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

Zhen Miao, John C. Beghin, and Helen H. Jensen*

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Abstract

We extend the existing literature on food taxes targeting obesity. We systematically incorporate the implicit substitution between added sugars and solid fats into a comprehensive food demand system and evaluate the effect of taxes on sugars and fats. The approach conditions how food and obesity taxes affect total calorie intake. The proposed methodology 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 calibrated demand system in addition to the substitution among food groups, using recent food intake data and existing demand elasticities. Simulations of taxes on added sugars and solid fat show that their impact on consumption patterns is understated and the induced welfare loss is overstated when abstracting from the substitution possibilities within food groups.

Keywords: Fat; sugar; low-fat and low-sugar substitutes; food demand; health policy nutrition; obesity; sweeteners; tax.

JEL code: I18, Q18

*Zhen Miao is a PhD candidate and graduate research assistant in the Department of Economics and Center for Agricultural and Rural Development at Iowa State University. John Beghin is the Marlin Cole Professor of International Agricultural Economics in the Department of Economics at Iowa State University. Helen Jensen is a professor of economics in the Department of Economics and Center for Agricultural and Rural Development at Iowa State University. The authors acknowledge partial financial support from USDA under the National Research Initiative Program (2006-55215-16720). Beghin also acknowledges support from the Marlin Cole Professorship.

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

The United States faces a major health problem in the high prevalence of obesity and its underlying cause—an imbalance between energy intake and energy requirements (Ogden and Carroll, 2010; and Ogden et al. 2007). Obesity is associated with excessive morbidity and raises concerns about determinants of dietary choice. 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. Health policies aim to encourage individuals to reduce excess calorie intake and choose healthier foods. Policy analysts and policymakers have considered several instruments to induce consumers to more closely adhere to current dietary guidance, including taxes on specific foods and food components.

The objective of this article is to explore the consumption and welfare effects of taxes that target two important sources of excess calorie intake: added sugars and caloric sweeteners, and solid fats (Ogden et al, 2011).[1] These food components are present in various foods. Most of the existing research on food taxes and obesity treat the food groups 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 systematically consider sub-categories within food groups or account for the possible trade-off between targeted food

[1] Although sugars are found naturally in food, most are "added" during food processing and preparation. The sugars and caloric sweeteners added during food processing, preparation and at the table are referred to "added sugars". Fats that are solid at room temperature are referred to as "solid fats". These fats occur naturally or can be added. Solid fats generally include a high percentage of saturated and/or trans fatty acids. The fat in fluid milk is also considered solid fat (USDA/DHHS 2010).

components such as added sugars and fats, and the overall effect on total calorie intake. Smed, Jensen, and Denver (2007) considered taxes on combinations of foods and food components and their impact on food and nutrient consumption in Denmark. They find that consumers trade off sugar and saturated fat when only one of these components is taxed by abating one but increasing the other. Other recent studies (Smith, Lin, and Lee, 2010; Bonnet and Requillart, 2011) 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, and this is the void we fill.

We investigate the attribution of excess calories and the welfare loss when taxes are imposed on added sugar and solid fat, 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 food groups. An important conjecture to investigate is that the welfare cost of abating sugar and fat and their associated calories could be systematically overstated by ignoring consumers' response to a tax as they substitute toward leaner and lighter offerings of the targeted items within food groups. The ineffectiveness of "obesity taxes" has been overstated.

We extend the existing literature with a methodological and empirical contribution. Our study focuses on the two major sources of calories consumed in excessive amounts: solid fat and caloric sweeteners. First, we incorporate the implicit substitution between sugar and fat nutrients implied by a complete food demand system. The approach conditions on how food taxes affect total calorie intake. Second, we propose an empirical methodology that accounts for the actual 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 calibrated 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 and then a tax on solid fat. Policy simulations show that the impact of these taxes on consumption patterns and associated 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 subsidies for “thin” foods because a subsidy on healthy foods may not decrease calorie intake and weight although the quality of diets may improve (French et al. (2001); Schroeter et al. 2008)

Background

The literature on obesity taxes finds that taxes on “unhealthy” food can change consumers’ dietary choices, but their effectiveness is often limited and may induce decreases in health promoting nutrients (Allais, Bertail, and Nichèle 2010; Kuchlet et al. 2005; and Powell and Chriqui, forthcoming). Taxes applied to foods or their calorie content tend to be regressive, falling disproportionally on poor consumers (Allais, Bertail, and Nichèle 2010; Miao, Beghin and Jensen forthcoming; and Smith, Lin, and Lee 2010). Since food demand is price inelastic, these taxes can provide revenue to support other ways of addressing obesity (Powell and Chriqui forthcoming; Smith, Lin, and Lee 2010; and Kuchler, Tegene, and Harris 2005).

Fat and soda taxes can be effective, but 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 a soda tax on caloric soft drinks works well to abate weight but this is not the case for a tax on food away from home because the latter induce substitution for calorie-dense home food. Offering a small subsidy on diet soft drinks reduces calorie intake and weight but not as much as does the soda tax.

One policy instrument designed to limit excessive 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 toward 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.

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, leading to changes in food choices. The changes in food demand translate into 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.

Other approaches target other nutrients or food components, for example added sugar or fat. An important and often neglected aspect of the policy design is the possible trade-off between nutrients and in particular between sugar and fat and the related total effect on calorie intake when a tax is imposed. Richards, Patterson, and Tegene (2007) showed that the addiction (habit persistence) to carbohydrates is a significant determinant of consumption and that taxes could effectively control excessive nutrient intake. However, there is some limited evidence that there is a trade-off between “bad” food components (e.g., fat and sweeteners) when only one nutrient is targeted. 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 and a tax on sugar solves the latter problem. Their results suggest the importance of accounting for substitution possibilities among food choices.

Taxes can be applied directly on the nutrients or food components themselves at the final consumer level (Richards, Patterson and Tegene, 2007) or on sweet and fat inputs in food processing (Bonnet and Requillart, 2011; Miao, Beghin, and Jensen in press;) In either case, the tax on the nutrient or food component 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) found that taxing pretzels did not reduce the carbohydrate intake and increased fat and calorie intake. Taxing nuts reduced fat intake but increased carbohydrate intake. Taxing potato chips successfully reduced fat, carbohydrate, and calorie intake since there were few close substitutes. They 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 at the product level. Smed, Jensen, and Denver (2007) also found that taxing nutrients has a larger effect on nutrient intake than taxing foods. We formalize this idea next.

Model

We systematically address the important aspect of substitution within food groups when assessing the impact of food tax policies by considering a complete food demand system that 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.

The foundations of our modeling approach rely on a two-stage budgeting approach to consumer demand based on homothetic separability. The sub-utility for each consumed composite good is homothetic; these sub-utilities do not have to be additive when aggregated into the utility function. The framework preserves much flexibility in terms of price and income responses of the composite demands at the top utility level. This approach is implicit in many empirical demand systems (Jorgenson, Slesnick, and Stocker 1988). Here, the sub-utility in our approach is characterized to be a CES composite, which is homothetic. Each consumption within any given composite group increases proportionally with the expenditure on the group.

The first level of the demand system is characterized as a LINQUAD demand system for the composite food goods (laFrance 1998; laFrance et al. 2002). The LINQUAD demand system has been used in calibrated applications (Beghin, Bureau, and Drogué 2004; and Miao, Beghin, and Jensen, in press). The LINQUAD model is linear in income and linear and quadratic in prices of composite goods. It is flexible; it does not impose restrictions on income responses or substitution among composite goods. The flexibility of the LINQUAD system mitigates the limitations of the traditional CES approach at the sub-utility level. Here the elasticity of substitution is only constant within each composite group but varies across groups. Similarly, income elasticities can vary across groups and are not unitary as implied by the traditional CES.

In addition, this foundation incorporates more nutrient information into the standard form and explicitly accounts for close substitutes with much variation in fat and/or sweetener content. It reflects the reality of feasible choice sets when shopping. In the actual physical organization of goods, retail outlets often locate the four close substitutes near each other by type of goods (all four types (High/Low fat and sweet) of ice cream products together, etc).

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

$$\underset{\mathbf{D},\mathbf{R}}{Max}\ U(\mathbf{D}, \mathbf{R}) \quad s.t.\ \ \mathbf{P'D} + \mathbf{P_R'R} \le I\ , \tag{1}$$

where U represents the utility function.

The LINQUAD incomplete demand systems approach is easy to calibrate while imposing proper curvature (Beghin, Bureau, and Drogué, 2004). The LINQUAD Marshallian demand equations for composite goods are

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

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 Groups

As stated, in the second stage, 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 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

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

The CES composite form for each food group *i* is

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

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

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

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

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

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

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

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* being a function of the cost share of the sub-category in the composite food group and the elasticity of substitution σ_i within in the composite food group

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

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 nutrient intakes implied by these consumption decisions. A conversion matrix converts the food consumption implied by **D** into the nutrients in food component consumption or $\mathbf{D'C} = \mathbf{N}$, with $\mathbf{N} = [N^F, N^S, N^{cal}]$ being the vector of aggregate nutrients/food components and calories contained in the final products **D**. Superscripts *F, S, cal* represent solid fat, added sugar, and calories contained, respectively. The nutrients could be extended to other nutrients or food components. $\mathbf{C} = [C^F, C^S, C^{cal}]$ is the conversion matrix between food and nutrients/food component and calories with similar superscripts. The price elasticity for the fat nutrient in all food (index j) 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, say, 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 measured by the equivalent variation, *EV*:

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

A similar impact on price and welfare can be derived with a tax imposed proportionally to solid fat. $\mathbf{P^1} = \mathbf{P^0} + \mathbf{C}^F t^F$

Data and Calibration

This section summarizes the key empirical steps of our analysis. An extensive appendix is available from the authors. The recommendations in the 2010 Dietary Guidelines on foods and food components to reduce include recommendations to reduce the intake of calories from solid fats and added sugars, and limit consumption of foods that contain solid fats and added sugars (USDA/DHHS 2010). In our study, the Dietary Guidelines (2010) and the related Food Guide (USDA/ARS 2006) are used as a reference for defining the food groups and sub-categories within the food groups that capture low-/high-fat and sweetener alternatives within each food group. (See Bowman, Friday, and Moshfegh, 2008 for further details).

Several national-level data sources were used to calibrate our model and then simulate scenarios. The National Health and Nutrition Examination Survey (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 that screening, the sample size was 3,015 individuals. The MyPyramid Equivalence Database (MPED) 2.0 was used to convert the amounts of food intake into intake of solid fat and added sugar. Sugar substitutes were not included in added sugars. For a representative individual, the daily calorie intake was 2,187 calories, with daily consumption of 46.58 grams of solid fat, and 82.33 grams of added sugars.

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 solid fat and of added sugar. 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 Table 1 for the group composition.

The initial consumption of calories and nutrients from the 25 composite food groups is shown in Table 1. By applying prices from the USDA Center for Nutrition and Policy Promotion (CNPP) Food Price database (USDA/CNPP 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, crackers and snacks from grain", "Grain mixtures", and two meats groups. "Grain mixtures", "Cakes, pastries and other grain products", "Cheeses", and "Meats" are the top sources of solid fat; and "Soft drinks, carbonated" , "Sugars and sweets" , and "Cakes, pastries, and other grain products" 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 fat and added sugars of each food (high fat/high sugar; high fat/low sugar; low fat/high sugar; low fat/low sugar). We simply delineate high/low by comparing the calorie percentage from fat and added sugars of each individual food item to the average level of the composite food group (see Table 2)[2]. Food items with higher values than the reference (average) value are classified as high fat/high sugar, while foods with equal or lower values than the reference are classified as low fat/low sugar. With 25 composite food groups in the LINQUAD demand

[2] The measures used to identify the four sub-categories within each composite food group were carried out in two alternative ways. A second method was based on setting the reference value based on the Dietary Guidelines (2005): allowing 13% of total calories to come from added sugar or solid fat. This would be 290 calories in a 2,200-calorie diet. If these calories are equally divided between 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 ex ante concern was that the approach chosen to delineate the sub-categories might influence the results, which, ex post, it does not.

system and each food group divided into four sub-categories (25x4), the calories and nutrients data are provided in Table 2. In the rest of the article, we report results for the average measure decomposition. Qualitative results using the cut-off decomposition 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 augment 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 narrow our choice as follows: we choose unconditional rather than conditional elasticities, and the most recent-year elasticities. Furthermore, we take 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 choose estimates for national rather than regional markets, and estimates that are for all the households instead of for disaggregated income groups.

Finally, we eliminate 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 remove outlying elasticities that 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.[3]

The summary statistics for the retail Marshallian own-price elasticities and income and 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", "Meat in mixtures", and "Grain mixtures" turn out to be price elastic while the others are price inelastic. The food groups "Creams" , "Milk desserts and sauces" , "Cheeses" , "Dry beans, legumes and nuts." , "Sugars and sweets" , "Coffee & Tea" , "Soft drinks, carbonated" , "Alcoholic beverages" , and "Water" are inferior goods. All the available cross-price elasticities, available from the same sources, 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 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 foods 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

[3] 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."

gain during the cooking process and the weight of any 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 the Bureau of Labor Statistics Consumer Price Index Database are used for all the "Alcoholic beverages" and the means of U.S. city average prices in 2003 and 2004 for "Malt beverages," "Bourbon whiskey," "Vodka," and "Wine" are matched to the USDA food codes.

The expenditures on food groups 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. 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. Once group expenditures are defined, all 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 the normalization.

(4) Elasticity of substitution σ_i

Last, 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 here is overidentification since for each own-price elasticity, four corresponding elasticities of substitution can be calculated from equation (10) based on which of the four sub-categories the own-price elasticity is assigned to. We take the mean of the elasticities of substitution of each sub-category after removing the outliers that are outside two standard deviations of the mean level. Small shares of the sub-category in the composite food group will lead to small values of elasticity of substitution. For shares that are lower than 5%, the corresponding elasticity of substitutions is removed. The final calculated σ_i's are listed in the last column of Table 3.

Taxing Added Sugar and Solid Fat

Equipped with the calibrated demand system for the 25 composite food groups, each with four within-group substitutes, we consider two tax scenarios focusing on "bad calories" from added sugar and then solid fat. First, for comparison purposes we establish a calorie reduction as the basis of equivalence between scenarios. We consider a calorie reduction equivalent to a soda tax of one cent per liquid ounce. The latter would abate calorie intake by 2.19% based on our model. A representative consumer consumes 2,187 calories daily. The 2.19% reduction gives roughly a 48-calorie daily reduction. The 1-cent per ounce tax reference is in the vicinity of tax proposals being debated (Adamy, 2009; Powell and Chriqui, forthcoming; and Smith, Lin, and Lee, 2010).

The tax on added sugar is imposed proportionally to the sugar content of goods and the rate is chosen to reduce calorie intake by 2.19%. Similarly, the fat tax is proportional to the solid fat content of goods and abates calories by 2.19%. We implement these two tax scenarios contrasting a simplified demand system without within-group substitution to the augmented system with the within-group substitution to explore the implications of abstracting from this important substitution in consumer choice. 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 one, these densities are calories and nutrients per dollar of consumption.

The composite food groups “Sugars and sweets” , “Soft drinks, carbonated” , “Cakes, pastries and other grain products” , “Milk desserts and sauces” , and “Fruit juices” are the most intensive in added sugar. The added sugars densities of the sub-categories within the composite food groups vary noticeably within food groups, and sometimes extremely. Such is the case of “Soft drinks, carbonated” for which the added-sugar density for the LH sub-category is high while that of the LL sub-category is zero (sugar free).

Results based on the simplified demand system (No sub-categories)

Table 4-A shows the changes in demand resulting from the sugar tax and then the fat tax. The column labeled “without CES” under the sugar tax shows that consumption of most composite food groups decrease except for “Potatoes” , “Fats” , “Water” , and “Alcoholic beverages” . Consumption of “Soft drinks, carbonated” , “Sugars and sweets” , “Cakes, pastries and other grain products” , “Fruit juices” , and “Milk desserts and sauces” decreases the most since these groups are the most intensive in added sugars.

The corresponding column for the fat tax in table 4-B shows that groups intensive in solid fat see the largest consumption reductions such as “Fats” , “Cheeses” , and “Creams” . The consumption of “Fruits excluding juice” and many drink categories increases slightly as they do not contain fat (“Coffee and tea” , “Alcoholic beverages” , and “Water” .

[Insert Table 4-A and Table 4- B here]

Calorie and nutrient consumption changes are shown in Tables 5, 6-A, and 6-B, along with their initial levels (calories, grams of added sugar, and grams of solid fat). The simplified simulation is based on the composite food groups only; the calorie and nutrient components for each composite food group remain constant throughout the policy shock.

With the added sugar tax, calories and sugar intake fall through reductions of “Soft drinks” , “Fruit juices” “Cakes, pastries and other grain products” , and “Milk desserts and sauces”. With the fat tax, calories and fat intake fall via lower consumption of “Fats” , “Creams” , “Cheeses” , and the three processed grain groups (“Breads, crackers and snacks from grain”, “Cakes, pastries and other grain products” and “Grain mixtures”).

The sugar tax lowers aggregate added sugars and solid fat intakes by 7.76% and 1.26%, for amounts equivalent to 18.95 and 3.91 calories assuming that added sugars provide 4 calories/gram and solid fat provides 9 calories/gram. Over half (53.4%) of the reduction in the daily calorie intake comes from the reduction in the added sugars consumption with the sugar tax.

With the tax on fat, the calorie reduction comes from an aggregate reduction of fat intake (- 3.12%), whereas sugar intake falls by -1.26%. The “Cakes, pastries and other grain products” sector is intensive in both fat and sugar and the two nutrients decrease with either tax scenario in that sector. The joint abatement of nutrients in other sectors under either tax scheme is limited.

Tax scenario results with the expanded demand system

The columns labeled “with CES” in tables 4-A and 4-B show results for sub-categories for the two scenarios. Each sub-category within any composite food group faces a different specific tax given heterogeneous intensity of added sugar. With the sugar tax, the HH and LH sub-categories see larger price increases than the other two categories because they are both “high” in the added sugar. With the fat tax, the HH and HL categories see the largest changes as they are the fat intensive categories. Looking at just composite groups suggests moderate difference in consumption changes with and without sub-categories. However, subcategories show a great diversity of effects within many groups. The sugar tax causes decreases in the demands of most composite food groups except “Potatoes” , “Fats” , “Water” , and “Alcoholic beverages” . More interestingly, Table 4-A show that the “Fruits excluding juice” group has large reductions in the demand of LH and HH sub-categories. “Soft drinks, carbonated” , “Sugars and sweets” , and “Coffee and tea” all have 16% or larger reductions in their HH or LH sub-categories demands. The group “Fruit juices” has a 11% reduction in the LH sub-category demand. The group “Breads, crackers and snacks from grain” has comparatively significant reductions in HH and LH sub-categories demands.

Several sub-categories exhibit increases in consumption in the low-sugar categories, reflecting the within-group substitution. The group “Fruit juices” has the largest demand increase in LL sub-category at over 4%; “Fruits excluding juice” , “Pasta and cereals” , and “Creams” have increases in the HL and/or 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. Table 4-B shows that a fat tax has similar patterns of heterogeneous consumption effects within groups leading to aggregate group consumption effects close to those of the simplified approach. For example, ”Organ meats, sausages and lunchmeats” has its two low fat categories increasing by nearly 3%; “Milk desserts and sauces” and “Fats” have comparable but somewhat smaller increases.

With the sugar tax, added-sugar densities of the composite groups fall. But whether the calorie and 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 solid fat choices depend on the particular composite food group. The “With CES” columns in Tables 5, 6-A and 6-B present the calorie and nutrient intake changes induced by the taxes under the sub-category approach.

The total calorie intake reduction is still 2.19%, by design. With the added sugar tax, the total solid fat intake reduction is small, at 1% (3.64 calories). The total sugars intake reduction is nearly 11%, much larger than that obtained with the simplified approach. Table 6-A in particular shows how much more added sugar is abated in all of the sugar-intensive groups compared to the abated sugar with the simplified approach. The latter approach leads to overlooking considerable reductions in the nutrient targeted by the consumption tax.

Results for the fat tax complement those of the added-sugar tax. More fat is abated when considering the within-group substitution (-4.41% compared to -3.12% under the simplified approach). All groups intensive in solid fat show greater reductions in fats. The aggregate added sugar reduction is nearly the same as under the simplified approach although at the group level, there are considerable differences between the two approaches but without sharp patterns.

Table 7 shows the welfare losses caused by the two taxes expressed by the EV per calorie abated. Although the welfare losses are small (around 11 cents per day), they are relatively larger when using the simple approach that does not account for the within-group substitution. This is especially the case for the added-sugar tax scenario. Abstracting from the within-group substitution leads to overstate the EV by 22% under the added-sugar tax. Further when looking at the EV per gram of sugar abated, the abatement cost is overstated by 72%. Under the fat tax the cost of abating fat (EV per gram of fat abated) is overstated by 50%.

[Insert Table 7 here]

Summary and Discussion

In the context of obesity taxes, we investigated the importance of accounting for consumers' possibilities to substitute low-fat and 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 solid fats) into a demand system for 25 food composite goods relevant for obesity policy analysis. We incorporated the four-substitute CES structure into the LINQUAD demand system and calibrated the augmented demand system for the (25x4) goods using NHANES data and existing estimates of price and income elasticities. The calibration step was done conservatively to avoid outlying elasticity values and to reflect central estimates available in the literature. Then we implemented taxes on calories from added sugars and solid fat to show the implications of ignoring within-food-group substitution possibilities. This abstraction characterizes most of the literature on 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 toward leaner and lighter choices to abate the taxes. Hence, the estimated impact on calorie and added sugars intake now reflects these choices and shows larger reductions when the within-group substitution occurs; the estimated welfare cost of the tax is considerably smaller than when it is estimated by abstracting from this within-group substitution. Under the added-sugar tax, the EVs per unit of calorie and sugar reduction are considerably overstated by the simpler approaches that overlook the consumers' ability to substitute within food groups. A similar logic holds for the tax on calories from fat but the difference in EVs per calorie (without and with substitution) is less striking. The difference in EVs per unit of fat abated is quite substantial however, as it is the case for the tax on sugar and the EVs per unit of sugar reduction.

The framework of this study could be extended. Beyond taxes on calories from added sweeteners and solid fat, other tax designs could be considered, including some "thin" subsidies. One could also include more demographics in 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 and their valuation.

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

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

Note: The numbers in parentheses refer to the specific food group classifications in the USDA Food and Nutrient Database 2.0 (USDA 2006).

Table 2. Calories and Nutrients of Food Groups by Average Measure

Composite food groups	Sub categories[a]	Calorie distribution within column (%)[b]	Solid fat density (%)[c]	Added sugars density (%)[c]	Food expenditure ($)
Milks and milk drinks (11)	aggregate	4.67	26.38	11.16	0.22
	HH	0.17	33.53	27.79	0.01
	HL	2.40	39.50	0.00	0.10
	LH	1.15	14.09	41.16	0.05
	LL	0.94	6.57	0.03	0.07
Creams (12)	aggregate	0.68	68.51	14.48	0.03
	HH	0.02	72.59	27.75	0.00
	HL	0.35	84.34	0.68	0.01
	LH	0.24	60.47	38.67	0.01
	LL	0.08	19.80	0.44	0.00
Milk desserts and sauces (13)	aggregate	2.12	42.88	33.31	0.07
	HH	1.09	48.73	36.54	0.03
	HL	0.37	58.97	21.37	0.01
	LH	0.36	21.74	45.75	0.02
	LL	0.30	27.30	21.49	0.01
Cheeses (14)	aggregate	2.74	65.93	0.31	0.14
	HH	0.00	87.06	2.51	0.00
	HL	1.87	71.47	0.00	0.08
	LH	0.23	59.98	3.64	0.01
	LL	0.64	51.80	0.00	0.04
Meats (20-24)	aggregate	7.90	20.98	0.14	0.58
	HH	0.28	38.58	3.35	0.02
	HL	3.88	35.20	0.00	0.23
	LH	0.11	9.28	1.36	0.01
	LL	3.63	4.78	0.00	0.33
Organ meats, sausages and lunchmeats (25)	aggregate	2.68	43.27	0.54	0.16
	HH	0.65	59.98	1.19	0.02
	HL	1.29	58.48	0.05	0.07
	LH	0.06	4.44	10.68	0.01
	LL	0.67	0.97	0.00	0.07
Fish and shellfish (26)	aggregate	1.27	16.16	0.56	0.19
	HH	0.35	32.02	1.41	0.04
	HL	0.18	27.70	0.00	0.02
	LH	0.19	8.16	1.16	0.02
	LL	0.55	4.81	0.00	0.12
Meat in mixtures (27, 28, 77)	aggregate	7.37	20.60	2.44	0.43
	HH	1.45	29.14	4.66	0.05
	HL	2.23	33.18	0.53	0.14
	LH	1.70	9.96	5.16	0.09
	LL	1.98	9.32	0.63	0.16
Eggs (31-35)	aggregate	2.14	36.79	0.42	0.07
	HH	0.26	48.03	1.56	0.01
	HL	0.57	45.67	0.00	0.02
	LH	0.16	23.24	3.02	0.01
	LL	1.15	31.80	0.00	0.04
Dry beans,	aggregate	3.37	3.92	3.29	0.12

legumes and nuts (41-43)	HH	0.23	9.91	17.24	0.01
	HL	0.52	18.19	0.07	0.01
	LH	0.26	0.05	21.34	0.02
	LL	2.37	0.66	0.72	0.07
Breads, crackers & snacks from grain (51, 52, 54)	aggregate	12.00	10.63	5.72	0.24
	HH	1.43	27.97	22.32	0.04
	HL	2.60	26.27	0.82	0.05
	LH	3.53	0.52	7.87	0.04
	LL	4.44	3.93	1.52	0.10
Cakes, pastries & other grain products (53, 55)	aggregate	6.43	30.44	28.45	0.18
	HH	1.43	35.49	38.80	0.03
	HL	2.04	44.83	20.75	0.05
	LH	1.50	18.80	42.53	0.04
	LL	1.45	17.25	14.54	0.05
Pasta and cereals (56-57)	aggregate	4.44	3.20	11.99	0.12
	HH	0.64	7.15	27.50	0.02
	HL	0.99	9.22	0.00	0.01
	LH	1.16	0.16	27.59	0.04
	LL	1.65	0.20	2.15	0.03
Grain mixtures (58-59)	aggregate	11.18	28.19	0.91	0.53
	HH	0.60	35.83	4.62	0.04
	HL	5.58	38.45	0.35	0.28
	LH	1.09	13.14	3.76	0.05
	LL	3.91	16.58	0.33	0.16
Fruits excluding juice (61-67, excluding 612+641+642+644)	aggregate	2.27	0.06	5.07	0.23
	HH	0.00	16.54	20.51	0.00
	HL	0.01	13.33	0.56	0.00
	LH	0.21	0.00	54.89	0.01
	LL	2.05	0.00	0.00	0.21
Fruit juices (612, 641, 642, 644, 92)	aggregate	3.51	0.08	41.41	0.16
	HH	0.02	15.04	57.78	0.00
	HL	0.00	3.79	40.58	0.00
	LH	1.70	0.00	82.79	0.08
	LL	1.79	0.00	2.11	0.08
Potatoes (71)	aggregate	4.70	24.79	0.10	0.12
	HH	0.00	57.91	16.92	0.00
	HL	2.59	43.40	0.00	0.06
	LH	0.19	2.93	2.35	0.01
	LL	1.91	1.85	0.00	0.05
Other vegetables (72-76)	aggregate	2.84	15.64	6.06	0.40
	HH	0.05	19.81	37.92	0.00
	HL	1.08	38.35	0.24	0.10
	LH	0.45	0.85	32.90	0.02
	LL	1.26	1.25	0.21	0.28
Fats (81)	aggregate	1.22	65.63	0.26	0.02
	HH	0.00	77.32	14.26	0.00
	HL	0.78	101.35	0.00	0.01
	LH	0.06	3.26	4.33	0.00
	LL	0.38	1.61	0.00	0.01

Oils (82-83)	aggregate	2.06	2.39	5.98	0.04
	HH	0.07	7.68	10.21	0.00
	HL	0.79	4.93	2.87	0.01
	LH	0.58	0.36	16.01	0.02
	LL	0.62	0.48	0.17	0.01
Sugars and sweets (91)	aggregate	3.31	7.19	60.30	0.10
	HH	0.11	13.43	72.39	0.01
	HL	1.26	17.09	36.40	0.04
	LH	1.44	0.09	87.21	0.03
	LL	0.50	1.37	39.73	0.02
Coffee & tea (921-923)	aggregate	1.01	6.57	61.48	0.12
	HH	0.01	25.42	68.31	0.00
	HL	0.21	30.39	25.14	0.01
	LH	0.57	0.00	98.14	0.02
	LL	0.22	0.00	0.01	0.08
Soft drinks, carbonated (924)	aggregate	5.91	0.00	95.00	0.30
	LH	4.87	0.00	98.03	0.18
	LL	1.03	0.00	80.68	0.12
Alcoholic beverages (93)	aggregate	4.21	0.19	3.45	0.68
	HH	0.03	29.41	14.88	0.00
	LH	0.62	0.00	22.61	0.15
	LL	3.56	0.00	0.00	0.52
Water (94)	aggregate	0.00	0.00	0.00	0.00
	LL	0.00	0.00	0.00	0.00

Note: The numbers in parentheses refer to the specific food group classifications in the USDA Food and Nutrient Database 2.0 (USDA 2006).

[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 oil and of solid fat provides 9 calories; each gram of added sugars provides 4 calories.

Table 1. Own-Price, Income, and Substitution Elasticities of Composite Food Groups

Composite food groups	Elasticities								
	Own-Price				Income (Total Expenditures)				Substitution
	Mean	SD	max	min	Mean	SD	max	min	Average
Milks and milk drinks (11)	-0.75	0.27	-0.24	-1.49	0.04	0.57	1.01	-0.56	1.04
Creams (12)	-0.45	0.13	-0.29	-0.60	-0.13	0.12	0.02	-0.26	0.65
Milk desserts and sauces (13)	-0.65	0.28	-0.34	-0.87	-0.19	0.31	0.04	-0.41	0.88
Cheeses (14)	-1.03	0.61	-0.33	-1.90	-0.08	0.28	0.50	-0.41	1.71
Meats (20-24)	-0.79	0.32	-0.07	-1.52	0.78	0.43	1.57	-0.06	1.56
Organ meats, sausages and lunchmeats (25)	-0.82	0.42	-0.36	-1.37	0.81	NA	0.81	0.81	1.14
Fish and shellfish (26)	-0.46	0.37	-0.18	-1.11	0.99	1.49	2.99	-0.48	0.70
Meat in mixtures (27, 28, 77)	-1.51	0.78	-0.95	-2.06	0.58	0.95	1.26	-0.09	2.04
Eggs (31-35)	-0.11	0.05	-0.06	-0.15	0.35	0.67	0.82	-0.12	0.15
Dry beans, legumes and nuts (41-43)	-0.77	0.50	-0.12	-1.19	-0.36	0.15	-0.21	-0.51	1.15
Breads, crackers & snacks from grain (51, 52, 54)	-0.80	0.31	-0.35	-1.15	0.00	0.54	0.73	-0.55	1.09
Cakes, pastries & other grain products (53, 55)	-0.70	NA	-0.70	-0.70	0.13	NA	0.13	0.13	0.94
Pasta and cereals (56-57)	-0.56	0.29	-0.15	-0.91	0.22	0.52	0.79	-0.23	0.76
Grain mixtures (58-59)	-1.51	0.78	-0.95	-2.06	0.58	0.95	1.26	-0.09	2.15
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	5.55
Fruit juices (612, 641, 642, 644, 92)	-0.87	0.37	-0.15	-1.53	0.39	0.99	2.12	-1.36	1.72
Potatoes (71)	-0.24	0.09	-0.17	-0.37	0.29	NA	0.29	0.29	0.46
Other vegetables (72-76)	-0.52	0.44	-0.01	-1.51	0.19	0.30	0.80	-0.27	0.86
Fats (81)	-0.41	0.26	-0.14	-0.99	0.63	0.68	1.01	-0.68	0.77
Oils (82-83)	-0.76	0.29	-0.43	-1.13	0.44	0.52	1.03	0.05	1.04
Sugars and sweets (91)	-0.74	0.54	0.00	-1.64	-0.20	0.29	0.19	-0.72	1.01
Coffee & tea (921-923)	-0.60	0.45	-0.19	-1.07	-0.27	0.17	-0.15	-0.39	1.18
Soft drinks, carbonated (924)	-0.95	0.36	-0.55	-1.26	-0.03	0.08	0.03	-0.09	1.96
Alcoholic beverages (93)	-0.90	0.87	-0.29	-2.17	-0.48	NA	-0.48	-0.48	2.55
Water (94)	-0.33	NA	-0.33	-0.33	-0.20	NA	-0.20	-0.20	[a]

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. The numbers in parentheses refer to the specific food group classifications in the USDA Food and Nutrient Database 2.0 (USDA 2006).

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

Table 4-A. Demand Changes with Tax on Calories from Added Sugars by Average Measure

Composite food groups	Relative change in demand (%)					
	Without CES	With CES				
		Composite	HH	HL	LH	LL
Milks and milk drinks (11)	-0.63	-0.49	-4.08	0.91	-4.32	0.90
Creams (12)	-0.89	-0.70	-0.11	0.63	-4.08	0.64
Milk desserts and sauces (13)	-3.96	-3.19	-4.99	-1.40	-3.17	-0.90
Cheeses (14)	-0.09	-0.07	-0.57	0.00	-0.65	0.00
Meats (20-24)	-0.51	-0.41	-0.78	-0.39	-0.55	-0.39
Organ meats, sausages and lunchmeats (25)	-0.77	-0.61	-0.78	-0.56	-1.04	-0.55
Fish and shellfish (26)	-1.12	-0.89	-0.93	-0.87	-0.93	-0.87
Meat in mixtures (27, 28, 77)	-0.58	-0.47	-1.63	-0.07	-1.17	-0.06
Eggs (31-35)	-0.50	-0.41	-0.43	-0.39	-0.46	-0.39
Dry beans, legumes and nuts (41-43)	-0.23	-0.19	-1.68	0.43	-1.50	0.29
Breads, crackers & snacks from grain (51, 52, 54)	-1.68	-1.34	-4.79	0.23	-3.64	0.06
Cakes, pastries & other grain products (53, 55)	-5.43	-4.34	-9.31	-3.04	-6.69	-1.06
Pasta and cereals (56-57)	-0.18	-0.17	-1.55	1.90	-1.30	1.43
Grain mixtures (58-59)	-0.33	-0.26	-0.83	-0.11	-1.06	-0.12
Fruits excluding juice (61-67, excluding 612+641+642+644)	-0.65	-0.49	-9.38	0.52	-24.03	0.99
Fruit juices (612, 641, 642, 644, 92)	-4.79	-3.71	-5.55	-4.63	-11.47	4.34
Potatoes (71)	0.68	0.53	-0.91	0.54	0.29	0.54
Other vegetables (72-76)	-0.59	-0.47	-4.49	-0.27	-3.79	-0.26
Fats (81)	0.06	0.06	-2.80	0.14	-1.31	0.14
Oils (82-83)	-1.96	-1.57	-1.61	-1.19	-3.00	0.41
Sugars and sweets (91)	-9.62	-7.54	-1.95	-3.20	-17.83	-2.78
Coffee & tea (921-923)	-3.04	-2.31	-17.10	-1.64	-16.48	1.05
Soft drinks, carbonated (924)	-13.15	-10.30	NA	NA	-18.28	1.63
Alcoholic beverages (93)	0.00	0.00	-1.40	NA	-1.10	0.32
Water (94)	0.04	0.03	NA	NA	NA	0.03

Note: The numbers in parentheses refer to the specific food group classifications in the USDA Food and Nutrient Database 2.0 (USDA 2006).

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 4-B. Demand Changes with Tax on Calories from Solid Fat by Average Measure

Composite food groups	Relative change in demand (%)					
	Without CES	With CES				
		Composite	HH	HL	LH	LL
Milks and milk drinks (11)	-0.62	-0.59	-2.79	-2.62	0.57	1.61
Creams (12)	-3.42	-3.23	0.23	-3.87	-4.02	0.05
Milk desserts and sauces (13)	-0.58	-0.59	-2.72	-2.12	2.54	1.84
Cheeses (14)	-5.13	-4.83	-9.43	-7.27	-3.09	-0.75
Meats (20-24)	-1.48	-1.39	-2.82	-3.62	-0.22	0.27
Organ meats, sausages and lunchmeats (25)	-1.01	-0.91	-5.95	-3.23	2.62	2.73
Fish and shellfish (26)	-2.52	-2.34	-2.94	-2.79	-2.30	-2.07
Meat in mixtures (27, 28, 77)	-2.74	-2.58	-7.18	-4.35	-1.09	-0.38
Eggs (31-35)	-0.77	-0.72	-0.87	-0.86	-0.40	-0.65
Dry beans, legumes and nuts (41-43)	-0.52	-0.49	-0.86	-3.28	0.11	0.00
Breads, crackers & snacks from grain (51, 52, 54)	-3.79	-3.54	-6.08	-6.93	-1.13	-1.76
Cakes, pastries & other grain products (53, 55)	-3.93	-3.69	-6.79	-5.99	-1.86	-1.07
Pasta and cereals (56-57)	-1.57	-1.46	-1.74	-3.47	-1.04	-1.06
Grain mixtures (58-59)	-4.54	-4.28	-3.32	-5.99	-1.31	-2.49
Fruits excluding juice (61-67, excluding 612+641+642+644)	0.29	0.27	-6.46	-8.17	0.28	0.28
Fruit juices (612, 641, 642, 644, 92)	-0.53	-0.49	-2.65	-1.19	-0.48	-0.48
Potatoes (71)	-1.43	-1.33	-3.08	-2.87	0.48	0.57
Other vegetables (72-76)	-1.25	-1.16	-2.51	-2.36	-0.79	-0.74
Fats (81)	-11.47	-10.60	-9.32	-15.84	1.43	1.89
Oils (82-83)	-0.50	-0.47	-1.06	-2.06	0.12	0.04
Sugars and sweets (91)	-0.99	-0.93	-0.58	-2.19	0.14	0.00
Coffee & tea (921-923)	0.45	0.42	-5.33	-1.84	0.73	0.73
Soft drinks, carbonated (924)	0.00	0.00	NA	NA	0.00	0.00
Alcoholic beverages (93)	0.14	0.13	-2.54	NA	0.14	0.14
Water (94)	0.03	0.02	NA	NA	NA	0.02

Note: The numbers in parentheses refer to the specific food group classifications in the USDA Food and Nutrient Database 2.0 (USDA 2006).

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 5. Percent Change in Calories with Tax on Added Sugar and Solid Fat

Composite food groups	Calories consumption				
	Initial level (calorie)	Consumption change (%)			
		Tax on added sugar		Tax on solid fat	
		Without CES	With CES	Without CES	With CES
Milks and milk drinks (11)	102.05	-0.63	-0.56	-0.62	-0.99
Creams (12)	14.83	-0.89	-1.02	-3.42	-3.39
Milk desserts and sauces (13)	46.39	-3.96	-3.48	-0.58	-1.07
Cheeses (14)	59.98	-0.09	-0.06	-5.13	-5.40
Meats (20-24)	172.88	-0.51	-0.41	-1.48	-1.75
Organ meats, sausages and lunchmeats (25)	58.55	-0.77	-0.62	-1.01	-2.27
Fish and shellfish (26)	27.75	-1.12	-0.90	-2.52	-2.45
Meat in mixtures (27, 28, 77)	161.10	-0.58	-0.63	-2.74	-3.09
Eggs (31-35)	46.78	-0.50	-0.40	-0.77	-0.71
Dry beans, legumes and nuts (41-43)	73.62	-0.23	0.04	-0.52	-0.56
Breads, crackers & snacks from grain (51, 52, 54)	262.36	-1.68	-1.57	-3.79	-3.21
Cakes, pastries & other grain products (53, 55)	140.55	-5.43	-4.84	-3.93	-4.09
Pasta and cereals (56-57)	97.14	-0.18	0.39	-1.57	-1.69
Grain mixtures (58-59)	244.54	-0.33	-0.25	-4.54	-4.17
Fruits excluding juice (61-67, excluding 612+641+642+644)	49.60	-0.65	-1.33	0.29	0.25
Fruit juices (612, 641, 642, 644, 92)	76.79	-4.79	-3.36	-0.53	-0.49
Potatoes (71)	102.70	0.68	0.53	-1.43	-1.33
Other vegetables (72-76)	62.15	-0.59	-0.90	-1.25	-1.40
Fats (81)	26.61	0.06	0.06	-11.47	-9.49
Oils (82-83)	44.98	-1.96	-1.23	-0.50	-0.78
Sugars and sweets (91)	72.44	-9.62	-9.48	-0.99	-0.79
Coffee & tea (921-923)	22.02	-3.04	-9.63	0.45	0.13
Soft drinks, carbonated (924)	129.16	-13.15	-14.80	0.00	0.00
Alcoholic beverages (93)	92.05	0.00	0.10	0.14	0.13
Water (94)	0.06	0.04	0.03	0.03	0.02
Total	2187.06	-2.19	-2.19	-2.19	-2.19

Note: The numbers in parentheses refer to the specific food group classifications in the USDA Food and Nutrient Database 2.0 (USDA 2006).

Table 6-A. Percentage Change in Added Sugars with Tax on Calories from Added Sugars and Solid Fat

Composite food groups	Added sugars consumption				
	Initial level (g)	Consumption change (%)			
		Tax on calories from added sugars		Tax on calories from solid fat	
		Without CES	With CES	Without CES	With CES
Milks and milk drinks (11)	2.85	-0.63	-4.29	-0.62	0.26
Creams (12)	0.54	-0.89	-3.77	-3.42	-3.81
Milk desserts and sauces (13)	3.86	-3.96	-3.79	-0.58	-1.01
Cheeses (14)	0.05	-0.09	-0.65	-5.13	-3.16
Meats (20-24)	0.06	-0.51	-0.75	-1.48	-2.47
Organ meats, sausages and lunchmeats (25)	0.08	-0.77	-0.88	-1.01	-2.23
Fish and shellfish (26)	0.04	-1.12	-0.93	-2.52	-2.74
Meat in mixtures (27, 28, 77)	0.98	-0.58	-1.19	-2.74	-3.55
Eggs (31-35)	0.05	-0.50	-0.45	-0.77	-0.61
Dry beans, legumes and nuts (41-43)	0.61	-0.23	-1.28	-0.52	-0.26
Breads, crackers & snacks from grain (51, 52, 54)	3.75	-1.68	-3.69	-3.79	-3.67
Cakes, pastries & other grain products (53, 55)	10.00	-5.43	-5.99	-3.93	-4.23
Pasta and cereals (56-57)	2.91	-0.18	-1.20	-1.57	-1.27
Grain mixtures (58-59)	0.55	-0.33	-0.69	-4.54	-2.92
Fruits excluding juice (61-67, excluding 612+641+642+644)	0.63	-0.65	-23.93	0.29	0.24
Fruit juices (612, 641, 642, 644, 92)	7.95	-4.79	-11.01	-0.53	-0.49
Potatoes (71)	0.03	0.68	0.26	-1.43	0.33
Other vegetables (72-76)	0.94	-0.59	-3.76	-1.25	-0.99
Fats (81)	0.02	0.06	-1.56	-11.47	-0.36
Oils (82-83)	0.67	-1.96	-2.56	-0.50	-0.35
Sugars and sweets (91)	10.92	-9.62	-12.34	-0.99	-0.43
Coffee & tea (921-923)	3.38	-3.04	-15.24	0.45	0.43
Soft drinks, carbonated (924)	30.67	-13.15	-15.33	0.00	0.00
Alcoholic beverages (93)	0.79	0.00	-1.11	0.14	0.07
Water (94)	0.00	0.04	0.00	0.03	0.00
Total	82.33	-7.76	-10.61	-1.03	-0.96

Note: The numbers in parentheses refer to the specific food group classifications in the USDA Food and Nutrient Database 2.0 (USDA 2006).

Table 6-B. Percentage Change in Solid Fat with Tax on Calories from Added Sugars and Solid Fat

Composite food groups	Discretionary solid fat consumption				
	Initial level (g)	Consumption change (%)			
		Tax on calories from added sugar		Tax on calories from solid fat	
		Without CES	With CES	Without CES	With CES
Milks and milk drinks (11)	2.99	-0.63	-0.02	-0.62	-2.00
Creams (12)	1.13	-0.89	-0.83	-3.42	-3.69
Milk desserts and sauces (13)	2.21	-3.96	-3.61	-0.58	-1.71
Cheeses (14)	4.39	-0.09	-0.05	-5.13	-5.76
Meats (20-24)	4.03	-0.51	-0.42	-1.48	-3.14
Organ meats, sausages and lunchmeats (25)	2.81	-0.77	-0.64	-1.01	-4.10
Fish and shellfish (26)	0.50	-1.12	-0.91	-2.52	-2.74
Meat in mixtures (27, 28, 77)	3.69	-0.58	-0.62	-2.74	-4.29
Eggs (31-35)	1.91	-0.50	-0.40	-0.77	-0.74
Dry beans, legumes and nuts (41-43)	0.32	-0.23	0.06	-0.52	-2.48
Breads, crackers & snacks from grain (51, 52, 54)	3.10	-1.68	-1.42	-3.79	-5.87
Cakes, pastries & other grain products (53, 55)	4.75	-5.43	-4.94	-3.93	-4.98
Pasta and cereals (56-57)	0.34	-0.18	0.74	-1.57	-2.82
Grain mixtures (58-59)	7.66	-0.33	-0.20	-4.54	-4.88
Fruits excluding juice (61-67, excluding 612+641+642+644)	0.00	-0.65	-4.20	0.29	-7.35
Fruit juices (612, 641, 642, 644, 92)	0.01	-4.79	-5.50	-0.53	-2.58
Potatoes (71)	2.83	0.68	0.53	-1.43	-2.75
Other vegetables (72-76)	1.08	-0.59	-0.38	-1.25	-2.30
Fats (81)	1.94	0.06	0.12	-11.47	-15.64
Oils (82-83)	0.12	-1.96	-1.22	-0.50	-1.73
Sugars and sweets (91)	0.58	-9.62	-3.18	-0.99	-2.01
Coffee & tea (921-923)	0.16	-3.04	-2.38	0.45	-2.01
Soft drinks, carbonated (924)	0.00	-13.15	0.00	0.00	0.00
Alcoholic beverages (93)	0.02	0.00	-1.40	0.14	-2.54
Water (94)	0.00	0.04	0.00	0.03	0.00
Total	46.58	-1.26	-1.00	-3.12	-4.41

Note: The numbers in parentheses refer to the specific food group classifications in the USDA Food and Nutrient Database 2.0 (USDA 2006).

Table 7. Welfare Loss per Unit of Nutrient Consumption Reduced with Tax on Calories from Added Sugars and Solid Fat

	Tax on added sugar			Tax on solid fat		
	Without CES	With CES	"without" Bias	Without CES	With CES	"Without" Bias
EV/Calorie reduction (cents/calorie)	0.22	0.18	22%	0.20	00.19	5%
EV/Discretionary solid fat reduction (cents/g)	18.22	18.20	0%	6.48	4.31	50%
EV/Added sugars reduction (cents/g)	1.67	0.97	72%	11.10	11.22	-1%

Note: EV is equivalent variation.

Appendix Table 1. 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/liqueurs, wines, and distilled liquors
Water (94)	Water, noncarbonated. Includes tap water, bottled water, and bottled/fortified water

Note: The numbers in parentheses refer to the specific food group classifications in the USDA Food and Nutrient Database 2.0 (USDA 2006).