Accounting for Product Substitution in the Analysis of Food Taxes Targeting Obesity

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Abstract

We extend the existing literature on food taxes targeting obesity. First, we incorporate the implicit substitution between sugar and fat nutrients implied by a complete food demand system and by conditioning on how food taxes affect total calorie intake. Second, we propose a methodology that accounts for the ability of consumers to substitute leaner low-fat and low-sugar items for rich food items within the same food group. This substitution is integrated into a demand system in addition to substitution among food groups. Simulations of a tax on added sugars show that the impact of the tax on consumption patterns is understated and the effect on welfare loss overstated when abstracting from this substitution within food groups.

Keywords: discretionary calories; fat; food demand; health policy nutrition; low-fat, low-sugar substitutes; obesity; sugar; sweeteners; tax.

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Introduction

The United States faces a major health problem of high prevalence of obesity and its underlying cause – an imbalance between energy intake and requirements (Ogden, et al., 2007). Obesity is associated with excessive morbidity and raises concerns about determinants of dietary choice. Policy analysts and policymakers have considered several instruments to induce consumers to more closely adhere to current dietary guidance, including targeted taxes on soda and fatty foods.

The objective of this paper is to rigorously explore the consumption and welfare effects of taxes that target two important sources of excess calorie intake: added sugars and sweeteners, and discretionary solid fats. These food components are present in various foods. Most of the existing research on food taxes and obesity treat the food group in a demand system as a composite of food items with a fixed (e.g., average) content of nutrient or food components. This body of research proceeds to assess the effect of the tax on a single target ingredient and the consequent changes on the taxed nutrient. In contrast, very few studies consider sub-categories within food groups or account for the possible trade-off between targeted food components such as added sugars and fats, and the overall effect on total calorie intake. For example, Smed, Jensen, and Denver (2007) considered taxes on various combinations of foods and food components, and the combination of several tax instruments and their impact on food and nutrient consumption in Denmark. They find consumers trade off sugar and saturated fat when only one of these components is taxed by abating one but increasing the other. Smith, Lin and Lee (2010) find cross-product substitution within the beverage group to be important. However, to our knowledge, no study has yet provided a systematic approach to account for the substitution between fatty and sweet food and their leaner close substitutes.

This is the void we fill. We investigate the attribution of excess (i.e., discretionary) calories and the welfare loss when taxes are imposed on calories from added sugar, both on composite food groups as well as on sub-categories within composite food groups. By explicitly recognizing differences in the composition of the food groups, we can evaluate potential substitution that occurs both across food groups as well as within the food groups. An important conjecture to investigate is that the welfare cost of abating sugar and associated calories could be systematically overstated by ignoring consumers' response to a tax as they substitute towards leaner and lighter substitutes of the targeted items within food groups. The ineffectiveness of "obesity taxes" may have been overstated.

We extend the existing literature with a methodological and empirical contribution. Our study focuses on the two major sources of discretionary calories: fat (and especially saturated fat) and added sugars and sweeteners. First, we incorporate the implicit substitution between sugar and fat nutrients implied by a complete food demand system and conditioning on how food taxes affect total calorie intake. Second, we propose an empirical methodology that accounts for the ability of consumers to substitute away from rich food items to leaner items within the same food group with available low-fat and low-sugar substitutes. This substitution is integrated into a food demand system in addition to substitution among food groups. The model is calibrated to recent U.S. data to investigate the impact of a tax on added sugar. Simulations show that the impact of the tax on consumption patterns and reduction of calorie intake is understated, and the effect on welfare loss is overstated when abstracting from the substitution within food groups.

We focus on taxes rather than subsidizing "thin" foods because a subsidy on healthy foods may not decrease calorie intake although the diet quality improves. For example, French et al. (2001) showed such ambiguity with subsidies on low-fat healthy snacks.

Background

The literature on obesity taxes finds that taxes can change consumers' diet choices, but their effectiveness is often limited (Powell and Chriqui, forthcoming) and taxes on selected foods tend to be regressive, falling disproportionally on poor consumers (Allais, Bertail and Nichèle, 2010; Smith, Lin and Lee, 2010). Demand for nutrients is found price inelastic. There is some limited evidence that there is trade-off between "bad" food components (e.g., fat and sweeteners) when only one nutrient is targeted (Smed, Jensen, and Denver, 2007). Fat and soda taxes can be effective with significant caveats. Gustavsen (2005) found that the increase of a tax on soft drinks works well, mostly with heavy consumers of soft drinks among the Norwegian households studied. Schroeter, Lusk, and Tyner (2008) also found the consumption of high-calorie foods to decrease when the price of high calorie foods increased, but changes in body-weight depend on the substitutability or complementarity among high-calorie and low-calorie foods and their relative effect on weight. Applying a tax on caloric soft drinks is relatively more efficient than a small subsidy on diet soft drinks in reducing calorie intake and weight. Richards, Patterson, and Tegene (2007) showed that the addiction (habit persistence) to carbohydrates is a significant determinant of consumption and taxes targeting nutrients instead of specific foods can effectively control excessive nutrient intake.

Other researchers have questioned the effectiveness of tax. Kuchler, Tegene, and Harris (2004) found that neither consumption nor diet quality would change much with relatively low tax rates on unhealthy snacks. Allais, Bertail, and Nichèle (2010) show that a fat tax may have unintended effects, such as reducing intakes of calcium and potassium of consumers. Since food demand is price inelastic, these taxes can provide revenue to support other ways to address obesity (Powell and Chriqui, forthcoming; Smith, Lin and Lee, 2010; and Kuchler, Tegene, and Harris, 2005).

An important and often neglected aspect of the policy design is the possible trade-off between sugar and fat and the related total effect on the calorie intake when a tax is imposed. Richards, Patterson, and Tegene (2007) found that taxing pretzels did not reduce the carbohydrate intake and actually increased fat and calorie intake. Taxing nuts reduced the fat intake but increased the carbohydrate intake. Taxing potato chips successfully reduced fat, carbohydrate, and calorie intake since there were few close substitutes. Smed, Jensen, and

Denver (2007) showed that a sugar tax reduced sugar consumption but increased saturated fat consumption. A tax on saturated fat combined with a subsidy on fiber, decreased saturated fat consumption, but increased sugar demand. Combining the tax on saturated fat with a subsidy on fiber subsidy and a tax on sugar solves the latter problem. Their results suggest the importance of accounting for substitution possibilities among food choices.

Policy Instruments

The growing prevalence of obesity and the social costs associated with poor dietary choices motivate government intervention because of externalities. Obesity has significant external effects on the health care system, employers and other people (Bhattacharya and Bundorf, 2005), which are typically not internalized when people make food choices.

One policy instrument designed to limit discretionary calorie intake is a calorie tax broadly defined. The calorie tax raises the price of calorie-intensive foods proportionate to their calorie content in order to encourage consumers to substitute away from high-calorie foods towards low-calorie foods. Whether or not the calorie tax will be effective depends on consumers' response to the price changes of high calorie foods and the availability of acceptable low-calorie substitutes. Under some proposals, the revenues generated from the calorie tax would finance a "thin" subsidy on healthy foods such as fruits and vegetables (Yaniv, Rosin, and Tobol, 2009; and Cash, Sunding and Zilberman, 2005) or education programs to promote dietary health.

A calorie tax could be applied at different levels: calories associated with targeted food groups, items, or specific food components, such as fat, saturated fat or sweeteners added in foods. Ad valorem taxes applied on high-calorie food items change food prices and act directly on the food demand system and lead to changes in food choices. The changes in food demand translate into the nutrient intake changes. Through a fixed linear conversion, an ad valorem tax can be applied in a flexible way to a larger set of goods or to all goods by levying a tax on the calories contained in many or all food items.

An alternative approach is to levy taxes on the nutrients or food components themselves (e.g. fat or sweeteners) directly. Essentially, the tax on the nutrient itself is translated into changes in food prices. Food price changes lead to food demand changes and these lead to nutrient intake changes. Richards, Patterson, and Tegene (2007) argued that targeting the nutrients or food components is more effective than targeting foods because consumers can switch to other foods when the tax is targeted initially at the product level. Smed, Jensen, and Denver (2007) also found that taxing nutrients has a larger effect on the nutrient intake than taxing foods. We formalize this idea here.

Target Food Components

In our study, the Dietary Guidelines for Americans (USDA/DHHS, 2005) and the related Food Guide (USDA, 2006) are used as a reference for defining the food groups and sub-categories within the food groups that capture low/high fat and sweeteners substitutes within each food group. Following the Dietary Guidelines, the concept of discretionary calories is used to identify excess calorie intake. Discretionary calories are available to form an upper limit to additional intake after recommended food choices are met and come from foods that include calories above those available from nutrient-dense foods -- foods which are low fat or free of fat and added sugar -- but allow little room for other calories without increased physical activity (USDA/DHHS, 2005). Calories from added sugars, solid fats and alcoholic beverages all contribute to discretionary calories. Fats above the lowest available fat level in food sold in retail outlets such as fats in whole milk compared to skim milk and fats and oils added at the table or in the cooking process are the discretionary fats. Discretionary fats come from both plant sources or fish (as discretionary oils), and from animal sources, hydrogenated vegetable oils and a few plant sources such as coconut oil and palm kernel (as discretionary solid fat) (Bowman, Friday, and Moshfegh, 2008). Solid fats contain more saturated fats and/or trans fats than do oils. The recommendations on fat consumption in the 2005 Dietary Guidelines (those in place at the time of this study) are to keep consumption of calories from saturated fats to less than 10% and calories from total fat between 20% to 35% of total calories; and limit food products high in saturated fat and/or trans fatty acid; and choose meat and poultry low in fat, dry beans and milk products that are low fat or fat free.

Added sugars are the sugars and syrups added to the food at the table or added in the food processing or preparation process. Added sugars provide few nutrients but do provide calories. The major sources of added sugars in the US diet are soft drinks; candies; cakes, cookies, pies; fruit drinks; dairy desserts and milk products such as ice cream, sweetened yogurt, and sweetened milk. The Dietary Guidelines recommend that individuals decrease the consumption of sweetened beverages to reduce caloric intake and control weight, (USDA/DHHS, 2005).

Recent data from the National Health and Nutrition Examination Survey (NHANES), a nationally representative survey of the non-institutionalized population, show that for adults (19 years and older) the usual intake of oils is 21.3 grams/day for males and 17.1 grams/day for females; the usual intake of solid fats is 55.7 grams/day for males and 39.5 grams/day for females in 2001-2004. For the same period, the usual intake of added sugars is 25.4 grams/day for males and 18.3 grams/day for females (National Cancer Institute, 2008). The daily amount of saturated fat would need to be below 22 grams for a reference 2000 total calorie intake, and below 24 grams for an intake of 2200 total calories.

Food demand elasticities

Two approaches are used to estimate the price and income elasticities of nutrients. One is to directly estimate the nutrient elasticities as the function of price, income and demographic variables (Abdulai and Aubert, 2004; and Shankar, 2009). The other is to estimate the demand system for foods and assume fixed nutrient contents per unit of each food type and derive nutrient elasticities from food demand. The nutrient intake change is derived through the food demand change (Smed, Jensen, and Denver (2007); and Allais, Bertail, and Nichèle (2010)) In both approaches, nutrients are price inelastic.

Aggregation is an issue with the indirect approach since there exist nutrient content differences within the aggregate food group. For example, the fat content in milk differs between skim and whole milk. Chouinard, et al. (2010) and Smith, Lin and Lee (2010) show that consumers can change their nutrient intake by substituting skim milk for whole milk. Our paper addresses the important aspect of substitution within food groups in effecting changes due to targeted nutrition-related price policies. We consider a complete food demand system which accounts for the ability of abating sugar and fat and associated calories when there is substitution among food products and within food categories between sugary and fatty items and leaner ones.

Model

We start with the calibrated LinQuad demand system (Beghin, Bureau, and Drogué, 2003; and Miao, Beghin, and Jensen, 2010) as a foundation and extend this demand system by incorporating more nutrient information to its standard form and by explicitly accounting for close substitutes with much variation in fat and/or sweetener content within most composite good groups. The within food group substitution is incorporated using the Armington constant elasticity of substitution (CES) function form for each composite group.

Let $\mathbf{D} = [D_1, ..., D_n]'$ be the vector of demands for the target sweet and fatty composite food groups, $\mathbf{P}=[P_1,...P_n]'$ be the corresponding price vector, $\mathbf{P_R}=[P_{R1},...P_{Rz}]'$ be the price vector for all the remaining foods $\mathbf{R}=[R_1,...,R_z]'$, and I be the income level. The consumer's utility maximization problem under the budget constraint is

$$\underset{\mathbf{D},\mathbf{R}}{Max}\ U(\mathbf{D},\mathbf{R}) \quad s.t.\ \mathbf{P}'\mathbf{D}+\mathbf{P_R}'\mathbf{R}\le I\ , \tag{0}$$

where U represents the utility function.

The LinQuad incomplete demand systems approach (LaFrance) is flexible in its ability to reflect consumer preferences by incorporating the quadratic price term. It is also easy to calibrate while imposing proper curvature. The LinQuad Marshallian demand equations are

$$\mathbf{D}=\boldsymbol{\varepsilon}+\mathbf{VP}+\boldsymbol{\chi}(I-\boldsymbol{\varepsilon}'\mathbf{P}-\frac{1}{2}\mathbf{P}'\mathbf{VP}), \tag{0}$$

where $\boldsymbol{\chi},\boldsymbol{\varepsilon},$ and $\mathbf{V}$ are preference parameters. Symmetry of the Slutsky substitution matrix implies $v_{ij}=v_{ji}$. The Marshallian price elasticity for food group i with respect to price j is

$$\eta_{ij}^{M}=[v_{ij}-\chi_i(\varepsilon_j+\sum_k v_{jk}P_k)]\frac{P_j}{D_i}\,. \tag{3}$$

The income elasticity for the same food group is

$$\eta_{iI}=\chi_i\frac{I}{D_i}\,. \tag{4}$$

A CES function form for composite food group

Each food group is further decomposed into a CES composite of four sub-categories of High fat & High sugar (HH), High fat & Low sugar (HL), Low fat & High sugar (LH), and Low fat & Low sugar (LL) based on the content intensity of added sugars and discretionary fat in food items within the group. The elasticity of substitution between any two sub-categories within each composite food group is high and constant. The consumer utility function is rewritten as

$$U(\mathbf{D},\mathbf{R}) = U(D_1, D_2, \ldots, D_n, \mathbf{R})$$
$$= U([D_{1HH}, D_{1HL}, D_{1LH}, D_{1LL}],[D_{2HH}, D_{2HL}, D_{2LH}, D_{2LL}],\ldots,[D_{nHH}, D_{nHL}, D_{nLH}, D_{nLL}], \mathbf{R}). \quad (5)$$

The CES composite form for each food group i is

$$D_i = (\alpha_{iHH} D_{iHH}^{-\rho_i} + \alpha_{iHL} D_{iHL}^{-\rho_i} + \alpha_{iLH} D_{iLH}^{-\rho_i} + \alpha_{iLL} D_{iLL}^{-\rho_i})^{-\frac{1}{\rho_i}}, \quad (6)$$

where $\alpha_{iHH}, \alpha_{iHL}, \alpha_{iLH}, \alpha_{iLL}$ represent consumers' preferences among the sub-categories within group i. The elasticity of substitution within each composite food group σ_i satisfies $\sigma_i = 1/(1+\rho_i)$ and with $\sigma_i \in [0,\infty)$, from complementarity to perfect substitution.

The price of each composite food group is a function of the sub-categories' prices

$$P_i = (\alpha_{iHH}^{\sigma_i} P_{iHH}^{1-\sigma_i} + \alpha_{iHL}^{\sigma_i} P_{iHL}^{1-\sigma_i} + \alpha_{iLH}^{\sigma_i} P_{iLH}^{1-\sigma_i} + \alpha_{iLL}^{\sigma_i} P_{iLL}^{1-\sigma_i})^{\frac{1}{1-\sigma_i}}. \quad (7)$$

From the consumer's optimization, the demand for each sub-category K within a particular composite food group i is a function of the demand for the composite food group and the relative price of sub-categories within the composite food group or

$$D_{iK} = \alpha_{iK}^{\sigma_i} D_i (\frac{P_{iK}}{P_i})^{-\sigma_i}, \; K = HH, HL, LH, LL. \quad (8)$$

So the expenditure shares of any sub-category K in the group i can be expressed as

$$s_{iK} = \frac{D_{iK} P_{iK}}{D_i P_i} = \frac{\alpha_{iK}^{\sigma_i} D_i (\frac{P_{iK}}{P_i})^{-\sigma_i} P_{iK}}{D_i P_i} = \alpha_{iK}^{\sigma_i} (\frac{P_{iK}}{P_i})^{-\sigma_i + 1}, \; K = HH, HL, LH, LL. \quad (9)$$

This share decreases as its relative price increases if $\sigma_i > 1$ and vice versa if $\sigma_i < 1$.

The CES structure leads to the own-price elasticity for any sub-category K is a function of the cost share of this sub-category in the composite food group and the elasticity of substitution σ_i within in the composite food group

$$\eta_{iK} = -\sigma_i (1 - s_{iK}), \; K = HH, HL, LH, LL, \quad (10)$$

or eventually for calibration purposes to $\sigma_i = \eta_{iK} / (s_{iK} - 1)$.

Conversion between foods and nutrients

The above system of equations is modeled in the form of the final products that consumers consume. We are also interested in the nutrients intake implied by these consumption decisions. A conversion matrix converts the food consumption implied by **D** to the nutrients in food component consumption or $\mathbf{D'C} = \mathbf{N}$, with $\mathbf{N} = [N^O, N^F, N^S, N^{cal}]$ being the vector of aggregate nutrients/food components and calories contained in the final products **D**. Superscripts *O, F, S, cal* represent discretionary liquid oil, discretionary solid fat, added sugar, and calories contained respectively. The nutrients could also be extended to total fat, saturated fat, monounsaturated fat and polyunsaturated fat. $\mathbf{C} = [C^O, C^F, C^S, C^{cal}]$ is the conversion matrix between food and nutrients/food component and calories with similar superscripts. The price elasticity for the fat nutrient in food is

$$\mu_i^F = \frac{\partial N^F / N^F}{\partial P_i / P_i} = \sum_j (\eta_{ji} \frac{D_j C_j^F}{\sum_l D_l C_l^F}), \qquad (11)$$

and similarly for the other nutrients in food by substituting their superscripts in (11).

Welfare effects of taxes

A tax imposed proportionally to added sugars at a tax rate t^S leads to new prices $\mathbf{P^1} = \mathbf{P^0} + \mathbf{C^S} t^S$ and consumer welfare changes which are measured by the equivalent variation, *EV*,

$$EV = (I - \boldsymbol{\varepsilon}'\mathbf{P^1} - \frac{1}{2}\mathbf{P^1}'\mathbf{V}\mathbf{P}^1)\exp(\boldsymbol{\chi}\mathbf{P^0} - \boldsymbol{\chi}\mathbf{P^1}) - (I - \boldsymbol{\varepsilon}'\mathbf{P^0} - \frac{1}{2}\mathbf{P^0}'\mathbf{V}\mathbf{P^0}). \qquad (12)$$

Data and Calibration

Several national level data sources were used in developing the underlying parameters used in our estimates and calculations.

Food, nutrient and food component intake

The NHANES 2003-2004 data were used to develop estimates of consumption of food and beverage intakes. The Dietary Interview data contain detailed food intake information for foods and beverages consumed during a 24-hour recall period, with the food amounts reported in the "as-consumed" form. We narrowed the sample to individuals age 20 and older who have records for both interview days and weighted the data to represent the national population. Women who were pregnant, and adults who had incomplete information on household income or household size were excluded from the sample. After screening, the sample size was 3015 individuals.

The MyPyramid Equivalence Database (MPED) 2.0 was used to convert the amounts of food intake into intake of discretionary fat (liquid and solid) and added sugar. Sugar substitutes were not included in added sugars. We focus on solid fat and added sugar. For a representative individual, the daily calorie intake was 2187 calories, with consumption of 19.85 grams of discretionary oil, 46.58 grams of discretionary solid fat, and 82.33 grams of added sugars per day.

Food groupings

The composite food groups included in the LinQuad demand system are determined by grouping the available foods that participants consumed into 25 food groups, and within each food group, into categories based on the relative amount of discretionary solid fat and of added sugar. Discretionary vegetable oils are not considered as a categorical criterion because many of these oils are "good" oil and the Guidelines focus mostly on solid fat as explained previously. The 25 food groups were defined from available USDA food groupings of foods as eaten based on relative calorie contribution and policy interest. See Appendix for detailed listing of foods in the food groups. The first 2 or 3 digits of the NHANES 2003-04 food codes are used to help identify food groups.

The initial consumption of calorie and nutrients from the 25 composite food groups are shown in Table 1. By applying prices from the USDA Center for Nutrition and Policy Promotion (CNPP) Food Price database (USDA, 2009) we estimate a daily food expenditure for all foods of $5.25 per capita for the total of the 25 composite food groups. Most of the calories that people consume daily are obtained from the composite food group "Breads, etc" (51, 52, and 54), "Grain mixtures" (58-59), and two meats groups. "Oil & Salad dressing" (82-83), "Breads, crackers and snacks" (51, 52, and 54), and "Dry beans, legumes, etc" (41-43) which includes peanut butter are the leading sources of the discretionary oil; "Grain mixtures" (58-59), "Cakes, etc" (53 and 55), "Cheeses" (14), and "Meats" (20-24) are the top sources of discretionary solid fat; and "Soft drinks, carbonated" (924), "Sugars and sweets" (91), and "Cakes, pastries, etc" (53 and 55) are the leading sources of added sugar.

[Insert Table 1 here]

Within each food group, four sub-categories are distinguished based on the calorie percentages from discretionary fat and added sugars of each food (high fat/high sugar; high fat/low sugar; low fat/high sugar; low fat/low sugar). The measures used to identify the four sub-categories within each composite food group are carried out by two alternative ways. One way, and the way reported in the analysis that follows, is by setting the cut-off value based on the Dietary Guidelines (2005). According to the Guidelines, the discretionary calorie allowance accommodated by a 2200 calorie level for an individual is 290 calories, or 13% of total calories. If these discretionary calories are equally divided between discretionary solid fat and added sugar, the cut-off value for the sub-categories of the composite food groups would be 6.59% of total calories for each component (solid fat and added sugar). The other categorical approach is to delineate high/low by comparing the calorie percentage from discretionary fat and added sugars of each individual food item to the average level of the composite food group. The ex-ante concern was that the chosen approach might influence results. Which ex post it does not.

Food items with higher values than the cut-off/average are classified as high fat/high sugar, while foods with equal or lower values than the cut-off/average are classified as low fat/low sugar. With 25 composite food groups in the LinQuad demand system and each food group divided into four sub-categories (25x4), the calories, nutrients, and expenditure data are calculated for the 100 sub-categories. In the rest of the paper, we report results for the cut-off decomposition and simulation results using the average decomposition of the four types of goods are available upon request from the authors. Qualitative results are similar.

[Insert Table 2 here]

Demand parameters

To recover the parameter values in the LinQuad demand system, measures of the income elasticity η_{iI} , own-price elasticity η_{ii}^{M} , cross-price elasticity η_{ij}^{M} , income I , prices P_i , and consumption levels D_i are needed. We obtain them from the following sources.

(1) Income elasticity η_{iI} *and price elasticity* $\eta_{ii}^{M}, \eta_{ij}^{M}$

The USDA/ERS Commodity and Food Elasticity Dataset provides a collection of existing elasticities. The estimates come mostly from academic and government research, as published in journals and working papers. We augmented these elasticities with others from Bhuyan and Lopez, 1997; Reed, Levedahl, and Clark, 2003; Reed, Levedahl, and Hallahan, 2005; and Chouinard et al., 2010. If more than one estimate appears in the same paper, we narrowed our choice as follows: we chose unconditional rather than conditional elasticities, and the most recent-year elasticities. Furthermore, we took the average of the elasticities in the same year, and the average of the elasticities for different brands of the same type of food. When available, we chose estimates for national rather than regional markets, and estimates which are for all the households instead of for disaggregated income groups. Finally, we eliminated positive own-price elasticities, and estimates for specialty foods such as organic milk with very small consumption shares because they would cause a problem in equation (10) by implying an extreme σ. After this initial selection, we removed outlying elasticities which are outside two standard deviations of the mean level of the elasticities for the composite food group and then take the average for the remaining ones.[1]

The summary statistics for the retail Marshallian own-price elasticities and income / total expenditure elasticities in the United States from USDA/ERS Commodity and Food Elasticity Database and other sources are listed in Table 3. The composite food groups “Cheeses” (14), “Meat mixtures” (27, 28, and 77) and “Grain mixtures” (58-59) turn out to be price elastic while others are price inelastic. The food groups “Creams” (12), “Milk desserts and sauces” (13), “Cheeses” (14), “Dry beans, etc” (41-43), “Sugars and sweets” (91), “Coffee & Tea” (921-923), “Soft drinks, carbonated” (924), “Alcoholic beverages” (93), and “Water” (94) are inferior goods. All the available cross-price elasticities are small in absolute value, which means the substitutability or complementarily among the final products will be limited.

[Insert Table 3 here]

(2) Income I

Annual household income in the NHANES 2003-2004 is reported as a range value in dollars. We choose the midpoint of the minimum and maximum of the range as the representative household income for all the individuals who fall in the range. Per capita income is obtained by dividing the

[1] Andreyeva, Long and Brownell (2010) provide a recent systematic review of price elasticities for foods. Although the list of foods differs, the central values for most of the price elasticities are alike except for “cheese” and “sweets/sugars”.

household income in dollars by the household size. Based on the survey sample, the daily income for a representative consumer is $52.68.

(3) Price and quantities

The CNPP Food Prices Database provides the cost of the food consumed in 2003-2004. It shows the average national prices of about 4,600 food items in the "as consumed" form, matched by code to the NHANES 2003-04. The "as consumed" form of the food accounts for the loss and gain during the cooking process and the weight of inedible portion. The food prices are the weighted averages of food prices at all food outlets and for all portion sizes, and reflect the location where the foods are purchased. There are no available "as purchased" food prices mapped to the USDA food codes, so we choose the "as consumed" food prices. The maintained assumption is that the purchased and finally prepared forms of any item are similar. For most of the food items, the food price from CNPP can be exactly matched to the consumption and nutrient data by the USDA food codes and a few missing prices are replaced by close substitutes. Prices from Bureau of Labor Statistics Consumer Price Index Database are used for all the "Alcoholic beverages" and the means of U.S. city average price in 2003 and 2004 for "Malt beverages", "Bourbon whiskey", "Vodka", and "Wine" are matched to the USDA food codes.

The expenditures on the foods are obtained by multiplying quantities of foods in the NHANES 2003-2004 times the food prices in the CNPP Food Price Database and BLS CPI Database. This allows aggregation by expenditures. And we also implicitly assume that the home preparation share for foods is the same for all foods, an approximation for which we have no other choice. All the prices for composite foods and sub-categories are initially set at $1 per unit and expenditures become the new quantities. This type of normalization is standard in calibration and results are independent of this normalization.

(4) Elasticity of substitution σ_i

We use the same source and screening process of the own-price elasticities for the sub-categories as elasticities for the composite food groups to derive the within group elasticities of substitution using equation (10). The problem is over identification since for each own-price elasticity, four corresponding elasticity of substitution can be calculated from equation (10) based on which of the four sub-category the own-price elasticity is assigned to. We take the mean of the elasticity of substitution for each sub-category after removing the outliers which are outside two standard deviations of the mean level. Small shares of sub-category in the composite food group will lead to small values of elasticity of substitution. For shares which are lower than 5%, the corresponding elasticity of substitutions is removed.

The cut-off classification approach shows that 98.82% products in the composite “Cheese” (14) group are High fat & Low sugar, which gives an elasticity of the value 86.94. The cut-off classification approach also shows that 90.13% products in the composite “Grain mixtures” (58-59) group are High fat & Low sugar, which gives an elasticity of the value 15.27. Since these two values are not credible, we replace them with the ones obtained from the average classification measure. The final calculated σ_i’s under the cut-off approach are listed in Table 4.

[Insert Table4 here]

Implementation and Results

Calibration of demand systems with CES

We calibrate the LinQuad demand system for the 25 composite food groups using the own-price and income/total expenditure elasticities from Tables 3 and cross-price elasticities. The Marshallian price elasticity matrix for the composite food groups is recovered with the parameters in the LinQuad demand system. The parameters are used in the calculation of the demand for foods, calorie, nutrients, and the welfare evaluation. The parameters within each composite food groups are derived from the values of elasticity of substitution σ_i from Table 4 through equations (8)-(9).

Next we implement a tax scenario with the simple demand system and then with the augmented system with the within group substitution to explore what is missed when one abstracts from this important substitution.

A tax on calories from added sugar

Our analysis focuses on a food tax proportional to calories from added sugars embodied in each food type. The calorie and nutrient densities for the composite food groups before tax are measured in calorie/nutrient content per unit of food. Since we normalized initial prices to $1 these densities can be interpreted as the calories and nutrients per dollar of consumption.

The composite food groups “Sugars and sweets” (91), “Soft drinks, carbonated” (924), “Cakes, etc” (53 and 55), “Milk desserts and sauces” (13), and “Fruit juices” (612, 641, 642, 644, and 92) are the most intensive in added sugar. The added sugars densities of the sub-categories within the composite food groups vary significantly within food groups. For example, the cut-off based measure shows that the added sugars density for the LH sub-category in “Soft drink, carbonated” (924) is high while that of the LL sub-category is zero since they are unsweetened or sugar free.

A representative consumer expends $5.25 per day on the 25 composite food groups which provide 2187 calories. We choose the ratio of the daily expense to the total calorie intake as the price of calories consumed (here, equal to $5.25/2187 = $0.0024/calorie). This is approximate of course but a transparent way to derive the calorie price. The policy scenario looks at the impact of a 10% tax on the price of calories. That is, the unit price of each calorie is assumed to be 0.24 cents and rises up to 0.264 cents with the tax. As example, a 12 ounce can of coke contains 140 calories which are all from added sugar. By imposing a 10% tax on calories from added sugar, the tax would be equivalent to 3.35 cents. This tax is reasonable and in the vicinity of tax proposals being debated (see for example, Adamy, 2009; Powell and Chriqui, forthcoming; and Smith, Lin and Lee, 2010).

Results based on the simple demand system (no sub-categories)

The 10% tax on calories from added sugars is proportionate to the added sugars density of food groups. Results are shown in Table 5. Table 5 shows that with 10% tax on the price of calories from added sugar, the demands in most composite food groups decrease except “Potatoes” (71), “Fats” (81), “Water” (94) and “Alcoholic beverages” (93). The demands for “Soft drinks, carbonated” (924), “Sugar and sweets” (91), “Cakes, etc” (53 and 55), “Fruit juices” (612, 641, 642, 644, and 92), and “Milk desserts and sauces” (13) decrease the most since they are the most intensive in added sugars.

[Insert Table 5 here]

Calorie and nutrient consumption changes along with quantities in the demand system. Since the simulation is based on the composite food groups only, the calorie and nutrient components for each composite food group are assumed to remain constant throughout the policy shock. The changes in calorie and nutrient intakes from each composite food group are exactly the same as those changes of the demands of the composite food groups. The exceptions are “Soft drinks, carbonated” (924) which has no discretionary solid fat content and “Water” (94). The corresponding nutrient consumptions from these composite food groups remain zeros throughout the simulation.

With the tax, the total calorie intake from the 25 composite food groups decreases 1.56%, or 34.09 calories per day (Table 6). The total discretionary solid fat and added sugars intakes obtained from all food groups decrease 0.90% and 5.53%, respectively, for amounts equivalent to 3.91 calories, and 18.95 calories assuming that solid fat provides 9 calorie/gram while added sugars provide 4 calorie/gram (Table 7). Over half (53.4%) of the reduction in the daily calorie intake comes from the reduction in the added sugars consumption. Nearly 70% of reduction in the daily calorie intake (23.72 calories out of 34.09 calories) is achieved from the reduction in discretionary oil, discretionary solid fat, and added sugars consumption.

Simulation with the expanded demand system (with sub-categories in composite groups)

Table 5 shows the results for the cut-off approach to sub-categories. Technical Appendices I and K show the results for the average classification. Each sub-category within any composite food group faces a different specific tax given heterogeneous intensity of added sugar. The HH and LH sub-categories see larger price increases than the other two categories because they are both "high" in the added sugar. The new composite food prices in this simulation based on sub-categories are derived from equation (8) reflecting the new shares of each sub-category. Differences are minor between the new composite food prices with or without accounting for the within group substitution. Not surprisingly, the 10% tax on calories from added sugars causes decreases in the demands of most composite food groups except "Potatoes" (71), "Fats" (81), "Water" (94) and "Alcoholic beverages" (93), just as the simulation based on composite food groups only did. Magnitudes are also comparable as shown in Table 5.

More interestingly, Table 5 also provides the proportional changes of sub-categories. The demands of HH and LH sub-categories within the composite food group decrease. Both measures show that "Fruits" (61-67) has big reductions in the demand of LH and HH sub-categories. "Soft drinks, carbonated" (924), "Sugars and sweets" (91), and "Coffee and Tea"

(921-923) all have around 15% reductions in their HH or LH sub-categories demands. “Fruit juices” (612, 641, 642, 644, and 92)” has a 10% reduction in the LH sub-category demand. “Breads, etc” (51, 52, and 54) has comparatively big reductions in HH and LH sub-categories demands. The largest demand increases -- over 15% -- are in the HL and LL sub-categories for “Milk desserts and sauces” (13). “Soft drinks, carbonated” (924) has the second largest demand increase in LL sub-category which is over 10%; “Sugars and sweets” (91), “Fruit juices” (612, 641, 642, 644, and 92), “Cakes, etc” (53 and 55), “Pastas and cereals” (56-57), and “Creams” (12) have relatively large increases in the HL and LL sub-categories demands as well. For those HL and LL sub-categories that have decreases in demands, the magnitudes of the decreases are small compared to the decreases in HH and LH sub-categories.

Comparing the calorie/nutrient densities before and after the tax shows that added sugars densities for all the composite food groups decline to lower levels with the tax. But whether the calorie and discretionary solid fat densities decrease or not varies for different composite food groups. This suggests that consumers switch to low-sugar choices within food groups but the side effects on the discretionary solid fat and oil choices depend on the particular composite food group. Tables 6 and 7 present the calorie and nutrient intake changes induced by the tax on calories from added sugar.

[Insert Tables 6-7 here]

The total calorie intake reduction is about 2%, equivalent to 47 calories per day. The total discretionary solid fat intake reduction is small (0.87% (3.64 calories)). The total added sugars intake reduction is around 11% or 35 calories per day. Nearly three fourths of the reduction in the daily calorie intake is achieved from the reduction in the added sugars consumption.

Comparison of simulations with and without sub-categories within the composite food groups

With the tax implemented, calorie and nutrient intakes obtained by accounting for sub-categories deviate from those obtained without sub-categories. The differences show up not only in the magnitude of the changes but a few times in their direction.

For the calorie, discretionary solid fat and added sugars intakes (Tables 6 and 7), simulations without sub-categories show that for some groups, a tax on calories from added sugars leads to decreases in the total calorie intake from the composite food group, but increase in total calorie intake when allowing within-group substitution (“Dry beans, etc” (41-43), and “Pastas and cereals” (56-57)). In addition, for solid fat, “Pastas and cereals” (56-57) shows a decrease without the CES composite good approach, but an increase once the within-group substitution is accounted for. For added sugar, “Fats” (81) shows a small increase without the CES, but a decrease with the within group substitution. As shown in Table 6, several foods exhibit much larger caloric decreases once the within-group substitution is accounted for, especially in food types intensive in added sugar, such as “Soft drinks” (924), and “Coffee and tea” (921-923). In aggregate, the decrease in calorie intake is considerably underestimated by the simple approach (2.17% versus 1.56% decreases). As shown at the bottom of Table 7, the aggregate reduction in added sugars in the simple approach is underestimated by nearly 100% (5.53% versus 10.78% decreases without and with the substitution).

Conversely, in some cases, ignoring the substitution within the food group leads to overstating reductions, as for solid fat intake for “Sugar and sweets” (91) (6.85% reduction versus 1.23% reduction). Similar discrepancies are present for other food groups as well. Total discretionary solid fat consumption decreases less when accounting for the within-group substitution, but the aggregate difference is small as shown at the bottom of Table 7 (0.90% reduction versus 0.87% reduction).

The real expenditure changes under either approach are small. Table 8 shows the welfare losses due to the tax. Although the welfare losses are small, they are relatively much larger when using the simple approach that does not account for the within-group substitution. The simple method without the within-group substitution considerably overstates the cost of abating added sugar. The cost of abating added sugars is twice as large in the simple approach in comparison to the approach that accounts for the within group substitution. Overall, the simple method overstates the cost of abating calories by over 40% with a tax on calories from added sugar. The efficiency measure is expressed as the ratio of dollars of EV per unit abated (grams or calories).

[Insert Table 8 here]

Summary and Discussion

In the context of obesity taxes, this paper investigated the importance of accounting for consumers' possibilities to substitute low fat/low sugar substitutes for high fat and high sugar food items that are targeted by taxes. To do so, we incorporated an explicit CES nesting of four close substitutes (with high or low intensity of added sugar, and discretionary fats) into a demand system for 25 food composite goods relevant for obesity policy analysis. We incorporated the 4-substitute CES structure into the LinQuad demand system and calibrate the augmented demand system for the (25x4) goods using NHANES data and estimates of price and income elasticities. The calibration step was done conservatively to avoid outlying elasticity values and reflect central estimates available in the literature. Then we implemented a tax on calories from added sugars to show the implications of ignoring within-food group substitution possibilities. This abstraction characterizes most of the literature analyzing food taxes.

Accounting for this substitution within food groups has important consequences on the assessment of food taxes targeting obesity. With taxes in place the internal composition of the food group changes towards leaner and lighter choices to abate the taxes. Hence, the estimated impact on calorie and added sugars intake now reflects these choices and so larger reductions when the within group substitution occurs; the estimated welfare cost of the tax is much smaller than when it is estimated by abstracting from this within-group substitution. The EV per unit of calorie/nutrient consumption reduction is considerably overstated by the simpler approaches overlooking the consumers' ability to substitute within food groups.

This framework of this paper could be extended. First, we only investigated the results when a tax is imposed on calories from added sweeteners. A tax on other nutrients and other tax designs could be considered including, some thin subsidies. One could also include more demographics into the analysis to explore the consumption patterns of at-risk sub demographic groups. Finally the analysis could incorporate various external effects on health and morbidity.

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Table 1. Initial Consumption of Calorie and Nutrients from Composite Food Groups

Composite food groups	Initial consumption			
	Calorie (kcal)	Discretionary oil (g)	Discretionary solid fat (g)	Added sugars (g)
Milk and milk drinks (11)	102.05	0.10	2.99	2.85
Creams (12)	14.83	0.11	1.13	0.54
Milk desserts and sauces (13)	46.39	0.04	2.21	3.86
Cheeses (14)	59.98	0.01	4.39	0.05
Meats (20-24)	172.88	0.99	4.03	0.06
Organ meats, sausages and lunchmeats (25)	58.55	0.01	2.81	0.08
Fish and shellfish (26)	27.75	0.29	0.50	0.04
Meat mixtures (27, 28, 77)	161.10	1.61	3.69	0.98
Eggs (31-35)	46.78	0.30	1.91	0.05
Dry beans, legumes, and nuts (41-43)	73.62	2.81	0.32	0.61
Breads, Crackers and salty snacks from grain (51, 52, 54)	262.36	2.83	3.10	3.75
Cakes, pastries & other grain products (53, 55)	140.55	0.59	4.75	10.00
Pastas and cereals (56-57)	97.14	0.25	0.34	2.91
Grain mixtures (58-59)	244.54	0.96	7.66	0.55
Fruits excluding juice (61-67, excluding 612, 641, 642, 644)	49.60	0.01	0.00	0.63
Fruit juices & Nonalcoholic beverages (612, 641, 642, 644, 92)	76.79	0.00	0.01	7.95
Potatoes (71)	102.70	1.96	2.83	0.03
Other vegetables (72-76)	62.15	0.61	1.08	0.94
Fats (81)	26.61	1.02	1.94	0.02
Oils & Salad dressings (82-83)	44.98	4.44	0.12	0.67
Sugars and sweets (91)	72.44	0.90	0.58	10.92
Coffee & Tea (921-923)	22.02	0.00	0.16	3.38
Soft drinks, carbonated (924)	129.16	0.00	0.00	30.67
Alcoholic beverages (93)	92.05	0.00	0.02	0.79
Water (94)	0.06	0.00	0.00	0.00
Total	2187.06	19.85	46.58	82.33

Table 2. Calories, Nutrients, and Expenditures of Selected Foods by Cut-off Measure

Composite food groups	Sub-categories[a]	Share of Total Calories[b]	Percent contribution to total calories			Food expenditure ($)
			Discret. oil[c]	Discret. solid fat[c]	sugars[c]	
Milk and milk drinks (11)	aggregate	4.67%	0.85%	26.38%	11.16%	0.22
	HH	1.09%	1.44%	19.88%	38.96%	0.05
	HL	2.73%	0.00%	36.96%	0.00%	0.11
	LH	0.23%	5.72%	1.22%	40.83%	0.01
	LL	0.61%	1.76%	0.16%	0.00%	0.06
Creams (12)	aggregate	0.68%	6.49%	68.51%	14.48%	0.03
	HH	0.28%	0.01%	64.28%	34.42%	0.01
	HL	0.39%	11.27%	72.24%	0.12%	0.01
	LL	0.00%	0.00%	0.00%	0.00%	0.00
Milk desserts and sauces (13)	aggregate	2.12%	0.78%	42.88%	33.31%	0.07
	HH	1.92%	0.56%	43.45%	35.48%	0.07
	HL	0.14%	1.97%	51.55%	0.66%	0.00
	LH	0.06%	5.43%	3.20%	43.43%	0.00
	LL	0.00%	0.44%	0.19%	0.00%	0.00
Cheeses (14)	aggregate	2.74%	0.15%	65.93%	0.31%	0.14
	HH	0.01%	0.03%	25.84%	24.46%	0.00
	HL	2.72%	0.15%	66.31%	0.25%	0.14
	LL	0.01%	0.24%	3.43%	0.00%	0.00
Breads, Crackers & snacks from grain products (51, 52, 54)	aggregate	12.00%	9.70%	10.63%	5.72%	0.24
	HH	1.49%	1.32%	26.79%	22.19%	0.04
	HL	3.88%	4.82%	20.94%	2.05%	0.08
	LH	1.73%	10.42%	0.16%	9.13%	0.01
	LL	4.90%	15.86%	1.24%	2.41%	0.11
Cakes, pastries & other grain products (53, 55)	aggregate	6.43%	3.78%	30.44%	28.45%	0.18
	HH	5.38%	2.07%	34.01%	31.01%	0.13
	HL	0.50%	1.99%	23.39%	1.56%	0.02
	LH	0.54%	22.04%	1.87%	28.25%	0.02
	LL	0.01%	36.35%	6.04%	0.00%	0.00
Pastas and cereals (56-57)	aggregate	4.44%	2.32%	3.20%	11.99%	0.12
	HH	0.17%	2.07%	13.19%	33.05%	0.01
	HL	0.17%	0.81%	29.17%	0.02%	0.00
	LH	1.93%	2.13%	1.28%	24.34%	0.07
	LL	2.17%	2.63%	2.06%	0.28%	0.03
Grain mixtures (58-59)	aggregate	11.18%	3.52%	28.19%	0.91%	0.53
	HH	0.08%	0.19%	27.04%	7.91%	0.00
	HL	10.01%	1.63%	31.09%	0.75%	0.48
	LH	0.05%	3.13%	0.00%	14.30%	0.00
	LL	1.04%	21.95%	1.76%	1.26%	0.05
Fruit juices (612, 641, 642, 644, 92)	aggregate	3.51%	0.04%	0.08%	41.41%	0.16
	HH	0.02%	0.42%	15.04%	57.78%	0.00
	LH	1.83%	0.07%	0.01%	78.86%	0.09
	LL	1.66%	0.00%	0.00%	0.00%	0.08
Sugars and sweets (91)	aggregate	3.31%	11.23%	7.19%	60.30%	0.10
	HH	1.38%	23.69%	16.40%	39.94%	0.05
	HL	0.01%	16.81%	38.56%	4.10%	0.00
	LH	1.84%	2.34%	0.35%	78.43%	0.04
	LL	0.08%	0.00%	0.00%	0.05%	0.00

Soft drinks, carbonated (924)	aggregate	5.91%	0.00%	0.00%	95.00%	0.30
	LH	5.80%	0.00%	0.00%	96.74%	0.21
	LL	0.11%	0.00%	0.00%	0.00%	0.09

a- HH stands for High fat & High sugar; HL stands for High fat & Low sugar; LH stands for Low fat & High sugar; LL stands for Low fat & Low sugar.

b- Calorie distribution within this column sums to 100%.

c- Each gram of discretionary oil and of discretionary solid fat provides 9 calories; each gram of added sugars provides 4 calories.

Table 3. Own-Price and Income (Total Expenditures) Elasticities of Composite Food Groups

Composite food groups	Elasticities							
	Own-Price Elasticity				Income (Total Expenditures) Elasticity			
	Mean	SD	Min	Max	Mean	SD	Min	Max
Milk and milk drinks (11)	-0.75	0.27	-0.24	-1.49	0.04	0.57	1.01	-0.56
Creams (12)	-0.45	0.13	-0.29	-0.60	-0.13	0.12	0.02	-0.26
Milk desserts and sauces (13)	-0.65	0.28	-0.34	-0.87	-0.19	0.31	0.04	-0.41
Cheeses (14)	-1.03	0.61	-0.33	-1.90	-0.08	0.28	0.50	-0.41
Meats (20-24)	-0.79	0.32	-0.07	-1.52	0.78	0.43	1.57	-0.06
Organ meats, sausages and lunchmeats (25)	-0.82	0.42	-0.36	-1.37	0.81	NA	0.81	0.81
Fish and shellfish (26)	-0.46	0.37	-0.18	-1.11	0.99	1.49	2.99	-0.48
Meat mixtures (27, 28, 77)	-1.51	0.78	-0.95	-2.06	0.58	0.95	1.26	-0.09
Eggs (31-35)	-0.11	0.05	-0.06	-0.15	0.35	0.67	0.82	-0.12
Dry beans, legumes, and nuts (41-43)	-0.77	0.50	-0.12	-1.19	-0.36	0.15	-0.21	-0.51
Breads, Crackers and salty snacks from grain (51, 52, 54)	-0.80	0.31	-0.35	-1.15	0.00	0.54	0.73	-0.55
Cakes, pastries & other grain products (53, 55)	-0.70	NA	-0.70	-0.70	0.13	NA	0.13	0.13
Pastas and cereals (56-57)	-0.56	0.29	-0.15	-0.91	0.22	0.52	0.79	-0.23
Grain mixtures (58-59)	-1.51	0.78	-0.95	-2.06	0.58	0.95	1.26	-0.09
Fruits excluding juice (61-67, excluding 612, 641, 642, 644)	-0.62	0.39	-0.03	-1.38	0.63	0.71	2.05	-0.47
Fruit juices & Nonalcoholic beverages (612, 641, 642, 644, 92)	-0.87	0.37	-0.15	-1.53	0.39	0.99	2.12	-1.36
Potatoes (71)	-0.24	0.09	-0.17	-0.37	0.29	NA	0.29	0.29
Other vegetables (72-76)	-0.52	0.44	-0.01	-1.51	0.19	0.30	0.80	-0.27
Fats (81)	-0.41	0.26	-0.14	-0.99	0.63	0.68	1.01	-0.68
Oils & Salad dressings (82-83)	-0.76	0.29	-0.43	-1.13	0.44	0.52	1.03	0.05
Sugars and sweets (91)	-0.74	0.54	0.00	-1.64	-0.20	0.29	0.19	-0.72
Coffee & Tea (921-923)	-0.60	0.45	-0.19	-1.07	-0.27	0.17	-0.15	-0.39
Soft drinks, carbonated (924)	-0.95	0.36	-0.55	-1.26	-0.03	0.08	0.03	-0.09
Alcoholic beverages (93)	-0.90	0.87	-0.29	-2.17	-0.48	NA	-0.48	-0.48
Water (94)	-0.33	NA	-0.33	-0.33	-0.20	NA	-0.20	-0.20

Source: USDA/ERS Commodity and Food Elasticity, 2008; Bhuyan, S. and R.A. Lopez, 1997; Reed, A.J., J.W. Levedahl, and J.S. Clark, 2003; Reed, A.J., J.W. Levedahl, and C. Hallahan, 2005; Chouinard, H.H., et al., 2010.
Note: NA = not available, i.e., only one elasticity is available.

Table 4. Elasticity of Substitution by Two Measures of Defining Sub-categories

Composite food groups	Elasticity of substitution
	Cut-off measure
Milk and milk drinks (11)	1.05
Creams (12)	0.89
Milk desserts and sauces (13)	3.82
Cheeses (14)	2.49
Meats (20-24)	1.63
Organ meats, sausages and lunchmeats (25)	1.60
Fish and shellfish (26)	0.98
Meat mixtures (27, 28, 77)	3.65
Eggs (31-35)	2.33
Dry beans, legumes, and nuts (41-43)	1.29
Breads, Crackers and salty snacks from grain (51, 52, 54)	1.21
Cakes, pastries & other grain products (53, 55)	1.49
Pastas and cereals (56-57)	0.97
Grain mixtures (58-59)	2.40
Fruits excluding juice (61-67, excluding 612, 641, 642, 644)	5.61
Fruit juices & Nonalcoholic beverages (612, 641, 642, 644, 92)	1.73
Potatoes (71)	0.49
Other vegetables (72-76)	1.03
Fats (81)	0.98
Oils & Salad dressings (82-83)	1.18
Sugars and sweets (91)	1.41
Coffee & Tea (921-923)	1.03
Soft drinks, carbonated (924)	2.22
Alcoholic beverages (93)	2.64
Water (94)	[a]

a- All the products in this composite food group are defined as Low Fat & Low Sugar.

Table 5. Demand Changes with Tax on Calories from Added Sugars by Cut-off Measure

Composite food groups	Relative change in demand (%)					
	Without CES	With CES				
		Composite	HH	HL	LH	LL
Milk and milk drinks (11)	-0.45%	-0.44%	-3.85%	0.82%	-3.83%	0.82%
Creams (12)	-0.63%	-0.63%	-2.77%	1.06%	NA	1.08%
Milk desserts and sauces (13)	-2.82%	-2.81%	-4.04%	16.52%	-3.93%	17.03%
Cheeses (14)	-0.06%	-0.06%	-3.81%	-0.05%	NA	0.02%
Meats (20-24)	-0.36%	-0.36%	-1.04%	-0.35%	NA	-0.35%
Organ meats, sausages and lunchmeats (25)	-0.55%	-0.54%	NA	-0.54%	-1.14%	-0.47%
Fish and shellfish (26)	-0.80%	-0.78%	NA	-0.79%	-1.89%	-0.77%
Meat mixtures (27, 28, 77)	-0.42%	-0.41%	-3.40%	-0.41%	-2.75%	-0.04%
Eggs (31-35)	-0.36%	-0.36%	-1.85%	-0.34%	-36.08%	-0.21%
Dry beans, legumes, and nuts (41-43)	-0.17%	-0.17%	-2.98%	0.44%	-1.25%	0.29%
Breads, Crackers and salty snacks from grain (51, 52, 54)	-1.20%	-1.18%	-4.55%	-0.03%	-8.17%	-0.10%
Cakes, pastries & other grain products (53, 55)	-3.87%	-3.84%	-5.41%	3.75%	-1.15%	4.07%
Pastas and cereals (56-57)	-0.13%	-0.15%	-2.67%	2.18%	-1.06%	2.09%
Grain mixtures (58-59)	-0.23%	-0.23%	-2.07%	-0.19%	-4.00%	-0.35%
Fruits excluding juice (61-67, excluding 612, 641, 642, 644)	-0.46%	-0.43%	-6.40%	-1.46%	-21.78%	0.90%
Fruit juices & Nonalcoholic beverages (612, 641, 642, 644, 92)	-3.42%	-3.29%	-4.91%	NA	-9.63%	4.35%
Potatoes (71)	0.48%	0.47%	-0.87%	0.48%	NA	0.46%
Other vegetables (72-76)	-0.42%	-0.41%	-3.99%	-0.21%	-4.57%	-0.21%
Fats (81)	0.04%	0.05%	-4.84%	0.13%	NA	-0.06%
Oils & Salad dressings (82-83)	-1.39%	-1.39%	-1.06%	0.28%	-2.82%	-0.33%
Sugars and sweets (91)	-6.85%	-6.69%	-1.05%	6.40%	-14.35%	6.79%
Coffee & Tea (921-923)	-2.17%	-2.07%	-3.94%	0.57%	-13.32%	0.57%
Soft drinks, carbonated (924)	-9.36%	-8.92%	NA	NA	-17.40%	11.09%
Alcoholic beverages (93)	0.00%	0.00%	-0.96%	NA	-1.06%	0.29%
Water (94)	0.03%	0.03%	NA	NA	NA	0.03%

a- HH stands for High fat & High sugar; HL stands for High fat & Low sugar; LH stands for Low fat & High sugar; LL stands for Low fat & Low sugar.
b- NA = not available, i.e., No food item is classified into the particular sub-category.

Table 6. Percentage Change in Calories with Tax on Calories from Added Sugars

Composite food groups	Calories consumption		
	Initial consumption (calorie)	Consumption change (%)	
		Without CES	With CES by Cut-off measure
Milk and milk drinks (11)	102.05	-0.45%	-0.51%
Creams (12)	14.83	-0.63%	-0.54%
Milk desserts and sauces (13)	46.39	-2.82%	-2.63%
Cheeses (14)	59.98	-0.06%	-0.05%
Meats (20-24)	172.88	-0.36%	-0.36%
Organ meats, sausages and lunchmeats (25)	58.55	-0.55%	-0.54%
Fish and shellfish (26)	27.75	-0.80%	-0.79%
Meat mixtures (27, 28, 77)	161.10	-0.42%	-0.44%
Eggs (31-35)	46.78	-0.36%	-0.36%
Dry beans, legumes, and nuts (41-43)	73.62	-0.17%	0.04%
Breads, Crackers and salty snacks from grain (51, 52, 54)	262.36	-1.20%	-1.79%
Cakes, pastries & other grain products (53, 55)	140.55	-3.87%	-4.33%
Pastas and cereals (56-57)	97.14	-0.13%	0.54%
Grain mixtures (58-59)	244.54	-0.23%	-0.23%
Fruits excluding juice (61-67, excluding 612, 641, 642, 644)	49.60	-0.46%	-1.20%
Fruit juices & Nonalcoholic beverages (612, 641, 642, 644, 92)	76.79	-3.42%	-2.98%
Potatoes (71)	102.70	0.48%	0.47%
Other vegetables (72-76)	62.15	-0.42%	-0.70%
Fats (81)	26.61	0.04%	0.05%
Oils & Salad dressings (82-83)	44.98	-1.39%	-0.96%
Sugars and sweets (91)	72.44	-6.85%	-8.24%
Coffee & Tea (921-923)	22.02	-2.17%	-7.88%
Soft drinks, carbonated (924)	129.16	-9.36%	-16.89%
Alcoholic beverages (93)	92.05	0.00%	0.09%
Water (94)	0.06	0.03%	0.03%
Total	2187.06	-1.56%	-2.17%

Table 7. Percentage Change in Calories from Discretionary Solid Fat and Added Sugars with Tax on Calories from Added Sugar

Composite food groups	Discretionary solid fat consumption			Added sugars consumption		
	Initial consumption (g)	Consumption change rate		Initial consumption (g)	Consumption change rate	
		Without CES	With CES by Cut-off measure		Without CES	With CES by Cut-off measure
Milk and milk drinks (11)	2.99	-0.45%	-0.02%	2.85	-0.45%	-3.85%
Creams (12)	1.13	-0.63%	-0.44%	0.54	-0.63%	-2.75%
Milk desserts and sauces (13)	2.21	-2.82%	-2.38%	3.86	-2.82%	-4.01%
Cheeses (14)	4.39	-0.06%	-0.05%	0.05	-0.06%	-0.77%
Meats (20-24)	4.03	-0.36%	-0.37%	0.06	-0.36%	-0.74%
Organ meats, sausages and lunchmeats (25)	2.81	-0.55%	-0.54%	0.08	-0.55%	-0.78%
Fish and shellfish (26)	0.50	-0.80%	-0.79%	0.04	-0.80%	-0.82%
Meat mixtures (27, 28, 77)	3.69	-0.42%	-0.47%	0.98	-0.42%	-0.79%
Eggs (31-35)	1.91	-0.36%	-0.34%	0.05	-0.36%	-4.99%
Dry beans, legumes, and nuts (41-43)	0.32	-0.17%	-0.10%	0.61	-0.17%	-1.41%
Breads, Crackers and salty snacks from grain (51, 52, 54)	3.10	-1.20%	-1.46%	3.75	-1.20%	-4.09%
Cakes, pastries & other grain products (53, 55)	4.75	-3.87%	-4.84%	10.00	-3.87%	-5.01%
Pastas and cereals (56-57)	0.34	-0.13%	0.80%	2.91	-0.13%	-1.19%
Grain mixtures (58-59)	7.66	-0.23%	-0.20%	0.55	-0.23%	-0.58%
Fruits excluding juice (61-67, excluding 612, 641, 642, 644)	0.00	-0.46%	-3.39%	0.63	-0.46%	-21.72%
Fruit juices & Nonalcoholic beverages (612, 641, 642, 644, 92)	0.01	-3.42%	-5.15%	7.95	-3.42%	-9.59%
Potatoes (71)	2.83	0.48%	0.48%	0.03	0.48%	0.42%
Other vegetables (72-76)	1.08	-0.42%	-0.30%	0.94	-0.42%	-4.08%
Fats (81)	1.94	0.04%	0.11%	0.02	0.04%	-2.44%
Oils & Salad dressings (82-83)	0.12	-1.39%	-0.34%	0.67	-1.39%	-2.19%
Sugars and sweets (91)	0.58	-6.85%	-1.23%	10.92	-6.85%	-10.68%
Coffee & Tea (921-923)	0.16	-2.17%	-1.57%	3.38	-2.17%	-12.40%
Soft drinks, carbonated (924)	0.00	0.00%	0.00%	30.67	-9.36%	-17.40%
Alcoholic beverages (93)	0.02	0.00%	-0.96%	0.79	0.00%	-1.04%
Water (94)	0.00	0.00%	0.00%	0.00	0.00%	0.00%
Total	46.58	-0.90%	-0.87%	82.33	-5.53%	-10.78%

Table 8. Welfare Loss per Unit of Nutrient Consumption Reduced with Tax on Calories from Added Sugars

	Without CES	With CES by Cut-off measure
EV/Calorie reduction ($/calorie)	0.0023	0.0016
EV/Discretionary solid fat reduction ($/g)	0.1842	0.1843
EV/Added sugars reduction ($/g)	0.0169	0.0084

Note: EV is equivalent variation.

Appendix Table. Food Groups and Details on Foods Included in the Food Groups

Food Group	**Detailed Components**
Milks and milk drinks (11)	
Creams (12)	Dairy cream, cream substitutes, sour cream
Milk desserts and sauces (13)	Milk desserts (frozen), puddings, and white sauces and gravies
Cheeses (14)	Cheese, cheese mixtures and soups
Meats (20-24)	Beef , Pork, Lamb, veal, game, other carcass meat & Poultry
Organ meats, sausages and lunchmeats (25)	
Fish and shellfish (26)	
Meat in mixtures (27, 28, 77)	Meat, poultry, fish with nonmeat items and sandwiches with meat; Frozen and shelf-stable plate meals, soups, and gravies with meat, poultry, fish base; Vegetables with meat, poultry, fish
Eggs (31-35)	Eggs, egg mixtures, substitutes and egg-based frozen plate meals
Dry beans, legumes and nuts (41-43)	Legumes (including frozen and soups), nuts, nut butters, seeds and carob products
Breads, Crackers & snacks from grain (51, 52, 54)	Yeast breads, rolls; Quick breads; Crackers and salty snacks from grain products
Cakes, pastries & other grain products (53, 55)	Cakes, cookies, pies, pastries & Pancakes, waffles, French toast, other grain products
Pasta and cereals (56-57)	Pastas, cooked cereals, rice & Cereals, not cooked or ns as to cooked
Grain mixtures (58-59)	Grain mixtures, frozen plate meals, soups & Meat substitutes, mainly cereal protein
Fruits excluding juice (61-67, excluding 612+641+642+644)	
Fruit juices (612, 641, 642, 644, 92)	Fruit juices & Nectars & Vinegar & Nonalcoholic beverages (excluding Coffee & Tea & Soft drinks, carbonated). Includes fruitades and drinks, energy drinks, and other noncarbonated beverages.
Potatoes (71)	White potatoes and Puerto Rican starchy vegetables
Other vegetables (72-76)	Dark green, deep yellow, tomatoes and tomato mixtures, other vegetables
Fats (81)	Table fats, cooking fats
Oils (82-83)	Vegetable oils & salad dressings
Sugars and sweets (91)	Sugars, syrups, honey, jellies, ices, and candies
Coffee & Tea (921-923)	Coffee and tea
Soft drinks, carbonated (924)	Soft drinks, carbonated
Alcoholic beverages (93)	Beers, cordials/liquers, wines, and distilled liquors
Water (94)	Water, noncarbonated. Includes tap water, bottled water, and bottled/fortified water