average adult over 20 years old in the United States is estimated to have consumed 3531mg of sodium per day (USDA-ARS, 2018).

the other hand, will result in a decrease in sugar and sodium consumption, and further lower the incidence of CHD and stroke.

This paper provides valuable insights into consumer response to manufacturers' reformulation strategies and reformulation policies promoting healthy diets. It can also shed light on the tradeoffs that consumers make between tastes and healthfulness, and help manufacturers develop food reformulation and innovation strategies.

To this end, the government should implement regulation on the use of some claims. Given that health claims such as "no/low sugar", "no/low sodium", and "no artificial sweetener" may lead to increased net sugar and sodium intake, policymakers may need to impose stricter regulations on the use of such claims. For instance, products should not be labeled "no/low sugar" or "no/low sodium" if they do not meet the requirements. The policymakers could also lower the content values to define no/low-sodium beverages to prevent overconsumption due to increased purchases of products labeled as low sodium. Our dataset shows that the average sodium content of beverages is about 74 mg/serving(12 oz), making them eligible to be labeled as low sodium.[15] Therefore, there needs to be another standard to define the no/low-sodium products in the beverage market instead of evaluating it together with other food categories.

In addition, policymakers should establish an official definition of no/low sugar. In 2020, the Center for Science in the Public Interest (CSPI) urged the FDA to take enforcement against implied "low sugar" and "reduced sugar" claims[16]. There are beverage products claimed to be low in sugar or slightly sweetened that actually are high in sugar content. Although the FDA has argued that food manufacturers cannot market foods as "low sugar", there is currently an absence of a

[15] According to the definition by the FDA, food and beverages that contains 140 mg of sodium or less per serving are eligible to label as sodium-free or low sodium.
[16] https://www.natlawreview.com/article/cspi-urges-fda-to-take-enforcement-against-implied-low-sugar-and-reduced-sugar

legal definition of "low sugar". Further, the products with "no artificial sweetener" can also contain other natural sweeteners, such as sugar. Therefore, the "no artificial sweetener" claim may need to be used with the "no/low sugar" claim to avoid biased exposure to the partial information. Moreover, given the numerous lawsuits related to fruit juice labeling in recent years, the labeling of real juice must be accurate and clear to avoid confusion. The claim for antioxidants should also be specific and clear about the types of antioxidants, such as natural antioxidants claim.

Second, when there is a goal to reduce the intake of a certain nutrient, policymakers should take a comprehensive approach to consider the potential effects on other nutrient intakes. The policy aimed at lowering the intake of one single nutrient may have an unintended spillover effect on other nutrient intakes. For example, when there is a reduction in sugar content, our counterfactual analysis shows that the intake of sodium and caffeine both increases, although there is a decrease in sugar intake. Similarly, when there is a reduction in sodium content, our analysis shows that the intake of sugar and caffeine both increases, although there is a decrease in sodium intake. Therefore, policymakers should consider the broader nutrient impact of any policy aimed at reducing a specific nutrient.

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Table 1. Summary Statistics of the Main Variables by Beverage Categories

Variable	Total	Soda Diet	Soda Regular	Energy Drink	Other Flavored Beverages	Sparkling water	Sports Drink
Price($/oz)	0.070	0.028	0.031	0.136	0.060	0.064	0.056
	(0.056)	(0.004)	(0.010)	(0.054)	(0.026)	(0.043)	(0.029)
Nutrients							
Sugar(g/oz)	1.392	0.000	3.489	1.702	0.220	0.254	0.750
	(1.612)	(0.000)	(0.397)	(1.624)	(0.456)	(0.749)	(0.788)
Sodium(mg/oz)	6.201	4.398	4.107	12.262	5.297	0.927	6.685
	(6.134)	(2.196)	(1.093)	(6.897)	(7.692)	(1.273)	(5.293)
Caffeine(mg/oz)	3.829	1.844	1.628	10.624	0.000	0.739	1.021
	(4.952)	(1.835)	(1.772)	(3.900)	(0.000)	(1.531)	(2.620)
Other Functionality and Ingredients							
Have Energy Ingredients	0.523	0.554	0.522	1.000	0.135	0.097	0.198
	(0.499)	(0.497)	(0.500)	(0.000)	(0.342)	(0.296)	(0.399)
Carbonated	0.821	1.000	1.000	0.974	0.000	1.000	0.000
	(0.383)	(0.000)	(0.000)	(0.159)	(0.000)	(0.000)	(0.000)
Have Preservative	0.792	1.000	0.886	1.000	0.451	0.203	0.921
	(0.406)	(0.000)	(0.318)	(0.000)	(0.498)	(0.403)	(0.270)
No Artificial Flavors	0.760	0.832	0.784	0.489	1.000	1.000	0.788
	(0.427)	(0.374)	(0.412)	(0.500)	(0.000)	(0.000)	(0.409)

Variable	Total	Soda Diet	Soda Regular	Energy Drink	Other Flavored Beverages	Sparkling water	Sports Drink
Marketing Practice							
Number of Product Lines	22.293	23.687	32.979	8.382	19.384	28.156	25.356
	(21.747)	(16.792)	(23.978)	(6.789)	(12.632)	(26.596)	(23.817)
No/Low Sugar Claim	0.492	1.000	0.000	0.448	0.705	0.750	0.387
	(0.500)	(0.000)	(0.000)	(0.497)	(0.456)	(0.433)	(0.487)
No/Low Sodium Claim	0.152	0.170	0.326	0.000	0.000	0.254	0.071
	(0.359)	(0.376)	(0.469)	(0.000)	(0.000)	(0.436)	(0.257)
No Artificial Sweetener Claim	0.103	0.000	0.000	0.000	0.158	0.330	0.295
	(0.304)	(0.000)	(0.000)	(0.000)	(0.365)	(0.470)	(0.456)
Vitamin Claim	0.172	0.000	0.000	0.321	0.271	0.097	0.433
	(0.378)	(0.000)	(0.000)	(0.467)	(0.444)	(0.296)	(0.496)
Antioxidants Claim	0.070	0.000	0.000	0.000	0.451	0.097	0.241
	(0.255)	(0.000)	(0.000)	(0.000)	(0.498)	(0.296)	(0.427)
Electrolytes Claim	0.102	0.000	0.000	0.039	0.707	0.038	0.397
	(0.303)	(0.000)	(0.000)	(0.193)	(0.455)	(0.191)	(0.489)
Real Juice Claim	0.199	0.114	0.151	0.172	0.135	0.273	0.375
	(0.399)	(0.317)	(0.358)	(0.378)	(0.342)	(0.445)	(0.484)
No. of Observations	348,352	51,795	77,345	96,369	18,554	62,944	41,345

Table 2 Demand Estimation Results: Impact of Nutrients Content, Functionality and Ingredients and Marketing Strategies on Consumer Demand

Variables	Mean	Standard Error
Constant (mean)	-12.2836***	0.0529
Constant (std. dev.)	0.8555***	0.0035
Price (mean)	-12.8022***	0.1378
Price (std. dev.)	0.8605***	0.2055
Nutrients		
Sugar	0.0363***	0.0059
Sodium	-0.0070***	0.0008
Caffeine	-0.0073***	0.0017
Other Ingredients and Functionality		
Have Energy Ingredients	0.4718***	0.0127
Carbonated	1.5853***	0.0395
Have Preservative	-0.1367***	0.0145
No Artificial Flavors	0.0871***	0.0106
Marketing Practice		
Number of Product Lines	0.0566***	0.0002
No/Low Sugar Claim	0.4086***	0.0200
No/Low Sodium Claim	0.2814***	0.0126
No Artificial Sweetener Claim	0.4718***	0.0127

Variables	Mean	Standard Error
Vitamin Claim	1.2108***	0.0138
Antioxidants Claim	-1.7997***	0.0333
Electrolytes Claim	0.3084***	0.0193
Real Juice Claim	-0.5039***	0.0116
Time Fixed Effects	Yes	
Category Fixed Effects	Yes	
Brand Fixed Effect	Yes	
State Fixed Effects	Yes	

Note: 1) *** p<0.01, ** p<0.05, * p<0.1. 2) The number of observations is 348,352, parameters are GMM estimates.

Table 3. Simulated Percentage Change in Market Share Across Beverage Categories

Simulation Scenarios	Percentage Change in Market Share (%)					
	Soda Diet	Soda R	Energy drink	Other Flavored Beverages	Sparkling Water	Sports Drinks
Scenario 1: Health Claims						
S1.1 Add a No/low sugar claim	0.684	0.937	0.886	3.721	0.804	13.507
S1.2 Add a No/low sodium claim	8.676	1.829	3.466	18.088	20.511	3.708
S1.3 Add a No artificial sweetener claim	0.638	0.920	0.858	8.076	17.165	5.224
S1.4 Add all three claims	8.088	1.301	2.875	32.886	41.008	22.481
Scenario 2: Reformulation on Nutrients						
S2.1 Reduce sugar content by 10%	0.977	-0.004	0.450	1.002	0.700	0.859
S2.2 Reduce sodium content by 10%	1.128	1.396	2.082	1.532	0.619	1.787
S2.3 Reduce both sugar and sodium content by 10%	1.214	0.239	1.409	1.434	0.668	1.462

Table 4. Simulated Percentage Change in Nutrient Intake

	% Change in Nutrient Intake		
Simulation Scenarios	Sugar	Sodium	Caffeine
Scenario 1: Health Claims			
S1.1 Add a No/low sugar claim	1.511	2.220	1.081
S1.2 Add a No/low sodium claim	2.219	2.433	4.350
S1.3 Add a No artificial sweetener claim	1.133	1.173	1.109
S1.4 Add all three claims	2.393	3.366	4.132
Scenario 2: Reformulation on Nutrients			
S2.1 Reduce sugar content by 10%	-9.801	0.614	0.570
S2.2 Reduce sodium content by 10%	1.649	-8.380	1.615
S2.3 Reduce sugar and sodium content by 10%	-9.514	-8.980	0.896

Table 5. Simulated Impact on Health Outcomes from Change in Sugar Intake

Simulation Scenarios	Change in BMI (<25)	Change in BMI (>=25)	% Change in the Incidence of CHD	% Change in the Incidence of Diabetes
Scenario 1: Health Claims				
S1.1 Add a No/low sugar claim	0.008	0.018	1.446	1.609
S1.2 Add a No/low sodium claim	0.012	0.026	2.123	2.362
S1.3 Add a No artificial sweetener claim	0.006	0.013	1.084	1.206
S1.4 Add all three claims	0.011	0.025	2.031	2.259
Scenario 2: Reformulation on Nutrients				
S2.1 Reduce sugar content by 10%	-0.053	-0.116	-9.379	-10.433
S2.2 Reduce sodium content by 10%	0.009	0.019	1.578	1.755
S2.3 Reduce both sugar and sodium content by 10%	-0.051	-0.113	-9.105	-10.128

Table 6. Simulated Impact on Health Outcomes from Changes in Sodium Intake

Simulation Scenarios	% Change in the Incidence of CHD	% Change in the Incidence of Stroke
Scenario 1: Health Claims		
S1.1 Add a No/low sugar claim	0.13	0.11
S1.2 Add a No/low sodium claim	0.14	0.12
S1.3 Add a No artificial sweetener claim	0.07	0.06
S1.4 Add all three claims	0.19	0.16
Scenario 2: Reformulation on Nutrients		
S2.1 Reduce sugar content by 10%	0.04	0.03
S2.2 Reduce sodium content by 10%	-0.49	-0.42
S2.3 Reduce sugar and sodium content by 10%	-0.53	-0.45