2012

Three essays on tax policies addressing the obesity epidemic and associated calorie intake

Zhen Miao
Iowa State University

Three essays on tax policies addressing the obesity epidemic and associated calorie intake

by

Zhen Miao

A dissertation submitted to the graduate faculty

in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Major: Economics

Program of Study Committee:
Helen H. Jensen, Co-major Professor
John C. Beghin, Co-major Professor
John R. Schroeter
Peter F. Orazem
Ulrike Genschel

Iowa State University

Ames, Iowa

2012

TABLE OF CONTENTS

LIST OF TABLES

ABSTRACT

Policymakers are considering various policies to reduce obesity and its associated costs, including consumption taxes on high-calorie foods. Essay 1 focuses on two tax schemes targeting sweetener-intensive foods. Both a consumption tax on sweetener-intensive goods and a sweetener input tax can reach the same policy target of reducing added sweetener consumption. Both tax instruments are regressive although the welfare impacts are small. The tax on sweetener inputs leads to loss in consumer surplus only one fifth of that caused by the final consumption tax applied to sweetener-intensive goods. Essay 2 proposed a methodology to account for the ability of consumers to substitute leaner low-fat and low-sugar items for rich food items within the same food group in addition to substitution among food groups. Simulations of taxes on added sugars illustrate how 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. Essay 3 applies the framework developed in essay 2 to analyze recent tax proposals to tackle obesity, such as using a tax on sodas, sweets, and other sources of added calories. To compare the policies, a basis of equivalence is established in terms of a calorie reduction which corresponds to the calorie reduction induced by a one-cent-per-ounce soda tax proposal. Simulations show that from a welfare perspective, targeting the right food group is more important than the type of tax. Taxes on butter and bakery goods should be targeted to minimize the welfare loss to abate calories. An ad valorem tax on carbonated soft drinks is a good way to raise revenue although its welfare loss is not the lowest one. A proportional tax on all calories applied to all foods has the lowest social cost per dollar of tax revenues but not the most efficient way to reduce calories.

CHAPTER 1. GENERAL INTRODUCTION

My dissertation has 3 essays dealing with tax policies addressing the obesity epidemic and associated calorie intake. Essay 1 focuses on sweetener-intensive food. Essay2 and 3 are complementary and address a more general problem of tax various food items not just sweetener-intensive food. Essays 2 and3 combined would have been rather long as a single chapter. Therefore, they were split into a methodology manuscript and a more policy oriented one.

In essay 1, which is accepted by *Contemporary Economic Policy*, I focus on tax schemes targeting sweetener-intensive food goods. Policymakers are considering various policies to reduce obesity and its associated costs, including consumption taxes on high-calorie foods and specifically sweetened foods. I investigate two tax policies to reduce added sweetener consumption: a consumption tax on sweetener-intensive goods and a sweetener input tax targeting sweetener used in processing the same consumption goods. Both tax instruments can reach the same policy target of reducing added sweetener consumption and are found to be regressive although the welfare impact of these taxes are fairly small. The tax on sweetener inputs targets sweeteners directly and leads to loss in consumer surplus that is only one fifth of that caused by the final consumption tax applied to final goods intensive in sweeteners. Previous analyses have overlooked this important point.

In essay 2, I extend the existing literature on food taxes targeting obesity with a methodological contribution. First, I 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, I 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, in a framework equivalent to a two-stage budgeting process. This substitution is integrated into a demand system in addition to substitution among food groups. Simulations of taxes on added sugars illustrate how 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.

In essay 3, I apply the framework developed in essay 2 to analyze recent tax proposals to tackle obesity, such as using a tax on sodas, sweets, and other sources of added calories. To compare the policies, I establish a basis of equivalence in terms of a calorie reduction which is then kept identical for all other tax scenarios. The chosen equivalent total calorie reduction corresponds to the calorie reduction induced by a one-cent-per-ounce soda tax proposal. Simulations show that from a welfare perspective, targeting the right food group is more important than the type of tax, that is, whether an ad valorem tax or proportional tax on calories or nutrient should be used. Taxes on butter and bakery goods such as breads, muffins, rolls, and crackers should be targeted to minimize the welfare loss to abate calories. In addition, an ad valorem tax on carbonated soft drinks is a good way to raise revenue although its welfare loss is not the lowest one. A proportional tax on all calories applied to all foods is the instrument that has the lowest social cost per dollar of tax revenues but not the most efficient way to reduce calories.

CHAPTER 2. TAXING SWEETS: SWEETENER INPUT TAX OR FINAL CONSUMPTION TAX?

Abstract

Policymakers are considering various policies to reduce obesity and its associated costs, including consumption taxes on high-calorie foods and specifically sweetened foods. We investigate two tax policies to reduce added sweetener consumption: a consumption tax on sweetened goods and a sweetener input tax. Both tax instruments can reach the same policy target of reducing added sweetener consumption and are found to be regressive. The tax on sweetener inputs targets sweeteners directly and leads to loss in consumer surplus that is only one-fifth of that caused by the final consumption tax. Previous analyses have overlooked this important point.

Keywords: consumption tax, demand, health policy, obesity, soda tax, sugar, sweeteners.

Introduction

Obesity has become a major public health concern in the United States, with relatively high obesity rates persisting among adults (Flegal et al., 2010). Obesity is most often a result of an imbalance between excess calorie intake and corresponding physical activity, although food technology innovations and the food environment have likely contributed (Cutler, Glaeser and Shapiro, 2003; DGAC, 2010). In the last four decades, per capita calories available for consumption in the food supply have increased by more than 500 calories daily in the United States.[1] The main contributors to the increase have been fats and oils, grains and caloric sweeteners (USDA, 2010).

Policymakers have debated and tried various policies and programs to change the consumption of high-calorie foods and reduce the prevalence of obesity. The Dietary Guidelines for Americans Committee (DGAC) 2010 recommends significantly reducing the intake of foods containing added sugars and solid fat (DGAC, 2010). In this article, we focus on policies targeted to reduce added sweetener consumption, including sugar, corn sweeteners, and other caloric sweeteners, and investigate the effect of alternative tax policies to reduce sweetener intake.[2]

Among policies considered, one approach is to use price penalties and incentives such as a soda tax or a subsidy on healthy food to change consumption. Altered incentives might encourage consumers to follow a healthy diet even though they might discount the long-run

[1] Reported changes in calorie intake from dietary surveys over a similar period also show an increase in intake. See Kantor (1998) for a discussion of the differences in data to measure consumption over time, and DGAC (2010) for further discussion of estimates of calorie increases over the last 30-40 years.

[2] We consider four categories of sweeteners. Three are caloric: sugars (cane or beet), corn sweeteners, and other natural sweeteners (dextrose, honey, molasses, and some blends). The fourth category is non- or low-caloric and includes sugar substitutes and artificial sweeteners.

health costs of unhealthy food (O'Donoghue and Rabin, 1999). Because fats and oils, refined grains, and sugar and sweeteners are the major contributors to the higher-calorie consumption, proposals to tax these products are popular as a means to reduce their intake (Kuchler, Tegene, and Harris, 2005; Gustavsen, 2005; Schroeter, Lusk, and Tyner, 2008; Cash, Sunding, and Zilberman, 2005; Smed, Jensen, and Denver, 2007; Richards, Patterson, and Tegene, 2007; Boizot-Szantaï and Etilé, 2005; and Chouinard et al., 2007; Fletcher, Frisvold and Tefft, 2010). However, most of the recent analyses of taxes and other incentives find that consumption reductions are more limited than expected, especially in the short run, principally because food demand is price inelastic and substitution among food compromises the abatement of high-calorie consumption. In addition, food taxes tend to be regressive because low-income consumers spend a larger share of income on food than do high-income consumers (Cash, Sunding, and Zilberman, 2005; Leicester and Windmeijer, 2004).

An alternative approach, less often discussed, is that taxing sweets can be undertaken at the processing levels. Applying a consumption tax to a specific sweetener-intensive food directly changes its price and thus reduces the consumer demand for that food item. In contrast, applying a sweetener tax on inputs induces manufacturers to reduce their use in food processing. The U.S. food industry uses various sweeteners as ingredients in the manufacturing process. Manufacturers choose among available technologies and ingredients, and can substitute among different sweeteners and away from certain sweeteners in the production process. Corn-based sweeteners are relatively cheaper compared to sugar, and high fructose corn sweetener (HFCS) is widely used in the beverage, breakfast cereal and bakery, and dairy industries. A tax on sweetener inputs increases the unit cost and price of foods intensive in sweeteners. Faced with a higher price, consumers reduce their consumption of final products as well. The extent to which the extra costs are transmitted along the food chain affects the final market price and ultimately determines the overall effectiveness of the tax imposed on manufacturers as a means of reducing calorie intake from sweetener consumption.

In this article, we explore the effect of taxes on inputs and on final goods designed to reduce intake of sweeteners. We evaluate the level of each of these taxes required to achieve a given reduction in sweeteners. And, we compare the allocative and distributional effects of both instruments (the taxes on final consumption and manufacturing ingredients). Both taxes are regressive, but welfare losses are small in absolute value and the tax on sweetener inputs causes a much smaller loss in welfare (about five times less) than does a tax on final products, such as a soda tax. Hence, the input tax reduces the incidence of the obesity-reduction policy on final consumers. In addition, these regressive effects may be overstated because low-income groups would benefit the most from the reduced sweetener consumption through improvements in their health status.

The Model

We rely on a multi-market, partial equilibrium displacement model encompassing four sweetener markets, multiple food processing sectors intensive in sweetener inputs, and several final consumer groups differentiated by income levels. The approach is well established and has been applied in various policy analysis contexts (Mullen, Wohlgenant, and Farris, 1988; Atwood and Helmers, 1998; Beghin, Bureau, and Drogué, 2004; and Sumner and Wohlgenant, 1985; among others). The added sweeteners are inputs used in food processing industries. We assume that there is an infinite supply in the sweeteners markets so that the added sweeteners' prices (before taxes) remain parametric and can be taken as given throughout our analysis. The input taxes imposed on one or more sweeteners will influence their relative prices.

For the final foods markets, we first model the supply decisions of the food processors. We show how processors transfer the sweet input tax onto the price of final products and by doing so we abstract from having an explicit retailing sector between food processors and consumers. Then we model the demand for the sweetener-intensive foods from the consumer's perspective. Finally, we combine these two sides to evaluate consumer welfare changes due to a tax on final products and on the manufacturing component sweeteners. The welfare change in our analysis is only measured by the equivalent variation (EV) corresponding to the price changes. By doing this, we abstract from the fact that consumers' health condition is an important component of their utility function. Consumers get immediate satisfaction from food consumption but the associated health costs will emerge in the future.

Producer's side

We first consider a tax imposed on sweetener inputs at the production level in food processing. Under a tax imposed at the production level, the degree of competition in the market and the ability to substitute among inputs determine the added cost and the extent to which it is passed on to the final consumers by the manufacturers of sweetener-intensive foods. As in many analyses, we assume that changes in production cost would be fully transmitted at the consumer level as under perfect competition. Under this assumption, the calculation of consumer expenditure and welfare change provides an upper bound of the potential burden of the tax on consumers. The calculated proportional changes in prices are upper bound estimates of the proportional price changes because any market power markup factor would decrease with the introduction of a tax. The latter occurs because demand as characterized by the Linquad demand system becomes more price-responsive as quantity demanded decreases with the tax. Hence, any price markup factor would become smaller with the change in elasticity and lead to a smaller proportional change in the price relative to the proportional change in the unit cost at the margin (see equation (2) below).

For each food manufacturing industry, the total cost of production and the cost share of each input are determined by input prices. In food manufacturing industry i, the input price w_{ik} of input k is a function of pre-tax input price $\tilde{w}_{ik}$ and the input tax t_{ik}, so that $w_{ik} = \tilde{w}_{ik}(1+t_{ik})$. Under the assumption of constant returns to scale, marginal cost equals average cost, and total costs increase in direct proportion to output. The change of marginal cost is proportional to the change in input prices $d \ln w_{ik} = d \ln(1+t_{ik})$. That is,

$$d(\ln MC_i) = \sum_k s_{ik} d \ln w_{ik} = \sum_k s_{ik} d \ln(1+t_{ik}), \qquad (1)$$

where MC_i is the marginal cost of production for food manufacturing industry i, and s_{ik} is the cost share of input k in total cost and whose input price is w_{ik}. In competitive markets, changes in final food producer prices PP_i are equal to the changes in marginal cost. In addition we abstract from the retail sector and assume that the producer and consumer prices change by the same proportion.

At equilibrium, the proportional changes in food price reflect the relative changes in input prices weighted by their respective cost share in the cost of the food. A 100% increase in sweetener price weighted by a cost share of sweetener s_{ik} in retail cost will cause an s_{ik} increase in final food prices. The input tax on sweeteners is transmitted to consumers of sweetener-intensive foods through higher input prices and thus output prices:

$$d \ln PP_i = d \ln MC_i = \sum_k s_{ik} d \ln w_{ik} = \sum_k s_{ik} d \ln(1+t_{ik}) . \quad (2)$$

A higher price induced by the tax on one sweetener would decrease the demand for that sweetener input and could boost the use of another sweetener or other inputs. Holding other things constant, higher prices for some sweeteners would cause substitution among sweeteners and raise the production cost of sweetener-intensive foods.[3] Given the CRS assumptions, the change of the usage of sweetener h caused by a tax on sweeteners k can be expressed as

$$d \ln x_{ih} = d \ln y_i + \sum_k s_{ik} \sigma_{ihk} d \ln w_{ik} = d \ln y_i + \sum_k \delta_{ihk} d \ln(1+t_{ik}). \quad (3)$$

where x_{ih} is the quantity of the sweetener input h in industry i, y_i is the quantity of output for industry i, σ_{ihk} is the elasticity of substitution between inputs h and k in food manufacturing industry i, and δ_{ihk} is the cross-price elasticity between inputs h and k in food manufacturing industry i satisfying the condition that $\delta_{ihk} = s_{ik}\sigma_{ihk}$ and $\delta_{ikk} = s_{ik}\sigma_{ikk}$. .

Consumer's side

We are mostly interested in the sweetener-intensive food consumption because

[3] If the industry is imperfectly competitive, the final food producer prices PP_i can be set above marginal cost with a price markup factor corresponding to the own-price demand elasticity η such that $PP = MC\ [|\eta| / (|\eta| - 1)]$. Given the assumed Linquad demand system, price elasticity η increases in absolute value with the higher price. Hence, the markup factor decreases with the tax and the percent change in price PP_i would actually be smaller than the percent change in unit cost. In either case, this does not exclude over-shifting of the tax burden in levels in the presence of market power, with the dollar increase in price being larger than the dollar increase in unit cost.

sweetener intake and consumer-level effects are our main research focus. The LinQuad incomplete demand systems approach developed by LaFrance (1998) is adopted to derive consumer demand equations and welfare evaluations. The LinQuad system is linear in income and quadratic in price. This incomplete demand system fits well here because only a subset of all foods is relevant to our analysis. It has a more common form than do complete systems and is more flexible in its ability to reflect consumer preferences by incorporating the quadratic price term. It is also easy to calibrate while imposing proper curvature (Beghin, Bureau, and Drogué, 2004).

Let $D=[D_1,...,D_m]'$ be the vector of demands for the target foods, $P=[P_1,...P_m]'$ be the corresponding price vector, $P_O=[P_{O1},...P_{Oz}]'$ be the consumer price vector for all the remaining foods $O=[O_1,...,O_z]'$, and I be the income level. The prices can include an ad valorem consumption tax. In this case, the producer and final consumer prices are linked through the identity $P_i = PP_i(1+\tau_i)$, where τ_i is the consumer tax imposed on final good *i*. The consumer tax τ is the second of the two instruments we consider to abate sweetener consumption.

The consumer's utility maximization problem under the budget constraint is

$$\underset{D,O}{Max}\ U(D,O) \quad s.t.\ \ P'D+P_O'O\le I\ , \tag{4}$$

where U represents the utility function. The Marshallian demands $D=D(P',P_O',I)$ satisfying the above maximization problem satisfy the usual properties. They are

$$D=\varepsilon+VP+\chi(I-\varepsilon'P-\frac{1}{2}P'VP)\,, \tag{5}$$

where χ,ε and V are parameters to be calibrated. Symmetry of the Slutsky substitution matrix is imposed by setting $v_{ij} = v_{ji}$. The Marshallian own- and cross-price elasticities are

$$\eta_{ii}^{M} = [v_{ii} - \chi_i(\varepsilon_i + \sum_k v_{ik} P_k)] \frac{P_i}{D_i}, \text{ and } \eta_{ij}^{M} = [v_{ij} - \chi_i(\varepsilon_j + \sum_k v_{jk} P_k)] \frac{P_j}{D_i}. \qquad (6)$$

With the values of the elasticities, income, price, and consumption levels, the demand system can be fully recovered.

When a tax is applied on sweetener inputs or on final goods that are sweetener intensive, the negative effects of the taxes affect consumers' consumption and welfare. But there are also positive effects on consumers' health conditions through reduced consumption of sweetener-intensive products. Consumers would lose from higher prices of sweetened foods as consumer surplus is decreased, but the consumers' health conditions would improve as they choose the healthier substitutes. In this study we only consider the negative effects from the market perspective. A limitation of this approach is that health status is not represented in the utility function. We abstract from the fact that consumers' health condition is an important component of their utility function. Given CRS in production, no welfare consideration arises in production. We also abstract from government tax revenues. Hence our focus is on consumer welfare.

Policy simulations

In the following policy simulations, we set the reduction of added sweetener use and evaluate how the changes in sweetener intake are determined across foods and across income groups under different tax proposals. In this way, we hold constant the health effects to be achieved through reduced intake of added sweetener as the equivalence basis of the policy target.

Suppose the prices of target foods change from P^0 to P^1 because of changes in either inputs or final goods taxes. If the tax on the final products τ_i is changed, then

$$P_i^1 = PP_i^0(1+\tau_i) \text{ and } d\ln P_i = d\ln(1+\tau_i)\,. \tag{7}$$

If the tax imposed on the sweetener inputs is changed, we have

$$d\ln P_i = d\ln PP_i = \sum_k s_{ik} d\ln w_{ik} = \sum_k s_{ik} d\ln(1+t_{ik}). \tag{8}$$

The EV of the price change is expressed as follows:

$$EV = (I - \varepsilon' P^1 - \frac{1}{2} P^{1\prime} V P^1)\exp(\chi P^0 - \chi P^1) - (I - \varepsilon' P^0 - \frac{1}{2} P^{0\prime} V P^0) \tag{9}$$

The EV derived from equation (9) shows the amount of money that consumers need to pay before a price increase to keep their utility level constant, and P^1 can be substituted into the EV equation to get the welfare changes.

We apply the LinQuad demand systems for all households in aggregate and also for five disaggregated income groups respectively to evaluate how to achieve the policy target of reducing the added sweeteners consumption by a fixed amount and minimizing the consumer welfare loss. Two alternative approaches are used: taxing final sweetener-intensive goods, and taxing sweetener inputs.

To investigate the tax effects on different income groups, the LinQuad demand systems are modified by the variation of shifters ε (the intercept of Marshallian demands). We assume the increase in income has the same marginal effect on the food demand for each of the n disaggregated income groups; that is, the partial derivatives of demand with respective to income, χ, are equal across the income groups. Meanwhile, the own- and cross-price elasticities for all households are weighted averages of own- and cross-price elasticities for disaggregated income groups, which satisfy the following condition:

$$\eta_{ijAll}^{M} = \frac{D_{i1}}{D_{iAll}}\eta_{ij1}^{M} + \frac{D_{i2}}{D_{iAll}}\eta_{ij2}^{M} + \cdots + \frac{D_{in}}{D_{iAll}}\eta_{ijn}^{M}, \tag{10}$$

where $\eta_{ijAll}^{M}, \eta_{ij1}^{M}, \eta_{ij2}^{M} \cdots \eta_{ijn}^{M}$ are the cross-price elasticities of food demand i to food price j for all households and disaggregated income groups.

Under the assumptions that $V_1 = V_2 = \cdots = V_n = V$, equations (5) and (6) can be solved simultaneously to get the values of the parameter ε for the linear price term and the parameter matrix V for the quadratic price term for each of the disaggregated income groups. The shifter ε contains two pieces of information. One is a common component across the income groups, which reflects the linear component of consumers' response to the price changes; the other includes the consumers' demographic characteristics as they would vary by income levels. So with the common component in ε and the assumption that V and χ are equal across the income groups, we establish that all consumers have equal price and income preferences. What makes the difference in response is only the demographic characteristics variation. The welfare evaluations are given as in equation (9) for each of the income groups. The differences across disaggregated income groups come from differences in income and the value of the demographic parameters.

Data and Calibration

Our data come from several sources and require some transformation as explained below. A detail description of these data steps and various estimates are available from the authors.

Production of sweetener-intensive foods

To measure the cost share of sweeteners in the food production process, we use data on materials used by each industry from the Economic Census Industry Series Report (U.S. Census Bureau, 2004). This series report comes from the Census Bureau and is based on an industry survey collected every five years. The 2002 Economic Census Industry Series Reports (Manufacturing) was the latest survey available at the time of this analysis. Manufacturing industries are identified by the 2002 North American Industry Classification System (NAICS). The industry reports include quantity and cost of materials put into production by establishments classified in the specified industry. All dollar values presented are expressed in 2002 dollars. From the Economic Census Industry report, we identify four sweeteners that are used in the food processing industries: Sugars (sugar from cane and beet), Corn Sweeteners, Other (caloric) Sweeteners (including natural sweeteners such as dextrose, honey, and molasses), and Artificial Sweeteners and Sugar Substitutes (including sugar substitutes, such as sorbitol, or artificial sweeteners such as aspartame).

The cost shares of sweeteners in the total cost of food processing are approximated from the respective shares in the value of shipments from the component materials consumed. Some caveats are in order regarding this approximation.

Intermediate materials used

As related industries always represent successive production stages of a final product, the products of some industries are used as materials by other industries. In addition to the sweetener inputs used directly, sweeteners are also used in intermediate products such as fluid milk; cheese; dry, condensed and evaporated milk; ice cream and yogurt mix; prepared mixes; flour; liquid beverage base; and chocolate. These sweetener-intensive intermediate materials contain relatively large amounts of sugar, corn sweeteners, artificial sweeteners, and other sweeteners. When calculating the cost share of sweeteners in the "final product" manufacturing industry, the sweeteners' value contained in these sweetener-intensive intermediate materials is included in addition to the direct use of the sweeteners.

Targeted sweetener-intensive foods

We calculate the value of sweetener inputs in food industries and determine the most sweetener-intensive food industries. The products of the industries, the foods, are the focus of our analysis. Table 2.1 lists the nine targeted sweetener-intensive foods and the food industries to which they are matched.

As explained in the previous section, some of the outputs of the food manufacturing industries are consumed directly by consumers while others are chosen as inputs by manufacturers from other food industries. The proportion of products going to direct consumption for each food industry is also provided in Table 2.1.

Table 2.2 provides the data for the values and shares of the sweeteners in the nine target sweetener-intensive foods listed in Table 2.1 and account for the values from direct and intermediate product use. The numbers in parentheses show the distribution of the sweeteners among the nine target sweetener-intensive foods based on their values. Note that 68.51% of the Sugars and 66.61% of the Artificial Sweeteners contained in the nine target sweetener-intensive foods are taken by the final food product group "Sweetener products"; 54.36% of the Corn Sweeteners is taken by the final food product group "Soft drink"; and 44.93% of the Other Sweeteners is taken by the final product group "Condiments/Spices." Among all the sweeteners contained in the nine target sweetener-intensive foods, "Sweetener products" includes nearly one-half of the sweeteners. And both "Soft drink" and "Breakfast cereal/Bakery" hold nearly one-fifth of the total sweetener value share across the nine food groups. These three groups of final products are the foods with the largest relative value share in sweeteners.

The 2002 Economic Census Industry Series Reports (Manufacturing) provide the value of shipments for different food industries. These data are compiled from the perspective of production. To analyze the component ingredients from the perspective of consumption, some adjustment is needed. Specifically, the reported data on food disappearance (USDA/ERS, 2010) need to be matched and calibrated to the consumption data. We calculate the ratio of food disappearance data to the production data from the food availability dataset for the different foods and apply the adjustment ratio λ to convert the value of shipments from production y to consumption D following $D = \lambda y$. The values of the adjustment ratio λ are listed in Table 2.1. The values vary, in part, due to the extent of trade and value-added after production.

Demand parameters

To recover the parameter values in the LinQuad demand system, measures of the income elasticities η_{iI}, own-price elasticities η_{ii}^{M}, cross-price elasticities η_{ij}^{M}, income I, prices P_i, and consumption levels D_i are needed. Since we carry out calibration for all households and for households by disaggregated income groups, data for these two sets of household aggregates are discussed separately.

For all households, income elasticities η_{iI} and price elasticities $\eta_{ii}^{M}, \eta_{ij}^{M}$ were obtained from USDA/ERS' Commodity and Food Elasticities Database (2008a) and Chouinard et al. (2010). The USDA/ERS database is a collection of elasticities mostly from academic and government research, as published in journals and working papers. Chouinard et al. provides detailed elasticities for dairy. We take the average of the available elasticities for each of the food groups, after removing those elasticities that were outside two standard deviations of the mean level of the elasticities for the food group. The summary statistics for the own-price elasticities and income/total expenditure elasticities obtained in this way are listed in Table 2.3. The food groups “Cheese,” “Processed fruits and vegetables,” and “Condiments/Spices” turn out to be price elastic while others are price inelastic. The food groups “Ice cream/yogurt” and “Soft drink” have negative income elasticities. All the available cross-price elasticities are very small in absolute value, which means the substitutability or complementarily among the final products is limited. The calibration of matrix V yields the missing Hicksian cross-price effects when cross-price elasticities are not available.

Consumption data

For income I, we rely on the 2002 Consumer Expenditure Survey (CEX) (Bureau of Labor Statistics, 2002) estimate of total number of households (the number represented in the survey is 112,108,000) and the average household income level after taxes ($46,934). Based on these values, the annual income for all the households is estimated to be $5.26 trillion. All final food prices P are initially set at $1 per unit. The consumption units are unknown but results are independent of the price normalization. For demand quantities, as all the prices are set at $1 per unit, we use the adjusted value of shipment of the foods in dollar values as physical quantities.

The 2002 CEX provides data on income and expenditures for different food groups for households disaggregated by quintiles of income. These data provide the disaggregated annual income and food expenditures (Table 2.4). The values of at-home food expenditures in the CEX were used to distribute the total adjusted industry level value of shipments in the 2002 Economic Census Industry Series Reports (Manufacturing) across the five income groups. Because there are no data for food away from home at a disaggregated (food group) level in the CEX, we abstract from differences between the composition of food at home and food away from home across the food categories and use the distribution of all foods as evidenced by the food at home component. All the food prices are initially set at $1 per unit for the quintile expenditures as in the "all households" calibration.

Consumers on average initially spend more than $100 per capita on each of the food groups "Breakfast cereal/Bakery," "Soft drink," "Condiments/Spices," and "Milk", listed in relative order of expenditures before a tax is imposed (Table 2.4). These four foods represent over 65% of the total per capita real expenditure on the nine sweetener-intensive foods (20.63%, 16.31%, 14.41%, and 13.83%, respectively). Consumers initially consume 61.90 pounds of Sugars, 54.81 pounds of Corn Sweeteners, 2.86 pounds of Other Sweeteners, and 0.54 pounds of Artificial Sweeteners. In terms of value (data not shown here in the tables), the initial per capita value of sweeteners consumption was about $22.66. Of that value, 60.90% was for Sugars, 32.26% for Corn Sweeteners, 4.15% for Other Sweeteners, and 2.69% for Artificial Sweeteners.

The five demand systems for quintile income groups are solved by utilizing the partial derivative of demand to income (χ) for all households and setting the parameter matrix of the quadratic price term to be equal among different income groups. The parameter for the linear term of the price for all households, ε_{All}, equals the summation of those for quintile income groups ε_1 to ε_5. By construction, this parameter includes not only the information of the response to price but also that of the demographic characteristics. With these parameters, the Marshallian price elasticity matrix for all households and disaggregated income groups are recovered. The absolute values of the own-price elasticities for each food category are monotonically decreasing from the lowest quintile to the top quintile income groups. Low-income consumers are more sensitive to price variations than high-income households.

Production technology in food industries

As shown in Table 2.5, the cost shares of sweeteners, including Sugars, Corn Sweeteners, Other Sweeteners, and Artificial Sweeteners used in the manufacturing process account for less than 4% of the total costs of production (except for the "Sweetener products" industry for which they account for 12.37%). All other materials used in the manufacturing process are summed up into one "All Other Inputs." The aggregation of the other inputs is done to focus on sweeteners and abstract from what happens to other inputs.

The five-by-five matrix of input price elasticities for sweetener-intensive industries is developed from food industry estimates of Goodwin and Brester (1995). The diagonal elements, (own-price elasticity of sweeteners), are set to -0.48. In the upper triangle elements, the cross-price elasticity of Sugars with respect to Corn Sweeteners is set to 0.30; if there is some usage of Other Sweeteners and Artificial Sweeteners, the cross-price elasticities of Sugars and Corn Sweeteners with respect to Other Sweeteners are both set to 0.01; and the cross-price elasticities of Sugars, Corn Sweeteners, and Other Sweeteners with respect to Artificial Sweeteners are all set to 0.005. The lower triangle elements are derived from the upper triangle elements because their ratios are proportional to their cost shares' ratio based on the definition of the Hessian matrix in the production. Further steps impose homogeneity via "All Other Inputs" and concavity is checked and imposed if needed by scaling off-diagonal terms.

Results

To formally compare the efficiency and distributional properties of the two types of tax instruments, the taxes are designed to reduce the quantity of all sweeteners (sugar equivalent) that all households consume by 10% while minimizing the associated surplus loss to all households as measured by their aggregate EV. This amounts to about 13.13 grams per capita daily sugar equivalent added sweeteners consumption, which contain 52.54 calories. The equal reduction of sweetener consumption is the basis of equivalence to compare the scenarios.

We simulate four policy shocks: a final consumption tax, a set of input taxes on caloric sweeteners, and two individual input taxes on sugars and then corn sweeteners. Table 2.6 shows the tax rates for the scenarios and the implied changes in food prices and consumption for all households. Table 2.7 shows the implied changes in sweetener consumption for all households and by quintile. Table 2.8 presents the expenditure and welfare implications of the taxes for the aggregate all households and households by income quintile.

Consumption taxes

We start with consumption taxes. To reach the 10%-reduction of the sugar equivalent quantity of all sweeteners, we solve for consumption taxes achieving the target while minimizing the associated EV of all households. The optimum tax scheme yields a tax falling nearly exclusively on the final product group "Sweetener Products" with a tax rate at 39.30% and at negligible rates on the other eight final products (see Table 2.6). This is determined by the fact that 47.82% of all sweeteners contained in the nine sweetener-intensive foods are in this particular food group. Food demand decreases the most (-19.82%) in the group of "Sweetener products" with the consumption tax. The demand for "Condiments/Spices" also decreases by a small amount. Demand for all other foods increases slightly through substitution effects.

Since the tax is imposed on the price of final products and does not cause any substitution among the sweeteners in the manufacturing process, the sweeteners consumed change at the same rate as the final products consumed (scale effects). Overall, the quantities of all sweeteners (sugar equivalent) consumed decrease by 10% by design. The quantity of Sugars consumed decreases by 13.39% and the Artificial Sweeteners by 13.14% (Table 2.7). These rates of decrease are much higher than the decrease of quantities of Corn Sweeteners and Other Sweeteners consumed because the tax falls mostly on "Sweetener products," and this food group has the highest use of Sugars and Artificial Sweeteners. Since the initial consumption of final products are not monotonically increasing or decreasing across the five income groups, the initial consumptions of sweeteners included in the foods are not monotonic across the groups either. However, the drop of the sugar equivalent of the quantity consumed of all sweeteners decreases monotonically from the lowest quintile income group (with a rate of -13.10%) to the highest quintile income group (with a rate of -6.26%) to achieve an average of -10% for all households. Sugar always ranks first among the four types of sweeteners in the rate of consumption change, followed by Artificial Sweeteners. For each type of sweetener, the drop in the sweetener's quantity decreases monotonically from the lowest quintile income group to the highest quintile income group. Although the per capita real expenditures for the target sweetener-intensive foods are not monotonic across income groups, the changes induced by the consumption tax increase from 0.51% for the lowest quintile income group to 2.70% for the highest quintile income group monotonically (Table 2.8).

Per capita real expenditure on all nine foods increases by 1.86% from the baseline condition of $726.13 per capita in 2002 (Table 2.8). The per capita welfare loss caused by the tax is $31.00, which represents 0.17% of the income. Although the per capita real expenditure increases the most for the highest income group and the per capita EV is highest for the highest income group, the welfare loss represents 0.60% of income for the lowest quintile income group while it represents only 0.10% of income for the highest quintile income group. The proportion of the market welfare loss in income for the lowest income group is six times that of the highest income group, which indicates that this consumption tax is regressive but its impact is small.

Finally, we also compare this consumption tax with a tax on soft drinks, an approach often considered in policy debates. Results are not shown in tables presented here. To reduce the sweetener consumption by 10%, the consumption tax on soft drinks would be 63.19%. The associated per capita EV is $52.92, which takes 0.28% of income. Hence, a soda tax is clearly less efficient than taxing food items in "Sweetener Products," but it is of the same order of magnitude.

Taxes on caloric sweetener inputs

Next, we simulate a tax imposed on caloric sweetener inputs. The input tax on the price of sweeteners is fully passed on to consumers of sweetener-intensive foods through higher output unit cost and prices. To reach the target of reducing the sugar equivalent quantity of all sweeteners that all households consume by 10% and minimizing the associated welfare loss of all households, the tax rates are estimated to be 27.47% on Sugars, 42.95% on Corn Sweeteners, and a very small rate on Other Sweeteners (see middle of Table 2.6). These simulated taxes have the most effect on the final price of "Sweetener products" and “Soft drink” because these two final foods hold 68.51% of the Sugars and 54.36% of the Corn Sweeteners that are contained in the nine sweetener-intensive food categories. With the highest new consumer prices, these two food categories have over a 1% decrease in their demand. Other food categories have smaller decreases compared to these two categories.

With different tax rates on different types of caloric sweeteners, the variation of the sweeteners’ price leads food manufacturers to make adjustments in their production process in terms of scale and substitution effects. Scale effects result from the consumers’ demand adjusting to higher unit cost and hence higher consumer prices. Further, the variation of sweetener input prices leads food processors to substitute away from expensive sweeteners to cheaper sweeteners and other inputs. Sugars and Corn Sweeteners used in each food category decrease and the Other Sweeteners and Artificial Sweeteners increase (data not shown here). Looking at the sweetener use by sector, there is some decrease in the usage of Artificial Sweeteners in the “Sweetener product” group. The use of Sugars declines the most in the “Sweetener products” and the use of Corn Sweeteners declines the most for “Soft drinks.” Among the nine products, the contribution of “Soft drinks” in aggregate-sweetener use falls the most (Table 2.6). “Processed fruits and vegetables,” “Juice,” and “Sweetener products” see their contribution fall by more than 10%.

The use of Sugars and Corn Sweeteners in food processing decreases because of the increase in their prices. However, the cost of all caloric sweeteners goes up as the increase in prices exceeds the drop in quantities because the inputs are price-inelastic. In aggregate – across all nine sweetened products -- Corn Sweeteners use decreases the most (by 12.41%), followed by Sugars use (by 8.95%) (Table 2.7). The quantities of Other Sweeteners and Artificial Sweeteners increase, as they are substitutes to the taxed sweeteners. In aggregate, the sugar equivalent sweetener quantity is reduced by 10%, again by design.

As shown in Table 2.7, as the sugar equivalent quantity of added sweeteners consumed by all households is reduced by 10%, the decrease varies across the income groups from an average decrease of 10.45% for the lowest quintile income group to 9.73% for the highest quintile. The consumption of Sugars and Corn Sweeteners decreases; Other Sweeteners and Artificial Sweeteners consumption increases. The absolute values of the rates of change in quantities of Sugars and Corn Sweeteners decrease monotonically from low-income to high-income groups, while the absolute values of the change rates in quantities of Other Sweeteners and Artificial Sweeteners increase in an ascending order from low-income to high-income groups. The expenditures on all four types of sweeteners consumed all rise because these derived demands are price-inelastic.

Detailed simulation results not reported here on the five-quintile income groups with the tax on Caloric Sweeteners show that the consumption of all nine sweetener-intensive foods falls for each of the income groups. The decreases in “Sweetener products” and “Soft drink” are much higher than for the other food categories. The comparison across the five income groups shows that for most food categories, demand drops less as income goes up as a consequence of the difference in the price elasticities for the different quintiles.

As shown in Table 2.8, the tax on Caloric Sweeteners causes the per capita real expenditure to increase 0.27%, which is smaller than with the final consumption tax. The change in per capita EV is $5.98 (or 0.032% of the per capita income), which is also much smaller than the one caused by consumption taxes. Looking at quintiles, the per capita real expenditure changes move at ascending rates from 0.007% for the lowest income group to 0.43% for the top income group. The highest income group has the largest market welfare loss. In per capita terms, the EV is small. It takes 0.12% of the income of the lowest income group and 0.02% of the income of the highest income group. The proportion of the market welfare loss in income for the lowest income group is six times that of the highest income group, just as was the case when the consumption tax was imposed. The simulated tax on Caloric Sweeteners is also regressive, as it puts a greater burden on low-income consumers. However, the welfare loss is much smaller than in the case of the consumer tax, almost to the point of being negligible. Hence, the tax burden on the lower-income consumers is drastically reduced with the input tax approach.

Tax on individual sweeteners

Finally, we consider an input tax alternatively imposed on two individual sweeteners. The health literature often discusses whether the intake of sugar and/or HFCS causes obesity, hence, the focus on these two major sweeteners. The bottom section of Table 2.6 shows the implied tax rates for all households with a tax imposed on Sugars or Corn Sweeteners to reach the same reduction target. An ad valorem tax of 61.25% on the price of Sugars or a tax of 156.85% on the price of Corn sweeteners is needed to reach the target. This case is motivated by the ongoing debate alleging that some sweeteners are healthier than others. HFCS has been heavily targeted in some debates as a major source of health problems (White, 2008; Melanson, et al., 2008). Although these claims have not been confirmed, it is still interesting to look at the consequences of singling out a caloric sweetener with a tax.

With the Sugars input tax, “Sweeteners products” consumption exhibits the largest decrease (-2.63%) because it uses Sugars the most. Considering all the Sugars in nine food categories together, the quantity of Sugars consumed decreases 22.09% while the associated expenditure increases (Table 2.7). Other types of sweeteners increase in both their quantities and values. The per capita real expenditure on all nine foods increases by 0.46% (Table 2.8). The per capita EV is $6.65 and it represents 0.035% of consumer income. The real expenditure increases monotonically from 0.25% for the lowest income group to 0.60% for the highest income group (Table 2.8).

With the tax on Corn Sweeteners, manufacturers switch away from Corn Sweeteners to other sweeteners. “Soft drink” has the largest (3.02%) decrease in its food demand because it uses Corn Sweeteners the most (Table 2.6). Counting all the Sugars in nine food categories together, Corn Sweeteners consumption decreases (37.64%) (Table 2.7). Other types of sweeteners increase in consumption. The per capita real expenditure of all nine foods increases by 0.09% (Table 2.8). The per capita EV is about $6.90 and it takes 0.037% of income. Real expenditures decrease for the lowest 20% and second 20% income groups but increase for the other three quintile income groups.

Finally, the absolute values of the per capita EV under both the consumption and the input taxes have a U-shaped trend across the income quintiles, with smallest losses in the second quintile income group. Relative to income, the fraction of EV in income decreases from the lowest income group to the highest income group. The tax on individual sweeteners is regressive too, but the welfare loss to those with low income is much lower than in the case of the consumer tax.

With a final consumption tax as the policy tool, the total reduction in sweetener (sugar equivalent) from the tax on a given sector can be approximated by the product of the share of the targeted sector in total sweetener consumption (see Table 2.2) times its own-price elasticity of final demand (Table 2.3). This approximation abstracts from cross-price effects in demand, which are small in our model. Hence, for the sweetener products sector, we have an approximate reduction of (-0.4782*0.5=-23.91%) for a 1% consumption tax on that sector. This is by far the largest reduction among the nine potential final tax candidates. The soft drink reduction is 18.29%, the second largest. So as long as the welfare costs of each of these candidate taxes are quite similar, the tax on sweetener products will be the most effective because that sector has the largest share of total sweetener use (as sugar equivalent). The tax on soft drinks would be the second most effective way to abate caloric sweetener use through a consumption tax.

This provides guidance and intuition for the sensitivity analysis. As long as the multiplier (share times own-price elasticity) is the highest for the sweetener product sector, it will remain the sector of choice for the final tax. Once the elasticity falls below a certain level in absolute value, it eventually becomes less effective at abating sweeteners and the tax moves to other sectors like a consumption tax on soft drinks.

The intuition for an input tax is somewhat less obvious. The percent change in total sweetener use (sugar equivalent) is the weighted sum of the percent changes in each type of sweetener use weighted by its initial share in the total sweetener use. Each percent change in a sweetener use is itself the weighted sum of nine proportional changes of that sweetener use in each of the nine final good sectors. The latter sectoral input change ($dln\ x_{hi}$) is the sum of a scale effect ($dlny_i$) and the price effect change from input taxes ($\sum\delta_{ihk}\ dln(1+t_k)$). As input own-price elasticities are assumed nearly similar for each sweetener and across sectors, a given tax change $dln(1+t_k)$ on sweetener k has an input price effect nearly similar across sweeteners, and then a scale effect, heterogeneous across sweeteners and sectors via an increase in marginal cost of the sector ($s_{ik}\ dln(1+t_k)$). So the major difference in the effectiveness of any input tax resides in the scale effect it produces in addition to the abatement induced by the input price response holding output y_i constant.

The input tax, which creates the largest scale effects in sectors that are intensive in caloric sweeteners, abates the most. Both sugars and HFCS are taxed because both contribute to large scale effects and hence sweetener abatement via scale effects. Other caloric sweeteners are not taxed because they do not create much abatement via scale effects as their contribution to all sweeteners and their cost shares are small.

Sensitivity analysis

We undertake sensitivity analysis. The real values of the substitutability among sweeteners are unknown so all of our simulations are based on the values we assumed for the input price elasticities. To test how the results depend on the input elasticities, we decrease all the cross-price elasticities between sweeteners by one-half in the upper-triangles of the price elasticities matrix for each of the nine food industries while keeping the own-price elasticities as before. In simulating the reduction in sugar equivalent quantity of all sweeteners by 10% with the new elasticities, we find that the tax rates on Caloric Sweeteners decrease only a little compared with the tax rates before changing the input elasticities. The results are similar for other configurations of the taxes (taxing Sugars, or Corn Sweeteners). From these simulations, we determine that if the substitutability among sweeteners is decreased by half, the change in the tax required to reach the desired goal is changed by very little.

However, the input price elasticities play a less important role than do the demand price elasticities for the final products. We extended the sensitivity analysis to include variation in the demand price elasticities by doubling and halving the elasticities used, as well as evaluating the results at the minimum and maximum of the elasticities (values reported in Table 2.3). As long as the elasticities keep similar (relative) magnitudes, our qualitative results do not change although tax rates increase as demand becomes less price elastic. When we considered the maximum (i.e., least responsive) values of Table 2.3, the consumption tax switched from sweetener products to soft drinks. This occurs because the (maximum) elasticity on sweetener products is -0.05, which reduces considerably the abatement of sweeteners through this sector. Such reduction in price responsiveness does not occur in soft drinks.

Conclusions

We analyzed the use of final consumption and input taxes as instruments to reduce sweetener intake and derive their welfare effects on different income groups. We applied the LinQuad approach to a partial demand system for selected food consumption in the United States in 2002. Nine sweetener-intensive food groups were constructed for all households from the 2002 Economic Census Industry Series Reports (Manufacturing). Because of the possible different consumption patterns across income levels, we divided all households into five quintile income groups. We calibrated demand systems for all households and for each income group. Sugars, Corn Sweeteners, Other Sweeteners, and Artificial Sweeteners are the four types of sweeteners considered. Substitution among sweeteners in food processing takes place when a tax is imposed on some sweeteners. We compared two ways to reach the target of reducing the sugar equivalent quantity of all sweeteners by a certain amount while minimizing the loss of consumer welfare from the taxes.

Taxing the price of final products intensive in sweeteners leads to the largest tax falling on “Sweetener products”, with associated decrease in the demand. All four types of sweeteners decrease in quantity. Note, this finding indicates that a final tax applied to "Sweetener products" is more effective at reducing sweetener intake than would be a soda tax on "Soft drinks", a product often proposed for taxation. In contrast to either of these final products, taxing Caloric Sweeteners inputs causes relatively large decreases in consumption of the final goods "Sweetener products" and "Soft drinks", and decreases in the quantities of Sugars and Corn Sweeteners used in final goods. Taxing individual sweeteners only lowers the quantity of the particular sweetener that is taxed, and has a relatively targeted effect on final demand of specific products. These results also apply to each of the income groups. Thus, the results of the policy may vary depending on which food category a policymaker may target or which sweetener may be targeted.

Increasing the price of the sweetener-intensive foods, whether by taxing final consumption or by taxing sweetener inputs, would reduce consumer welfare by a relatively small magnitude: $31.00 per capita EV with a consumption tax, and $5.98 per capita EV with a caloric sweeteners input tax. Both amounts are less than 0.2% of income. No matter which tax instrument is applied, the lowest income group is always the group most affected and the highest income group the least affected. Both the final consumption and input taxes are regressive.

Our results hold as well under several proposed policy options currently under consideration. For example, a one-cent-per-ounce soda tax can be converted to a 48.86% ad valorem tax applied to the "Soft drinks" food group. Such a tax would abate 7.73% of sweeteners with a per capita EV of $44.75. The removal of corn subsidies would imply a tax on HFCS of 3.72%. This tax would abate 0.53% of all sweeteners, and hence this policy, although fairly efficient in abating sweetener use, is an ineffective way to abate sweetener use compared to a soda tax.

All the existing studies to date, including ours, overestimate the regressive nature of food taxes because the reduction in sweetener consumption, along with the associated calories, is relatively more significant for the low-income group than for the high-income group (Baum and Ruhm 2009). Socioeconomic status is inversely associated with body weight, and obesity is associated with higher health risk. So the low-income consumers benefit more than the high-income consumers if health status is incorporated into the welfare evaluation. Higher weights on the EV of the low-income groups relative to the high-income groups when designing the policy choices would account for poverty aversion.

Overall, the tax on sweeteners has a smaller impact on consumers' real expenditures and market welfare than does the tax on final products. The tax on Caloric Sweeteners causes a loss to consumers on a per capita basis ($5.98). Although a bit larger, a tax on individual sweeteners is similar, with losses of $6.65 from a tax on Sugars and of $6.90 from a tax on Corn Sweeteners. Because the tax on final consumption has an EV loss about five times as great on all households and for each income group compared with the input tax on caloric sweeteners, taxing caloric sweeteners is the most efficient way to achieve the policy target based on the EV criteria.

There are obvious limitations in our analysis. First, the measurement of the food demand, real expenditure, sweeteners consumption value, and welfare evaluation are all based on the adjusted value of shipments from the Economic Census report. These wholesale values underestimate the demand, expenditure, and EV at retail prices. Second, we only account for the consumption effect of the policy instruments. Third, food items included in the investigation are relatively limited. Some caloric-intensive foods are not included (such as food with fat). Future extension could take into account the substitution between the added sugar and fat component or go to the sub-food sectors to capture sector-specific effects. Finally, other demographic variables than income could be included in future studies to investigate the role of elasticities in the consumption patterns and to examine the changes in welfare.

References

Atwood, J.A., and G.A. Helmers. “Examining Quantity and Quality Effects of Restricting Nitrogen Applications to Feedgrains.” *American Journal of Agricultural Economic*, 80, 1998, 369-381.

Baum, C.L., and C.J. Ruhm. “Age, Socioeconomic Status and Obesity Growth.” *Journal of Health Economics* 28(3), 2009, 635-648.

Beghin, J.C., J. Bureau, and S. Drogué. “The Calibration of Incomplete Demand Systems in Quantitative Analysis.” *Applied Economics*, 36(8), 2004, 839-847.

Boizot-Szantaï, C., and F. Etilé. “The Food Prices / Body Mass Index Relationship: Theory and Evidence from a Sample of French Adults.” Paper prepared for presentation at the Congress of the EAAE (European Association of Agricultural Economists), Copenhagen, Denmark, 24-27 August 2005.

Bureau of Labor Statistics. *2002 Expenditure Tables*. U.S. Department of Labor, 2002, http://www.bls.gov/cex/csxstnd.htm#2002 (accessed July 2008).

Cash, S.B., D.L. Sunding, and D. Zilberman. “Fat Taxes and Thin Subsidies: Prices, Diet, and Health Outcomes.” *Acta Agriculturae Scand C: Food Economics* (special issue on the economics and policy of diet and health), 2, 2005, 167-174.

Chouinard, H.H., D.E. Davis, J.T. LaFrance, and J.M. Perloff. “Fat Taxes: Big Money for Small Changes.” *Forum for Health Economics & Policy*, 10(2), Art.2, 2007, available online at http://www.bepress.com/fhep/10/2/2.

Chouinard, H.H., D.E. Davis, J.T. LaFrance, and J.M. Perloff. “Milk Marketing Order Winners and Losers.” *Applied Economic Perspectives and Policy*, 32(1), 2010, 59-76.

Cutler, D.M., E.L. Glaeser, and J.M. Shapiro. “Why Have Americans Become More Obese?”

Journal of Economic Perspectives, 17(3), 2003, 93-118.

Dietary Guidelines Advisory Committee (DGAC). Report of the Dietary Guidelines Advisory Committee on the Dietary Guidelines for Americans, 2010, to the Secretary of Agriculture and the Secretary of Health and Human Services. U.S. Department of Agriculture, Agricultural Research Service, Washington, DC.

Flegal, K.M., M.D. Carroll, C.L. Ogden, and L.R. Curtin. "Prevalence and Trends in Obesity among US Adults, 1999-2008." *Journal of the American Medical Association*, 303(3), 2010, 235-241.

Fletcher, J.M., D. Frisvold, and N. Tefft. "Can Soft Drink Taxes Reduce Population Weight?" 28(1), 2010, 23-35.

Goodwin, B., and G. Brester. "Structural Change in Factor Demand Relationship in the U.S. Food and Kindred Products Industry." *American Journal of Agricultural Economics*, 77, 1995, 69-79.

Gustavsen, G. "Public Policies and the Demand for Carbonated Soft Drinks: A Censored Quartile Regression Approach." Paper prepared for presentation at the Congress of the EAAE (European Association of Agricultural Economists), Copenhagen, Denmark, 24-27 August 2005.

Kantor, L. *A Dietary Assessment of the U.S. Food Supply: Comparing Per Capita Food Consumption with Food Guide Pyramid Servings Recommendations*. U.S. Department of Agriculture, Agricultural Economic Report 772. 1998.

Kuchler, F., A Tegene, and J.M. Harris. "Taxing Snacks Foods: Manipulating Diet Quality or Financing Information Programs?" *Review of Agricultural Economics*, 27 (1), 2005, 4-20

LaFrance, J.T. “The LINQUAD Incomplete Demand Model.” Working Paper, Department of Agricultural and Resource Economics, University of California, Berkeley, 1998.

Leicester, A., and F. Windmeijer. “The ‘Fat Tax’ Economic Incentives to Reduce Obesity.” London: The Institute for Fiscal Studies. Briefing Note No. 49, 2004.

Melanson, K., T.J. Angelopoulos, v. Nguyen, L. Zukley, J. Lowndes, and J.M. Rippe. “High-fructose corn syrup, energy intake, and appetite regulation.” *American Journal of Clinical Nutrition,* 88(suppl), 2008, 1738S–44S.

Mullen, J.D., M.K. Wohlgenant, and D.E. Farris. “Input Substitution and the Distribution of Surplus Grains from Lower U.S. Beef-Processing Costs.” *American Journal of Agricultural Economics*, 70, 1998, 245-254.

Nakamura, E. “Pass-Through in Retail and Wholesale.” *American Economic Review*, 98(2), 2008, 430-437.

O’Donoghue, T., and M. Rabin. “Doing It Now or Later.” *The American Economic Review*, 89(1), 1999, 103-124.

Richards, T.J., P.M. Patterson, and A. Tegene. “Obesity and Nutrient Consumption: A Rational Addiction?” *Contemporary Economic Policy*, 25(3), 2007, 309-324.

Schroeter, C., J. Lusk, and W. Tyner. “Determining the Impact of Food Price and Income Changes on Body Weight.” *Journal of Health Economics*, 27, 2008,45-68.

Smed, S., J.D. Jensen, and S. Denver. “Socio-economic Characteristics and the Effect of Taxation as a Health Policy Instrument.” *Food Policy,* 32, 2007, 5-6.

Sumner, D.A., and M.K.Wohlgenant. “Effects of an Increase in the Federal Excise Tax on Cigarettes.” *American Journal of Agricultural Economics*, 67(2), 1985, 235-242.

U.S. Census Bureau. Economic Census, Manufacturing Reports, Industry Series, 2002. U.S.

Department of Commerce, Census Bureau. 2004. www.census.gov/econ/census02/ guide/INDRPT31.HTM (accessed April 2008).

U.S. Department of Health and Human Services and U.S. Department of Agriculture, Economic Research Service. *Dietary Guidelines for Americans, 2005*. 2005. http://www.health.gov/dietaryguidelines/dga2005/document/ (accessed November 2009).

U.S. Department of Agriculture, Economic Research Service. "Commodity and Food Elasticities". 2008a. http://www.ers.usda.gov/Data/Elasticities/ (accessed August 2008).

U.S. Department of Agriculture, Economic Research Service. "Food Availability (Per Capita) Data System" 2010. http://www.ers.usda.gov/Data/FoodConsumption/ (accessed January 2011).

White, J. S. "Straight talk about high-fructose corn syrup: what it is and what it ain't." *American Journal of Clinical Nutrition,* 88(suppl), 2008,1716S–21S.

Table 2.1 Nine Sweetener-Intensive Food Groups in U.S. Food Manufacturing

	Food Industries			
Sweetener-Intensive Foods	NAICS Code	NAICS Definition	Products Going to Direct Consumption (%)	Consumption Adjustment Ratio[a]
Milk	311511	Fluid milk mfg	91.06	1.00
	311514	Dry, condensed, & evaporated dairy product mfg	86.30	0.75
Cheese	311513	Cheese mfg	81.08	1.03
Ice cream / yogurt	311520	Ice cream & frozen dessert mfg	93.86	1.00
Breakfast cereal / Bakery	311211	Flour milling	65.06	0.75
	311230	Breakfast cereal mfg	100	0.75
	311812	Commercial bakeries	100	0.75
	311813	Frozen cakes, pies, & other pastries mfg	100	0.75
	311821	Cookie & cracker mfg	100	0.75
	311822	Flour mixes & dough mfg from purchased flour	91.94	0.75
Soft drink	312111	Soft drink mfg	100	1.00
	311930	Flavoring syrup & concentrate mfg	16.42	1.00
Juice	311411[b]	Frozen fruit, juice & vegetable mfg	100	1.78
	311421[c]	Fruit & vegetable canning	100	1.52
Sweetener products	311312/ 311313	Cane sugar refining / Beet sugar mfg	58.02	1.02
	311320	Chocolate & confectionery mfg from cacao beans	64.44	1.07
	311330	Confectionery mfg from purchased chocolate	100	1.07
	311340	Non-chocolate confectionery mfg	100	1.07
	311999[d]	All other miscellaneous food mfg	100	0.72
Processed fruits & vegetables	311421[e]	Fruit & vegetable canning	100	1.52
	311423[f]	Dried & dehydrated food mfg	100	0.63
	311421[g]	Fruit & vegetable canning	100	1.52
Condiments / Spices	311941	Mayonnaise, dressing, & other prepared sauce mfg	100	1.00
	311942	Spice & extract mfg	100	4.28

Source: 2002 Economic Census Industry Series Reports (Manufacturing).
a- Ratio of food disappearance to food production based on USDA/ERS Food Availability Data.
b- Includes "Frozen juices, aides, drink, & cocktail" of sector 311411.
c- Includes "Canned fruit juices, nectars, & concentrates" and "Fresh fruit juices & nectars" of sector 311421.
d- Includes "Desserts (ready-to-mix)" and "Sweetening syrup & molasses" of sector 311999.
e- Includes "Canned jams, jellies & preserves" of sector 311421.
f- Includes "Dried & dehydrated fruits & vegetables, including freeze-dried" of sector 311423.
g- Includes "Canned catsup & other tomato based sauce" of sector 311421.

Table 2.2 Values and Shares of Sweeteners in Nine Sweetener-Intensive U.S. Food Sectors

Sweetener-Intensive Food	Values of Sweeteners (million dollars) and Industry Value Shares				
	Sugars	Corn Sweeteners	Other Sweeteners	Artificial Sweeteners	All Sweeteners
Milk	145,566 (3.76%)	204,833 (10.00%)	0 (0.00%)	112 (0.07%)	350,510 (5.52%)
Cheese	7,005 (0.18%)	14,768 (0.72%)	0 (0.00%)	0 (0.00%)	21,773 (0.34%)
Ice cream / yogurt	88,003 (2.28%)	78,184 (3.82%)	0 (0.00%)	162 (0.10%)	166,349 (2.62%)
Breakfast cereal / Bakery	792,602 (20.49%)	171,138 (8.35%)	118,478 (44.93%)	13,367 (7.88%)	1,095,585 (17.25%)
Soft drink	58,065 (1.50%)	1,113,977 (54.36%)	42,982 (16.30%)	33,746 (19.89%)	1,248,770 (19.67%)
Juice	26,169 (0.68%)	86,191 (4.21%)	0 (0.00%)	0 (0.00%)	112,360 (1.77%)
Sweetener products	2,649,603 (68.51%)	255,077 (12.45%)	19,093 (7.24%)	112,986 (66.61%)	3,036,759 (47.82%)
Processed fruits and vegetables	18,493 (0.48%)	65,167 (3.18%)	0 (0.00%)	0 (0.00%)	83,660 (1.32%)
Condiments / Spices	81,830 (2.12%)	59,832 (2.92%)	83,132 (31.53%)	9,255 (5.46%)	234,049 (3.69%)
Total Sweetener-Intensive Foods	17,350,095 (100.00%)	15,361,063 (100.00%)	800,258 (100.00%)	151,400 (100.00%)	29,622,486 (100.00%)

Source: 2002 Economic Census Industry Series Reports (Manufacturing).
Note: Numbers in parentheses are the (value) shares of the respective sweetener used in the nine target sweetener-intensive foods.

Table 2.3 Own-Price and Income / Total Expenditure Elasticities of Nine Target Sweetener-Intensive Foods

Food groups	Own-Price Elasticity				Income / Total Expenditure Elasticity			
	Mean	Standard deviation	Minimum	Maximum	Mean	Standard deviation	Minimum	Maximum
Milk	-0.72	0.32	-1.49	-0.19	0.03	0.50	-0.48	1.01
Cheese	-1.07	0.62	-1.90	-0.33	0.22	0.75	-0.42	1.40
Ice cream / yogurt	-0.83	0.07	-0.91	-0.74	-0.17	0.22	-0.41	0.04
Breakfast cereal / Bakery	-0.47	0.29	-1.03	-0.04	0.23	0.49	-0.55	1.18
Soft drink	-0.93	0.40	-1.26	-0.48	-0.03	0.08	-0.09	0.02
Juice	-0.85	0.38	-1.58	-0.15	0.38	0.98	-1.36	2.12
Sweetener products	-0.50	0.72	-2.63	-0.05	0.05	0.40	-0.71	0.19
Processed fruits and vegetables	-1.97	0.90	-3.07	-0.64	0.49	0.56	-0.30	1.16
Condiments / Spices	-1.04	0.49	-1.93	-0.58	0.12	0.42	0.05	1.00

Source: USDA/ERS Commodity and Food Elasticities, 2008a; Chouinard et al., 2010.

Table 2.4 Per Capita Income and Food Expenditure Distribution among Nine Sweetener-Intensive Foods (Dollars)

	All Households	Lowest quintile	2d quintile	3rd quintile	4th quintile	Top quintile
Population (billion)	0.28	0.04	0.05	0.06	0.06	0.07
Average annual income after taxes	18,774	4,857	9,407	14,214	20,019	35,049
Annual food expenditure (per capita)	726.13	702.63	679.00	691.40	731.25	793.57
Milk	100.44	104.98	107.31	95.18	99.59	98.18
Cheese	65.55	60.44	56.54	62.73	66.77	75.57
Ice cream / yogurt	27.39	25.26	23.62	26.21	27.90	31.58
Breakfast cereal / Bakery	149.78	150.03	141.06	138.98	148.90	164.84
Soft drink	118.41	114.12	109.23	112.87	120.07	129.86
Juice	42.96	41.98	40.55	40.33	42.70	47.40
Sweetener products	87.56	86.58	79.50	85.20	87.20	95.78
Processed fruits and vegetables	29.39	28.84	27.74	28.36	29.48	31.53
Condiments / Spices	104.65	90.40	93.45	101.54	108.64	118.83
All Sweeteners (sugar equivalent lbs)	105.69	103.83	97.85	101.28	105.85	115.37
Sugars (s.e. lbs)	61.90	61.21	56.96	59.54	61.73	67.67
Corn Sweeteners (s.e. lbs)	54.81	53.41	51.24	52.26	55.22	59.63
Other Sweeteners (s.e. lbs)	2.86	2.72	2.63	2.71	2.89	3.17
Artificial Sweeteners (s.e. lbs)	0.54	0.53	0.49	0.52	0.54	0.59

Source: Consumer Expenditure Survey (CEX) 2002, BLS; 2002 Economic Census Industry Series Reports (Manufacturing).
Note: s.e. is "sugar equivalent".

Table 2.5 Cost Shares of Sweetener Inputs in Nine Sweetener-Intensive U.S. Food Sectors

Food	Cost Shares of Sweeteners (%)				
	Sugars	Corn Sweeteners	Other Sweeteners	Artificial Sweeteners	All Sweeteners
Milk	0.5171	0.7276	0.0000	0.0004	1.2451
Cheese	0.0381	0.0804	0.0000	0.0000	0.1185
Ice cream / yogurt	1.1464	1.0185	0.0000	0.0021	2.1670
Breakfast cereal / Bakery	1.8881	0.4077	0.2822	0.0318	2.6098
Soft drink	0.1750	3.3567	0.1295	0.1017	3.7628
Juice	0.2174	0.7159	0.0000	0.0000	0.9333
Sweetener products	10.7965	1.0394	0.0778	0.4604	12.3740
Processed fruits and vegetables	0.2245	0.7912	0.0000	0.0000	1.0157
Condiments / Spices	0.2790	0.2040	0.2834	0.0316	0.7980

Source: Calculated from 2002 Economic Census Industry Series Reports (Manufacturing).

Table 2.6 Four Tax Scenarios and their Tax Rates and Changes in Price and Consumption

Consumption Tax on Nine Sweetener-Intensive Foods

Food	Consumption Tax Rate (%)	Price with Tax	Food Demand Change (%)
Milk	0.000	1.000	0.214
Cheese	0.000	1.000	1.431
Ice cream / yogurt	0.000	1.000	0.027
Breakfast cereal / Bakery	0.000	1.000	0.796
Soft drink	0.000	1.000	0.005
Juice	0.000	1.000	1.893
Sweetener products	39.295	1.393	-19.820
Processed fruits and vegetables	0.007	1.000	0.498
Condiments / Spices	0.000	1.000	-0.019

Joint Input Taxes on the Three Caloric Sweeteners

Tax rates: Sugars (27.47%); Corn Sweeteners (42.95%); and Other Sweeteners (0.00001%)

Food	Price with input taxes	Food Demand Change (%)
Milk	1.004	-0.369
Cheese	1.000	-0.002
Ice cream / yogurt	1.006	-0.560
Breakfast cereal / Bakery	1.006	-0.232
Soft drink	1.013	-1.182
Juice	1.003	-0.103
Sweetener products	1.030	-1.498
Processed fruits and vegetables	1.003	-0.580
Condiments / Spices	1.001	-0.150

Input Tax on Individual Sweetener

Food	Tax on sugars (61.24%)		Tax on Corn Sweeteners (156.85%)	
	Price with Tax	Food Demand Change (%)	Price with Tax	Food Demand Change (%)
Milk	1.002	-0.182	1.007	-0.733
Cheese	1.000	0.101	1.001	-0.138
Ice cream / yogurt	1.005	-0.488	1.010	-0.825
Breakfast cereal / Bakery	1.009	-0.330	1.004	-0.171
Soft drink	1.001	-0.092	1.032	-3.025
Juice	1.001	0.189	1.007	-0.525
Sweetener products	1.053	-2.633	1.010	-0.458
Processed fruits and vegetables	1.001	-0.061	1.007	-1.450
Condiments / Spices	1.001	-0.142	1.002	-0.204

Table 2.7 Sweeteners Consumption Changes for All Households and Disaggregated Income Groups

	All Households	Households by Quintiles				
		Lowest 20%	Second 20%	Third 20%	Fourth 20%	Highest 20%
Tax on Price of Final Products	Sweeteners consumption quantity change (%)					
All Sweeteners (sugar equivalent)[a]	-10.00	-13.10	-10.73	-9.13	-7.79	-6.26
Sugars	-13.39	-19.78	-16.41	-13.82	-11.89	-9.49
Corn Sweeteners	-2.27	-3.40	-2.74	-2.36	-2.00	-1.62
Other Sweeteners	-1.08	-1.65	-1.32	-1.13	-0.95	-0.76
Artificial Sweeteners	-13.14	-19.62	-16.23	-13.51	-11.62	-9.27
Tax on the Price of Caloric Sweeteners	Sweetener consumption quantity change (%)					
All Sweeteners (sugar equivalent)[a]	-10.00	-10.45	-10.19	-10.04	-9.90	-9.73
Sugars	-8.95	-9.46	-9.14	-9.01	-8.83	-8.67
Corn Sweeteners	-12.41	-12.80	-12.58	-12.44	-12.33	-12.17
Other Sweeteners	3.22	3.07	3.12	3.21	3.26	3.33
Artificial Sweeteners	1.32	0.68	1.06	1.24	1.48	1.70
Tax on the Price of Sugars	Sweetener consumption quantity change (%)					
All Sweeteners (sugar equivalent)[a]	-10.00	-10.61	-10.13	-10.10	-9.82	-9.71
Sugars	-22.09	-22.80	-22.43	-22.14	-21.92	-21.65
Corn Sweeteners	7.40	7.21	7.30	7.39	7.42	7.56
Other Sweeteners	2.81	2.71	2.72	2.80	2.82	2.91
Artificial Sweeteners	0.20	-0.68	-0.19	0.11	0.41	0.74
Tax on the Price of Corn Sweeteners	Sweetener consumption quantity change (%)					
All Sweeteners (sugar equivalent)[a]	-10.00	-10.27	-10.25	-9.98	-9.99	-9.74
Sugars	7.73	7.43	7.77	7.64	7.82	7.83
Corn Sweeteners	-37.64	-38.24	-37.88	-37.69	-37.49	-37.29
Other Sweeteners	4.73	4.39	4.56	4.71	4.83	4.91
Artificial Sweeteners	3.12	2.55	2.92	3.03	3.28	3.43

a. The quantity of total sweeteners is converted into sugar equivalent based on the sweeteners' caloric content. Cane sugar and beet sugar are relatively pure sucrose and they have 4 kcal per gram. HFCS is the primary corn sweetener in the United States and it has 3 kcal per gram. As a representative of Other Sweeteners, honey has 3 kcal per gram. Aspartame is the most popular artificial sweetener currently used in the U.S. food industry and it has 4 kcal per gram.

Table 2.8 Real Expenditure and Welfare Changes for All Households and Disaggregated Income Groups for Four Tax Scenarios

	All Households	Households by Quintiles				
		Lowest 20%	Second 20%	Third 20%	Fourth 20%	Highest 20%
Annual Food Expenditure (per capita) ($)	726.13	702.63	679.00	691.40	731.25	793.57
Final Consumption Tax						
Real expenditure change (%)	1.86	0.51	1.14	1.85	2.16	2.70
EV (million $)	-8,688	-1,115	-1,362	-1,700	-1,978	-2,534
Per capita EV ($)	-31.00	-29.04	-27.40	-30.10	-31.25	-35.00
EV/Income (%)	0.165	0.598	0.291	0.212	0.156	0.100
Input Tax on the 3 Caloric Sweeteners						
Real expenditure change (%)	0.28	0.01	0.15	0.26	0.34	0.43
EV (million $)	-1,677	-225	-275	-324	-380	-473
Per capita EV ($)	-5.98	-5.86	-5.54	-5.73	-6.00	-6.54
EV/Income (%)	0.032	0.121	0.059	0.040	0.030	0.019
Input Tax on Sugars						
Real expenditure change (%)	0.46	0.25	0.35	0.45	0.51	0.60
EV (million $)	-1,865	-251	-304	-361	-420	-528
Per capita EV ($)	-6.65	-6.55	-6.11	-6.40	-6.64	-7.29
EV/Income (%)	0.035	0.135	0.065	0.045	0.033	0.021
Input Tax on Corn Sweeteners						
Real expenditure change (%)	0.09	-0.34	-0.08	0.06	0.20	0.34
EV (million $)	-1,934	-257	-320	-372	-441	-545
Per capita EV ($)	-6.90	-6.69	-6.44	-6.58	-6.96	-7.53
EV/Income (%)	0.037	0.138	0.068	0.046	0.035	0.021

Appendix

Appendix 2.1 Categories of Sweetener-Intensive Intermediate Materials in the U.S. Food Manufacturing Industry

Selected intermediate products	Representative industry NAICS code	Representative industry NAICS definition	Material code[a]	Materials consumed[a]
Fluid milk	311511	Fluid milk mfg	31151101	Fluid skim milk
			31151103	Cream
Cheese	311513	Cheese mfg	31151301	Natural cheese (excluding cottage cheese)
			31151305	Processed cheese
Dry, condensed and evaporated milk	311514	Dry, condensed, and evaporated dairy product mfg	31151401	Condensed and evaporated milk
			31151403	Whey (liquid, concentrated, and dried) and modified whey products
			31151405	Milk and milk replacers (dry milk, dry whey, blends, soy whey, etc.)
			31151407	Dry milk
Ice cream and yogurt mixes	311520	Ice cream and frozen dessert mfg	31152001	Ice cream mixes (excluding low-fat and nonfat)
			31152003	Sherbet mix
			31152005	Ice cream mix, low-fat
			31152007	Yogurt mix
			31152009	Ice cream mix, nonfat
Prepared mixes	311822	Flour mixes and dough mfg from purchased flour	31100005	Prepared doughnut mixes, cake and yeast types
			31100007	Prepared bread mixes, including franchise mixes
			31100009	Prepared cake mixes
			31100011	Other prepared mixes, including sweet-goods
Flour	311211	Flour milling	31121101	Wheat flour
			31121103	Wheat flour, cookie and cracker type (excluding prepared mixes)
			31121105	Wheat flour, other (including whole wheat, and clear flour), excluding prepared mixes
			31121109	Wheat flour, cake type (excluding prepared mixes)
			31121111	Wheat flour, white bread type (excluding prepared mixes)
			31121119	Corn grits
			31121121	Corn meal and flakes
			31121131	Prepared flour mixes
			31121133	Flour (excluding wheat)
			31122121	Wheat gluten
Liquid beverage base	311930	Flavoring syrup and concentrate mfg	31193001	Liquid beverage base concentrates with some juice content (finished drink basis)
			31193003	Other liquid beverage base concentrates (finished drink basis)
			31193005	Liquid beverage base syrups (finished drink basis)
Chocolate	311320	Chocolate and confectionery mfg from cacao beans	31132001	Chocolate (compounds, cocoa, chocolate liquor, coatings, chocolate flavoring, etc.)
			31132003	Chocolate coatings
			31132005	Unsweetened chocolate (chocolate liquor)
			31132007	Cocoa, pressed cake and powder
			31132009	Cocoa butter

a- Material code and material categories are based on Table 7 in the 2002 Economic Census Industry Series Reports (Manufacturing).

Appendix 2.2 Quantities of Sweeteners in Nine Target Sweetener-Intensive U.S. Food Manufacturing Industry

Food	Quantities of Sweeteners (million lbs)				
	Sugars (22.29 ¢/lb)	Corn Sweeteners (13.34 ¢/lb)	Other Sweeteners (32.95 ¢/lb)	Artificial Sweeteners (112.04 ¢/lb)	All Sweeteners[a]
Milk	653056.21	1535477.40	0.00	99.55	1804763.81
Cheese	31426.79	110704.39	0.00	0.00	114455.09
Ice cream / yogurt	394810.52	586084.41	0.00	144.84	834518.67
Breakfast cereal / Bakery	3555864.25	1282891.04	359568.28	11930.98	4799639.72
Soft drink	260497.98	8350652.17	130446.13	30119.60	6651441.31
Juice	117403.74	646109.47	0.00	0.00	601985.85
Sweetener products	11886958.58	1912122.36	57945.23	100844.09	13465353.37
Processed fruits and vegetables	82963.98	488507.45	0.00	0.00	449344.57
Condiments / Spices	367113.35	448513.82	252298.66	8260.59	900983.29

Source: 2002 Economic Census Industry Series Reports (Manufacturing).

a- Converted to sugar equivalent based on sweeteners' calories content (See footnote in Table 2.7).

Appendix 2.3 Calculation of Consumption of Adjustment Ratio from Food Availability Data

The food availability (food disappearance) data compiled by USDA/ERS is a measure of the amount of food available for human consumption in the United States, and derived from estimates of food supplies moving from production to domestic consumption. Food for human consumption is not measured directly by the food disappearance data. Instead, food disappearance is calculated as the difference between available commodity supplies (production, imports, and beginning stocks) and nonfood use (farm inputs, exports, ending stocks) with adjustment for losses. Food availability data measure food supplies available for consumption for all the outlets, both at home and away from home.

As a measure of final consumption, the food availability data measure the use of raw and semi-processed agricultural commodities from which final food products are made. For the majority of foods, the association between the categories in the food availability data and the final consumption forms is fairly direct; examples are dairy products and juice. However, for some categories, the forms of final products are unknown, and little data are available on supplies of further processed foods.

The food supply data for the grain group are available only in their primary form—white and wheat flour, durum flour, rice, oat, corn, barley, and rye flour. They are presented in grain equivalents and do not estimate food consumption very precisely. Hence, food availability data provide limited information on the final products consumed in this group. Instead of measuring an estimate of consumption of the pasta, oatmeal, breakfast cereals, bread, and grits, data are only available as supplies of flour, oats, corn, and barley.

So in order to obtain the adjustment ratio of the Breakfast cereal and Bakery products group, the adjusted ratios of wheat flour, rye flour, rice, corn for food use (cereals and other products), oat, and barley are averaged by their disappearance data weight to get a weighted average adjustment ratio 0.75 for this whole group and applied to measure the grain ingredients. This corresponds to the “Flour milling” (NAICS 311211), “Breakfast Cereal Manufacturing” (NAICS 3111230), “Commercial Bakeries” (NAICS 311812), “Frozen Cakes, Pies, and Other Pastries Manufacturing” (NAICS 311813), “Cookie and Cracker Manufacturing” (NAICS 311821), “Flour Mixes and Dough Manufacturing from Purchased Flour” (NAICS 311822).

Appendix 2.4 Price Elasticity between the Sweeteners for Nine Sweetener-Intensive Foods[a]

Food	Sweeteners	Sugars	Corn Sweeteners	Other Sweeteners	Artificial Sweeteners	All other inputs[b]
Milk	Sugars	-0.4800000	0.3000000[c]	0.0000700[d]	0.0001400[d]	0.1797900
	Corn Sweeteners	0.2131978	-0.4800000	0.0000700[d]	0.0001400[d]	0.2665922
	Other Sweeteners	0.0309245	0.0435153	-0.4800000	0.0001400[d]	0.4054202
	Artificial Sweeteners	0.1827121	0.2571023	0.0004136	-0.4800000	0.0397721
	All other materials	0.0009414	0.0019642	0.0000048	0.0000002	-0.0029106
Cheese	Sugars	-0.4800000	0.3000000[c]	0.0005000[e]	0.0005000[e]	0.1790000
	Corn Sweeteners	0.1423019	-0.4800000	0.0005000[e]	0.0005000[e]	0.3366981
	Other Sweeteners	0.0106298	0.0224097	-0.4800000	0.0005000[e]	0.4464605
	Artificial Sweeteners	0.0031261	0.0065905	0.0001470	-0.4800000	0.4701363
	All other materials	0.0000683	0.0002710	0.0000080	0.0000287	-0.0003760
Ice cream / yogurt	Sugars	-0.4800000	0.3000000[c]	0.0002000[d]	0.0004000[d]	0.1794000
	Corn Sweeteners	0.3376790	-0.4800000	0.0002000[d]	0.0004000[d]	0.1417210
	Other Sweeteners	0.0534163	0.0474559	-0.4800000	0.0004000[d]	0.3787278
	Artificial Sweeteners	0.2169210	0.1927165	0.0008122	-0.4800000	0.0695503
	All other materials	0.0021022	0.0014754	0.0000166	0.0000015	-0.0035958
Breakfast cereal / Bakery	Sugars	-0.4800000	0.1000000[f]	0.0100000[g]	0.0050000[h]	0.3650000
	Corn Sweeteners	0.4631372	-0.4800000	0.0100000[g]	0.0050000[h]	0.0018628
	Other Sweeteners	0.0668988	0.0144447	-0.4800000	0.0050000[h]	0.3936565
	Artificial Sweeteners	0.2964668	0.0640127	0.0443157	-0.4800000	0.0752048
	All other materials	0.0070761	0.0000078	0.0011408	0.0000246	-0.0082493

a- The own-price elasticity of sweeteners are set to be -0.48. The lower triangle elements are derived from the upper triangle elements because their ratios are proportional to their cost shares' ratio based on the definition of Hessian matrix in the production.
b- The price elasticities of sweeteners to "All Other Inputs" is derived using the homogeneity property of the Hessian matrix from the output-constant cost function of food manufacturers with respect to prices.
c- The cross-price elasticity of Sugars with respect to Corn Sweeteners is set to be 0.30.
d- There is no usage of Other Sweeteners in the final products "Milk" and "Ice cream / yogurt". For "Milk", the cross-price elasticities of Sugars and Corn Sweeteners with respect to Other Sweeteners are both set to be 0.00007, the cross-price elasticities of Sugars, Corn Sweeteners, and Other Sweeteners with respect to Artificial Sweeteners are all set to be 0.00014.
e- If there is neither Other Sweeteners nor Artificial Sweeteners used, the sweeteners' cross-price elasticities in upper triangle are all set to be 0.0005 except the one between Sugars and Corn Sweeteners.
f- The concavity curvature of the cost function requires that the Hessian matrix be negative semi-definite. When some sweeteners' cost shares are very small or equal to zero, the corresponding elements in upper-triangle of the input price elasticity matrix need to be set to smaller values to satisfy the homogeneity condition.
For "Ice cream / yogurt", these two numbers are set to be 0.0002 and 0.0004.
g- The cross-price elasticities of Sugars and Corn Sweeteners with respect to Other Sweeteners are both set to be 0.01.
h- The cross-price elasticities of Sugars, Corn Sweeteners, and Other Sweeteners with respect to Artificial Sweeteners are all set to be 0.005.

Appendix 2.4 (continued)

Food	Sweeteners	Sugars	Corn Sweeteners	Other Sweeteners	Artificial Sweeteners	All other inputs[b]
Soft drink	Sugars	-0.4800000	0.3000000[c]	0.0100000[g]	0.0050000[h]	0.1650000
	Corn Sweeteners	0.0156372	-0.4800000	0.0100000[g]	0.0050000[h]	0.4493628
	Other Sweeteners	0.0135091	0.2591729	-0.4800000	0.0050000[h]	0.2023179
	Artificial Sweeteners	0.0086032	0.1650532	0.0063685	-0.4800000	0.2999751
	All other materials	0.0003000	0.0156733	0.0002723	0.0003170	-0.0165625
Juice	Sugars	-0.4800000	0.3000000[b]	0.0005000[e]	0.0005000[e]	0.1790000
	Corn Sweeteners	0.0910859	-0.4800000	0.0005000[e]	0.0005000[e]	0.3879141
	Other Sweeteners	0.0397106	0.1307906	-0.4800000	0.0005000[e]	0.3089988
	Artificial Sweeteners	0.0116786	0.0384644	0.0001470	-0.4800000	0.4297100
	All other materials	0.0003928	0.0028033	0.0000085	0.0000404	-0.0032450
Sweetener products	Sugars	-0.4800000	0.0400000[f]	0.0030000[f]	0.0010000[f]	0.4360000
	Corn Sweeteners	0.4154983	-0.4800000	0.0030000[f]	0.0010000[f]	0.0605017
	Other Sweeteners	0.4163216	0.0400793	-0.4800000	0.0010000[f]	0.0225991
	Artificial Sweeteners	0.0234508	0.0022576	0.0001690	-0.4800000	0.4541226
	All other materials	0.0537199	0.0007176	0.0000201	0.0023860	-0.0568436
Processed fruits and vegetables	Sugars	-0.4800000	0.3000000[c]	0.0005000[e]	0.0005000[e]	0.1790000
	Corn Sweeteners	0.0851322	-0.4800000	0.0005000[e]	0.0005000[e]	0.3938678
	Other Sweeteners	0.0280617	0.0988876	-0.4800000	0.0005000[e]	0.3525507
	Artificial Sweeteners	0.0082527	0.0290820	0.0001470	-0.4800000	0.4425183
	All other materials	0.0004060	0.0031483	0.0000142	0.0000608	-0.0036294
Condimen ts / Spices	Sugars	-0.4800000	0.3000000[c]	0.0100000[g]	0.0050000[h]	0.1650000
	Corn Sweeteners	0.4102984	-0.4800000	0.0100000[g]	0.0050000[h]	0.0547016
	Other Sweeteners	0.0098433	0.0071972	-0.4800000	0.0050000[h]	0.4579596
	Artificial Sweeteners	0.0442075	0.0323234	0.0449114	-0.4800000	0.3585577
	All other materials	0.0004640	0.0001125	0.0013084	0.0001141	-0.0019990

Appendix 2.5 Parameters of the income term (χ) and linear price term (ε) in the LinQuad Demand Systems

Food	χ	ε					
		ε_{All}	ε_1	ε_2	ε_3	ε_4	ε_5
		All household	**Lowest 20% quintile**	**Second 20% quintile**	**Third 20% quintile**	**Fourth 20% quintile**	**Highest 20% quintile**
Milk	0.00015	51062.05	8740.34	10004.52	9996.22	10855.01	11465.96
Cheese	0.00077	35704.07	6449.18	6726.63	7202.93	7530.81	7794.53
Ice cream / yogurt	-0.00025	16535.57	2524.77	2799.56	3189.63	3591.33	4430.29
Breakfast cereal / Bakery	0.00180	52595.44	9421.28	10179.61	10421.44	11171.35	11401.76
Soft drink	-0.00020	67038.67	10978.79	12084.01	13096.47	14413.70	16465.71
Juice	0.00087	16840.66	3313.71	3479.41	3454.00	3480.93	3112.61
Sweetener products	0.00022	33349.38	5275.03	5842.78	6629.58	7235.25	8366.75
Processed fruits and vegetables	0.00076	19535.95	4017.12	4079.74	4051.03	3966.38	3421.69
Condiments / Spices	0.00068	56409.76	9464.30	10454.22	11319.98	12151.45	13019.81

Note: Elasticities for final products used in the calculation are from USDA/ERS and Chouinard, H.H., D.E. Davis, J.T. LaFrance, and J.M.Perloff. 2010.

Appendix 2.6 Parameter matrix of the quadratic price term (V_{All}) in the LinQuad Demand Systems for All households

Food	Milk	Cheese	Ice cream / yogurt	Breakfast cereal / Bakery	Soft drink	Juice	Sweetener products	Processed fruits and vegetables	Condiments / Spices
Milk	-20396.35	-749.33	0.00	-786.49	-1990.45	482.51	156.63	-385.17	0.00
Cheese	-749.33	-19613.08	-883.41	-681.62	0.00	-279.64	685.06	318.54	0.00
Ice cream / yogurt	0.00	-883.41	-6399.86	-276.29	0.00	-37.95	0.00	0.00	0.00
Breakfast cereal / Bakery	-786.49	-681.62	-276.29	-19858.86	0.00	242.11	888.05	864.42	0.00
Soft drink	-1990.45	0.00	0.00	0.00	-30764.59	-101.04	0.00	0.00	0.00
Juice	482.51	-279.64	-37.95	242.11	-101.04	-10257.30	597.97	219.56	0.00
Sweetener products	156.63	685.06	0.00	888.05	0.00	597.97	-12373.77	123.44	0.00
Processed fruits and vegetables	-385.17	318.54	0.00	864.42	0.00	219.56	123.44	-16236.25	0.00
Condiments / Spices	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-30462.10

Note: Elasticities for final products used for the calculation are from USDA/ERS and Chouinard, H.H., D.E. Davis, J.T. LaFrance, and J.M.Perloff. 2010.

Appendix 2.7 Parameter matrix of the quadratic price term (V) in the LinQuad Demand Systems for Disaggregated Income Groups

Food	Milk	Cheese	Ice cream / yogurt	Breakfast cereal / Bakery	Soft drink	Juice	Sweetener products	Processed fruits and vegetables	Condiments / Spices
Milk	-4079.27	-149.87	0.00	-157.30	-398.09	96.50	31.33	-77.03	0.00
Cheese	-149.87	-3922.62	-176.68	-136.32	0.00	-55.93	137.01	63.71	0.00
Ice cream / yogurt	0.00	-176.68	-1279.97	-55.26	0.00	-7.59	0.00	0.00	0.00
Breakfast cereal / Bakery	-157.30	-136.32	-55.26	-3971.77	0.00	48.42	177.61	172.88	0.00
Soft drink	-398.09	0.00	0.00	0.00	-6152.92	-20.21	0.00	0.00	0.00
Juice	96.50	-55.93	-7.59	48.42	-20.21	-2051.46	119.59	43.91	0.00
Sweetener products	31.33	137.01	0.00	177.61	0.00	119.59	-2474.75	24.69	0.00
Processed fruits and vegetables	-77.03	63.71	0.00	172.88	0.00	43.91	24.69	-3247.25	0.00
Condiments / Spices	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-6092.42

Note: Elasticities for final products used for the calculation are from USDA/ERS and Chouinard, H.H., D.E. Davis, J.T. LaFrance, and J.M.Perloff. 2010.

Appendix 2.8 Lowest 20% Quintile of Income Mashallian Elasticities of Nine Target Sweetener-Intensive Foods

Food	Milk	Cheese	Ice cream / yogurt	Breakfast cereal / Bakery	Soft drink	Juice	Sweetener products	Processed fruits and vegetables	Condiments / Spices
Milk	-1.01280	-0.03729	-0.00004	-0.03926	-0.09899	0.02390	0.00765	-0.01916	-0.00013
Cheese	-0.06595	-1.69197	-0.07651	-0.06061	-0.00147	-0.02461	0.05797	0.02713	-0.00113
Ice cream / yogurt	0.00104	-0.18173	-1.32049	-0.05559	0.00115	-0.00744	0.00086	0.00026	0.00088
Breakfast cereal / Bakery	-0.02857	-0.02437	-0.00991	-0.69160	-0.00138	0.00795	0.02982	0.02972	-0.00105
Soft drink	-0.09073	0.00010	0.00005	0.00025	-1.40488	-0.00455	0.00015	0.00005	0.00015
Juice	0.05774	-0.03590	-0.00525	0.02710	-0.01491	-1.27415	0.07246	0.02672	-0.00181
Sweetener products	0.00916	0.04109	-0.00007	0.05309	-0.00030	0.03590	-0.74508	0.00736	-0.00023
Processed fruits and vegetables	-0.07235	0.05605	-0.00069	0.15243	-0.00302	0.03866	0.02005	-2.93468	-0.00231
Condiments / Spices	-0.00078	-0.00043	-0.00020	-0.00107	-0.00086	-0.00029	-0.00064	-0.00019	-1.75701

Note: Elasticities for final products used for the calculation are from USDA/ERS and Chouinard, H.H., D.E. Davis, J.T. LaFrance, and J.M.Perloff. 2010.

Appendix 2.9 Second 20% Quintile of Income Mashallian Elasticities of Nine Target Sweetener-Intensive Foods

Food	Milk	Cheese	Ice cream / yogurt	Breakfast cereal / Bakery	Soft drink	Juice	Sweetener products	Processed fruits and vegetables	Condiments / Spices
Milk	-0.76487	-0.02817	-0.00004	-0.02967	-0.07478	0.01804	0.00576	-0.01447	-0.00012
Cheese	-0.05478	-1.39643	-0.06322	-0.05023	-0.00152	-0.02036	0.04769	0.02238	-0.00120
Ice cream / yogurt	0.00113	-0.14992	-1.08972	-0.04571	0.00119	-0.00611	0.00083	0.00023	0.00094
Breakfast cereal / Bakery	-0.02379	-0.02008	-0.00821	-0.56806	-0.00141	0.00648	0.02434	0.02438	-0.00112
Soft drink	-0.07313	0.00009	0.00005	0.00023	-1.13307	-0.00366	0.00014	0.00004	0.00016
Juice	0.04561	-0.02881	-0.00432	0.02133	-0.01240	-1.01840	0.05767	0.02133	-0.00188
Sweetener products	0.00763	0.03453	-0.00007	0.04459	-0.00031	0.03017	-0.62647	0.00619	-0.00025
Processed fruits and vegetables	-0.05877	0.04484	-0.00071	0.12194	-0.00304	0.03094	0.01578	-2.35566	-0.00240
Condiments / Spices	-0.00077	-0.00036	-0.00019	-0.00091	-0.00080	-0.00024	-0.00056	-0.00015	-1.31214

Note: Elasticities for final products used for the calculation are from USDA/ERS and Chouinard, H.H., D.E. Davis, J.T. LaFrance, and J.M.Perloff. 2010.

Appendix 2.10 Third 20%Quintile of Income Mashallian Elasticities of Nine Target Sweetener-Intensive Foods

Food	Milk	Cheese	Ice cream / yogurt	Breakfast cereal / Bakery	Soft drink	Juice	Sweetener products	Processed fruits and vegetables	Condiments / Spices
Milk	-0.75889	-0.02796	-0.00005	-0.02944	-0.07423	0.01790	0.00570	-0.01436	-0.00015
Cheese	-0.04344	-1.10762	-0.05023	-0.03989	-0.00143	-0.01614	0.03765	0.01775	-0.00114
Ice cream / yogurt	0.00090	-0.11882	-0.86419	-0.03621	0.00111	-0.00485	0.00079	0.00018	0.00089
Breakfast cereal / Bakery	-0.02124	-0.01804	-0.00742	-0.50743	-0.00150	0.00580	0.02156	0.02179	-0.00120
Soft drink	-0.06227	0.00009	0.00005	0.00020	-0.96485	-0.00312	0.00015	0.00003	0.00016
Juice	0.04036	-0.02568	-0.00397	0.01878	-0.01135	-0.90123	0.05074	0.01889	-0.00199
Sweetener products	0.00627	0.02833	-0.00008	0.03661	-0.00030	0.02478	-0.51446	0.00508	-0.00024
Processed fruits and vegetables	-0.05058	0.03836	-0.00079	0.10484	-0.00309	0.02664	0.01321	-2.02750	-0.00248
Condiments / Spices	-0.00062	-0.00035	-0.00020	-0.00077	-0.00077	-0.00019	-0.00055	-0.00012	-1.06283

Note: Elasticities for final products used for the calculation are from USDA/ERS and Chouinard, H.H., D.E. Davis, J.T. LaFrance, and J.M.Perloff. 2010.

Appendix 2.11 Fourth 20%Quintile of Income Mashallian Elasticities of Nine Target Sweetener-Intensive Foods

Food	Milk	Cheese	Ice cream / yogurt	Breakfast cereal / Bakery	Soft drink	Juice	Sweetener products	Processed fruits and vegetables	Condiments / Spices
Milk	-0.64715	-0.02385	-0.00005	-0.02512	-0.06333	0.01527	0.00484	-0.01224	-0.00015
Cheese	-0.03657	-0.92853	-0.04217	-0.03358	-0.00144	-0.01353	0.03145	0.01490	-0.00111
Ice cream / yogurt	0.00088	-0.09956	-0.72435	-0.03025	0.00112	-0.00406	0.00075	0.00014	0.00087
Breakfast cereal / Bakery	-0.01785	-0.01509	-0.00626	-0.42271	-0.00150	0.00482	0.01784	0.01816	-0.00116
Soft drink	-0.05221	0.00009	0.00005	0.00019	-0.80923	-0.00261	0.00014	0.00002	0.00016
Juice	0.03374	-0.02175	-0.00347	0.01559	-0.00999	-0.75947	0.04256	0.01594	-0.00194
Sweetener products	0.00543	0.02469	-0.00008	0.03188	-0.00032	0.02160	-0.44849	0.00443	-0.00024
Processed fruits and vegetables	-0.07235	0.05605	-0.00069	0.15243	-0.00302	0.03866	0.02005	-2.93468	-0.00231
Condiments / Spices	-0.00078	-0.00043	-0.00020	-0.00107	-0.00086	-0.00029	-0.00064	-0.00019	-1.75701

Note: Elasticities for final products used for the calculation are from USDA/ERS and Chouinard, H.H., D.E. Davis, J.T. LaFrance, and J.M.Perloff. 2010.

Appendix 2.12 Highest 20% Quintile of Income Mashallian Elasticities of Nine Target Sweetener-Intensive Foods

Food	Milk	Cheese	Ice cream / yogurt	Breakfast cereal / Bakery	Soft drink	Juice	Sweetener products	Processed fruits and vegetables	Condiments / Spices
Milk	-0.57407	-0.02116	-0.00006	-0.02229	-0.05622	0.01355	0.00427	-0.01085	-0.00015
Cheese	-0.02835	-0.71751	-0.03271	-0.02598	-0.00140	-0.01040	0.02414	0.01159	-0.00098
Ice cream / yogurt	0.00074	-0.07690	-0.55962	-0.02335	0.00109	-0.00318	0.00070	0.00004	0.00077
Breakfast cereal / Bakery	-0.01420	-0.01196	-0.00507	-0.33395	-0.00149	0.00386	0.01392	0.01443	-0.00104
Soft drink	-0.0422	0.00008	0.00006	0.00016	-0.65425	-0.00212	0.00014	0.00001	0.00015
Juice	0.02642	-0.01720	-0.00295	0.01222	-0.00839	-0.59819	0.03324	0.01270	-0.00175
Sweetener products	0.00430	0.01964	-0.00009	0.02537	-0.00032	0.01721	-0.35709	0.00355	-0.00022
Processed fruits and vegetables	-0.03599	0.02673	-0.00097	0.07326	-0.00329	0.01881	0.00869	-1.42286	-0.00231
Condiments / Spices	-0.00053	-0.00028	-0.00023	-0.00059	-0.00078	-0.00010	-0.00050	-0.00003	-0.70874

Note: Elasticities for final products used for the calculation are from USDA/ERS and Chouinard, H.H., D.E. Davis, J.T. LaFrance, and J.M.Perloff. 2010.

Appendix 2.13 Changes on All Households and Disaggregated Income Groups with Tax on the Price of Final Products for Nine Sweetener-Intensive Foods

Food	All households		Households by quintiles									
			Lowest 20%		Second 20%		Third 20%		Fourth 20%		Highest 20%	
	Food demand (per capita)											
	Initial value ($)[a]	Change (%)	Initial value ($)[a]	Change (%)	Initial value ($)[a]	Change (%)	Initial value ($)[a]	Change (%)	Initial value ($)[a]	Change (%)	Initial value ($)[a]	Change (%)
Milk	100.44	0.214	104.98	0.301	107.31	0.227	95.18	0.224	99.59	0.191	98.18	0.168
Cheese	65.55	1.431	60.44	2.285	56.54	1.879	62.73	1.484	66.77	1.239	75.57	0.951
Ice cream / yogurt	27.39	0.027	25.26	0.029	23.62	0.028	26.21	0.028	27.90	0.027	31.58	0.026
Breakfast cereal / Bakery	149.78	0.796	150.03	1.178	141.06	0.962	138.98	0.852	148.90	0.705	164.84	0.550
Soft drink	118.41	0.005	114.12	0.005	109.23	0.005	112.87	0.005	120.07	0.005	129.86	0.005
Juice	42.96	1.893	41.98	2.858	40.55	2.275	40.33	2.001	42.70	1.679	47.40	1.311
Sweetener products	87.56	-19.820	86.58	-29.277	79.50	-24.616	85.20	-20.215	87.20	-17.623	95.78	-14.032
Processed fruits and vegetables	29.39	0.498	28.84	0.779	27.74	0.613	28.36	0.513	29.48	0.431	31.53	0.337
Condiments / Spices	104.65	-0.019	90.40	-0.022	93.45	-0.020	101.54	-0.020	108.64	-0.019	118.83	-0.018
	Sweeteners consumption quantities (per capita)											
Sweeteners	Initial value (lbs)	Change (%)	Initial value (lbs)	Change (%)	Initial value (lbs)	Change (%)	Initial value (lbs)	Change (%)	Initial value (lbs)	Change (%)	Initial value (lbs)	Change (%)
All Sweeteners (sugar equivalent)[b]	105.69	-10.000	103.83	-13.102	97.85	-10.734	101.28	-9.128	105.85	-7.794	115.37	-6.256
Sugars	61.90	-13.390	61.21	-19.775	56.96	-16.408	59.54	-13.816	61.73	-11.892	67.67	-9.488
Corn Sweeteners	54.81	-2.270	53.41	-3.400	51.24	-2.737	52.26	-2.363	55.22	-1.996	59.63	-1.618
Other Sweeteners	2.86	-1.083	2.72	-1.652	2.63	-1.321	2.71	-1.132	2.89	-0.950	3.17	-0.761
Artificial Sweeteners	0.54	-13.139	0.53	-19.621	0.49	-16.232	0.52	-13.507	0.54	-11.615	0.59	-9.274

Note: Elasticities for final products are from USDA/ERS and Chouinard, H.H., D.E. Davis, J.T. LaFrance, and J.M.Perloff. 2010.
a- Initial prices are normalized to $1/unit.
b- See footnote in Table 2.7.

Appendix 2.14 Changes on All Households and Disaggregated Income Groups with Tax on the Price of Caloric Sweeteners for Nine Sweetener-Intensive Foods

Food	All households		Households by quintiles									
			Lowest 20%		Second 20%		Third 20%		Fourth 20%		Highest 20%	
	Food demand (per capita)											
	Initial value ($)[a]	Change (%)	Initial value ($)[a]	Change (%)	Initial value ($)[a]	Change (%)	Initial value ($)[a]	Change (%)	Initial value ($)[a]	Change (%)	Initial value ($)[a]	Change (%)
Milk	100.44	-0.369	104.98	-0.516	107.31	-0.390	95.18	-0.387	99.59	-0.330	98.18	-0.293
Cheese	65.55	-0.002	60.44	0.000	56.54	-0.001	62.73	-0.002	66.77	-0.002	75.57	-0.003
Ice cream / yogurt	27.39	-0.560	25.26	-0.889	23.62	-0.733	26.21	-0.580	27.90	-0.486	31.58	-0.375
Breakfast cereal / Bakery	149.78	-0.232	150.03	-0.336	141.06	-0.277	138.98	-0.248	148.90	-0.208	164.84	-0.165
Soft drink	118.41	-1.182	114.12	-1.791	109.23	-1.445	112.87	-1.230	120.07	-1.032	129.86	-0.834
Juice	42.96	-0.103	41.98	-0.150	40.55	-0.121	40.33	-0.109	42.70	-0.093	47.40	-0.075
Sweetener products	87.56	-1.498	86.58	-2.212	79.50	-1.860	85.20	-1.528	87.20	-1.332	95.78	-1.061
Processed fruits and vegetables	29.39	-0.580	28.84	-0.856	27.74	-0.690	28.36	-0.596	29.48	-0.513	31.53	-0.422
Condiments / Spices	104.65	-0.150	90.40	-0.251	93.45	-0.188	101.54	-0.153	108.64	-0.128	118.83	-0.103
	Sweeteners consumption quantities (per capita)											
Sweeteners	Initial value (lbs)	Change (%)	Initial value (lbs)	Change (%)	Initial value (lbs)	Change (%)	Initial value (lbs)	Change (%)	Initial value (lbs)	Change (%)	Initial value (lbs)	Change (%)
All Sweeteners (sugar equivalent)[b]	105.69	-10.000	103.83	-10.451	97.85	-10.193	101.28	-10.039	105.85	-9.899	115.37	-9.727
Sugars	61.90	-8.954	61.21	-9.460	56.96	-9.141	59.54	-9.006	61.73	-8.829	67.67	-8.668
Corn Sweeteners	54.81	-12.412	53.41	-12.798	51.24	-12.580	52.26	-12.443	55.22	-12.331	59.63	-12.174
Other Sweeteners	2.86	3.221	2.72	3.066	2.63	3.122	2.71	3.210	2.89	3.257	3.17	3.326
Artificial Sweeteners	0.54	1.322	0.53	0.682	0.49	1.057	0.52	1.241	0.54	1.482	0.59	1.703
	Sweeteners consumption values (per capita)											
Sweeteners	Initial value ($)	Change (%)	Initial value ($)	Change (%)	Initial value ($)	Change (%)	Initial value ($)	Change (%)	Initial value ($)	Change (%)	Initial value ($)	Change (%)
All Sweeteners	22.66	20.133	22.26	19.520	20.95	19.952	21.72	20.054	22.68	20.292	24.75	20.456
Sugars	13.8	17.498	13.64	16.842	12.70	17.270	13.27	17.424	13.76	17.662	15.08	17.862
Corn Sweeteners	7.31	28.823	7.12	28.266	6.84	28.579	6.97	28.776	7.37	28.935	7.95	29.173
Other Sweeteners	0.94	3.346	0.89	3.193	0.87	3.247	0.89	3.336	0.95	3.381	1.04	3.450
Artificial Sweeteners	0.61	1.322	0.59	0.682	0.55	1.057	0.58	1.241	0.61	1.482	0.66	1.703

Note: Elasticities for final products are from USDA/ERS and Chouinard, H.H., D.E. Davis, J.T. LaFrance, and J.M.Perloff. 2010.
a- Initial prices are normalized to $1/unit.
b- See footnote in Table 2.7.

Appendix 2.15 Changes on All Households and Disaggregated Income Groups with Tax on the Price of Sugars for Nine Sweetener-Intensive Foods

Food	All households		Households by quintiles: Lowest 20%		Second 20%		Third 20%		Fourth 20%		Highest 20%	
	Food demand (per capita)											
	Initial value ($)[a]	Change (%)	Initial value ($)[a]	Change (%)	Initial value ($)[a]	Change (%)	Initial value ($)[a]	Change (%)	Initial value ($)[a]	Change (%)	Initial value ($)[a]	Change (%)
Milk	100.44	-0.182	104.98	-0.254	107.31	-0.192	95.18	-0.191	99.59	-0.163	98.18	-0.144
Cheese	65.55	0.101	60.44	0.163	56.54	0.133	62.73	0.105	66.77	0.087	75.57	0.066
Ice cream / yogurt	27.39	-0.488	25.26	-0.775	23.62	-0.638	26.21	-0.506	27.90	-0.423	31.58	-0.326
Breakfast cereal / Bakery	149.78	-0.330	150.03	-0.478	141.06	-0.394	138.98	-0.353	148.90	-0.294	164.84	-0.234
Soft drink	118.41	-0.092	114.12	-0.139	109.23	-0.112	112.87	-0.095	120.07	-0.080	129.86	-0.064
Juice	42.96	0.189	41.98	0.288	40.55	0.228	40.33	0.200	42.70	0.167	47.40	0.130
Sweetener products	87.56	-2.633	86.58	-3.888	79.50	-3.270	85.20	-2.685	87.20	-2.341	95.78	-1.864
Processed fruits and vegetables	29.39	-0.061	28.84	-0.084	27.74	-0.070	28.36	-0.063	29.48	-0.056	31.53	-0.048
Condiments / Spices	104.65	-0.142	90.40	-0.239	93.45	-0.179	101.54	-0.146	108.64	-0.122	118.83	-0.098
	Sweeteners consumption quantities (per capita)											
Sweeteners	Initial value (lbs)	Change (%)	Initial value (lbs)	Change (%)	Initial value (lbs)	Change (%)	Initial value (lbs)	Change (%)	Initial value (lbs)	Change (%)	Initial value (lbs)	Change (%)
All Sweeteners (sugar equivalent)[b]	105.69	-10.000	103.83	-10.613	97.85	-10.132	101.28	-10.098	105.85	-9.821	115.37	-9.707
Sugars	61.90	-22.089	61.21	-22.804	56.96	-22.426	59.54	-22.139	61.73	-21.921	67.67	-21.652
Corn Sweeteners	54.81	7.405	53.41	7.207	51.24	7.302	52.26	7.389	55.22	7.418	59.63	7.559
Other Sweeteners	2.86	2.809	2.72	2.709	2.63	2.719	2.71	2.798	2.89	2.816	3.17	2.906
Artificial Sweeteners	0.54	0.203	0.53	-0.676	0.49	-0.193	0.52	0.109	0.54	0.407	0.59	0.745
	Sweeteners consumption values (per capita)											
Sweeteners	Initial value ($)	Change (%)	Initial value ($)	Change (%)	Initial value ($)	Change (%)	Initial value ($)	Change (%)	Initial value ($)	Change (%)	Initial value ($)	Change (%)
All Sweeteners	22.66	20.312	22.26	19.590	20.95	19.869	21.72	20.293	22.68	20.434	24.75	20.828
Sugars	13.8	29.226	13.64	28.042	12.70	28.677	13.27	29.137	13.76	29.505	15.08	29.950
Corn Sweeteners	7.31	7.405	7.12	7.207	6.84	7.302	6.97	7.389	7.37	7.418	7.95	7.559
Other Sweeteners	0.94	2.809	0.89	2.709	0.87	2.719	0.89	2.798	0.95	2.816	1.04	2.906
Artificial Sweeteners	0.61	0.203	0.59	-0.676	0.55	-0.193	0.58	0.109	0.61	0.407	0.66	0.745

Note: Elasticities for final products are from USDA/ERS and Chouinard, H.H., D.E. Davis, J.T. LaFrance, and J.M.Perloff. 2010.
a- Initial prices are normalized to $1/unit.
b- See footnote in Table 2.7.

Appendix 2.16 Changes on All Households and Disaggregated Income Groups with Tax on the Price of Corn Sweeteners for Nine Sweetener-Intensive Foods

Food	All households		Food demand by household quintiles									
			Lowest 20%		Second 20%		Third 20%		Fourth 20%		Highest 20%	
	Food demand (per capita)											
	Initial value ($)[a]	Change (%)	Initial value ($)[a]	Change (%)	Initial value ($)[a]	Change (%)	Initial value ($)[a]	Change (%)	Initial value ($)[a]	Change (%)	Initial value ($)[a]	Change (%)
Milk	100.44	-0.733	104.98	-1.025	107.31	-0.774	95.18	-0.768	99.59	-0.655	98.18	-0.581
Cheese	65.55	-0.138	60.44	-0.215	56.54	-0.179	62.73	-0.143	66.77	-0.121	75.57	-0.095
Ice cream / yogurt	27.39	-0.825	25.26	-1.310	23.62	-1.079	26.21	-0.855	27.90	-0.716	31.58	-0.552
Breakfast cereal / Bakery	149.78	-0.171	150.03	-0.245	141.06	-0.203	138.98	-0.182	148.90	-0.153	164.84	-0.122
Soft drink	118.41	-3.025	114.12	-4.585	109.23	-3.698	112.87	-3.149	120.07	-2.641	129.86	-2.135
Juice	42.96	-0.525	41.98	-0.778	40.55	-0.624	40.33	-0.554	42.70	-0.469	47.40	-0.372
Sweetener products	87.56	-0.458	86.58	-0.675	79.50	-0.568	85.20	-0.467	87.20	-0.407	95.78	-0.324
Processed fruits and vegetables	29.39	-1.450	28.84	-2.150	27.74	-1.729	28.36	-1.490	29.48	-1.282	31.53	-1.051
Condiments / Spices	104.65	-0.204	90.40	-0.343	93.45	-0.257	101.54	-0.209	108.64	-0.175	118.83	-0.140
	Sweeteners consumption quantities (per capita)											
Sweeteners	Initial value (lbs)	Change (%)	Initial value (lbs)	Change (%)	Initial value (lbs)	Change (%)	Initial value (lbs)	Change (%)	Initial value (lbs)	Change (%)	Initial value (lbs)	Change (%)
All Sweeteners (sugar equivalent)[b]	105.69	-10.000	103.83	-10.273	97.85	-10.250	101.28	-9.979	105.85	-9.993	115.37	-9.744
Sugars	61.90	7.727	61.21	7.428	56.96	7.767	59.54	7.645	61.73	7.821	67.67	7.830
Corn Sweeteners	54.81	-37.636	53.41	-38.236	51.24	-37.884	52.26	-37.686	55.22	-37.491	59.63	-37.290
Other Sweeteners	2.86	4.729	2.72	4.394	2.63	4.564	2.71	4.710	2.89	4.829	3.17	4.909
Artificial Sweeteners	0.54	3.117	0.53	2.554	0.49	2.923	0.52	3.028	0.54	3.280	0.59	3.426
	Sweeteners consumption values (per capita)											
Sweeteners	Initial value ($)	Change (%)	Initial value ($)	Change (%)	Initial value ($)	Change (%)	Initial value ($)	Change (%)	Initial value ($)	Change (%)	Initial value ($)	Change (%)
All Sweeteners	22.66	31.635	22.26	30.681	20.95	31.685	21.72	31.405	22.68	31.988	24.75	31.935
Sugars	13.8	7.727	13.64	7.428	12.70	7.767	13.27	7.645	13.76	7.821	15.08	7.830
Corn Sweeteners	7.31	82.578	7.12	80.848	6.84	81.875	6.97	82.433	7.37	82.993	7.95	83.577
Other Sweeteners	0.94	4.729	0.89	4.394	0.87	4.564	0.89	4.710	0.95	4.829	1.04	4.909
Artificial Sweeteners	0.61	3.117	0.59	2.554	0.55	2.923	0.58	3.028	0.61	3.280	0.66	3.426

Note: Elasticities for final products are from USDA/ERS and Chouinard, H.H., D.E. Davis, J.T. LaFrance, and J.M.Perloff. 2010.

a- Initial prices are normalized to $1/unit.

b- See footnote in Table 2.7.

Appendix 2.17 Changes for All Households with Tax on the Price of Final Products for Nine Sweetener-Intensive Foods (Reduce the Sugar Equivalent Quantity of All Sweeteners by 20%)

Food	Initial per capita food demand ($)[a]	Tax rate (%)	Price with tax	Food demand change (%)
Milk	100.44	0.000	1.000	0.429
Cheese	65.55	0.000	1.000	2.870
Ice cream / yogurt	27.39	0.000	1.000	0.048
Breakfast cereal / Bakery	149.78	0.000	1.000	1.600
Soft drink	118.41	0.000	1.000	0.009
Juice	42.96	0.000	1.000	3.799
Sweetener products	87.56	78.602	1.786	-39.645
Processed fruits and vegetables	29.39	0.002	1.000	1.039
Condiments / Spices	104.65	0.000	1.000	-0.034
Sweeteners	**Initial per capita sweeteners consumption (lbs)**		**Sweeteners consumption quantity change (%)**	
All Sweeteners (sugar equivalent)[b]		105.69		-20.000
Sugars		61.90		-26.781
Corn Sweeteners		54.81		-4.539
Other Sweeteners		2.86		-2.161
Artificial Sweeteners		0.54		-26.280
Real expenditure on above nine foods	**Initial per capita real expenditure ($)**		**Real expenditure change (%)**	
		726.13		1.854
Welfare		**Market welfare change**		
EV (million $)				-15465.240
Per capita EV ($)				-55.180
EV/Income (%)				0.294

Note: Elasticities for final products are from USDA/ERS and Chouinard, H.H., D.E. Davis, J.T. LaFrance, and J.M.Perloff. 2010.
a- Initial prices are normalized to $1/unit.
b- See footnote in Table 2.7.

Appendix 2.18 Changes for All Households with Tax on the Price of Caloric Sweeteners for Nine Sweetener-Intensive Foods (Reduce the Sugar Equivalent Quantity of All Sweeteners by 20%)

Food	Initial per capita food demand ($)[a]	Price with tax	Food demand change (%)	Tax rate				
				Sugars	Corn Sweeteners	Other Sweeteners		
				80.587%	117.118%	0.00012%		
				Sweeteners consumption quantity change (%)				
				Sugars	Corn Sweeteners	Other Sweeteners	Artificial Sweeteners	All Sweeteners (sugar equivalent)[b]
Milk	100.44	1.009	-0.828	-5.716	-22.420	4.527	34.928	-14.824
Cheese	65.55	1.001	0.014	-4.970	-25.015	2.409	0.713	-17.386
Ice cream / yogurt	27.39	1.015	-1.285	-6.205	-16.930	5.699	30.301	-11.043
Breakfast cereal / Bakery	149.78	1.014	-0.548	-18.967	-9.745	4.770	24.697	-14.317
Soft drink	118.41	1.027	-2.595	-7.449	-32.239	20.036	11.266	-25.850
Juice	42.96	1.007	-0.193	-5.273	-27.483	12.954	3.424	-20.345
Sweetener products	87.56	1.075	-3.680	-25.391	-15.360	26.734	-2.430	-21.231
Processed fruits and vegetables	29.39	1.007	-1.266	-6.379	-28.581	8.161	1.271	-21.411
Condiments / Spices	104.65	1.003	-0.344	-5.845	-12.954	0.229	4.298	-6.761

Sweeteners	Initial per capita sweeteners consumption (lbs)	Sweeteners consumption quantity change (%)	Initial per capita sweeteners consumption ($)	Sweeteners consumption value change (%)
All Sweeteners (sugar equivalent)[b]	105.69	-20.000	22.66	68.139
Sugars	61.90	-19.551	13.8	58.016
Corn Sweeteners	54.81	-22.447	7.31	100.228
Other Sweeteners	2.86	8.103	0.94	8.968
Artificial Sweeteners	0.54	3.282	0.61	3.282

Real expenditure on above nine foods	Initial per capita real expenditure ($)	Real expenditure change (%)
	726.13	0.642

Welfare	Market welfare change
EV (million $)	-3908.899
Per capita EV ($)	-13.947
EV/Income (%)	0.074

Note: Elasticities for final products are from USDA/ERS and Chouinard, H.H., D.E. Davis, J.T. LaFrance, and J.M.Perloff. 2010.

a- Initial prices are normalized to $1/unit.

b- See footnote in Table 2.7.

Appendix 2.19 Price Elasticity between the Sweeteners for Nine Sweetener-Intensive Foods (Reduce the Substitutability between Sweeteners by One Half)[a]

Food	Sweeteners	Sugars	Corn Sweeteners	Other Sweeteners	Artificial Sweeteners	All other inputs[b]
Milk	Sugars	-0.4800000	0.3000000[c]	0.0000350[d]	0.0000700[d]	0.1798950
	Corn Sweeteners	0.2131978	-0.4800000	0.0000350[d]	0.0000700[d]	0.2666972
	Other Sweeteners	0.0154623	0.0217576	-0.4800000	0.0000700[d]	0.4427101
	Artificial Sweeteners	0.0913560	0.1285511	0.0002068	-0.4800000	0.2598860
	All other materials	0.0009419	0.0019650	0.0000052	0.0000010	-0.0029132
Cheese	Sugars	-0.4800000	0.3000000[c]	0.0002500[e]	0.0002500[e]	0.1795000
	Corn Sweeteners	0.1423019	-0.4800000	0.0002500[e]	0.0002500[e]	0.3371981
	Other Sweeteners	0.0053149	0.0112048	-0.4800000	0.0002500[e]	0.4632303
	Artificial Sweeteners	0.0015631	0.0032952	0.0000735	-0.4800000	0.4750682
	All other materials	0.0000685	0.0002714	0.0000083	0.0000290	-0.0003772
Ice cream / yogurt	Sugars	-0.4800000	0.3000000[c]	0.0001000[d]	0.0002000[d]	0.1797000
	Corn Sweeteners	0.3376790	-0.4800000	0.0001000[d]	0.0002000[d]	0.1420210
	Other Sweeteners	0.0267081	0.0237280	-0.4800000	0.0002000[d]	0.4293639
	Artificial Sweeteners	0.1084605	0.0963582	0.0004061	-0.4800000	0.2747752
	All other materials	0.0021058	0.0014785	0.0000188	0.0000059	-0.0036091
Breakfast cereal / Bakery	Sugars	-0.4800000	0.1000000[f]	0.0050000[g]	0.0025000[h]	0.3725000
	Corn Sweeteners	0.4631372	-0.4800000	0.0050000[g]	0.0025000[h]	0.0093628
	Other Sweeteners	0.0334494	0.0072224	-0.4800000	0.0025000[h]	0.4368282
	Artificial Sweeteners	0.1482334	0.0320064	0.0221579	-0.4800000	0.2776024
	All other materials	0.0072215	0.0000392	0.0012659	0.0000908	-0.0086174

a- The own-price elasticity of sweeteners are set to be -0.48. The lower triangle elements are derived from the upper triangle elements because their ratios are proportional to their cost shares' ratio based on the definition of Hessian matrix in the production.
b- The price elasticities of sweeteners to "All Other Inputs" is derived using the homogeneity property of the Hessian matrix from the output-constant cost function of food manufacturers with respect to prices.
c- The cross-price elasticity of Sugars with respect to Corn Sweeteners is set to be 0.30.
d- There is no usage of Other Sweeteners in the final products "Milk" and "Ice cream / yogurt". For "Milk", the cross-price elasticities of Sugars and Corn Sweeteners with respect to Other Sweeteners are both set to be 0.000035, the cross-price elasticities of Sugars, Corn Sweeteners, and Other Sweeteners with respect to Artificial Sweeteners are all set to be 0.00007. For "Ice cream / yogurt", these two numbers are set to be 0.0001 and 0.0002.
e- If there is neither Other Sweeteners nor Artificial Sweeteners used, the sweeteners' cross-price elasticities in upper triangle are all set to be 0.00025 except the one between Sugars and Corn Sweeteners.
f- The concavity curvature of the cost function requires that the Hessian matrix be negative semi-definite. When some sweeteners' cost shares are very small or equal to zero, the corresponding elements in upper-triangle of the input price elasticity matrix need to be set to smaller values to satisfy the homogeneity condition.
g- The cross-price elasticities of Sugars and Corn Sweeteners with respect to Other Sweeteners are both set to be 0.005.
h- The cross-price elasticities of Sugars, Corn Sweeteners, and Other Sweeteners with respect to Artificial Sweeteners are all set to be 0.0025.

Appendix 2.19 (continued)

Food	Sweeteners	Sugars	Corn Sweeteners	Other Sweeteners	Artificial Sweeteners	All other inputs[b]
Soft drink	Sugars	-0.4800000	0.3000000[c]	0.0050000[g]	0.0025000[h]	0.1725000
	Corn Sweeteners	0.0156372	-0.4800000	0.0050000[g]	0.0025000[h]	0.4568628
	Other Sweeteners	0.0067546	0.1295865	-0.4800000	0.0025000[h]	0.3411590
	Artificial Sweeteners	0.0043016	0.0825266	0.0031842	-0.4800000	0.3899876
	All other materials	0.0003136	0.0159349	0.0004591	0.0004121	-0.0171197
Juice	Sugars	-0.4800000	0.3000000[c]	0.0002500[e]	0.0002500[e]	0.1795000
	Corn Sweeteners	0.0910859	-0.4800000	0.0002500[e]	0.0002500[e]	0.3884141
	Other Sweeteners	0.0198553	0.0653953	-0.4800000	0.0002500[e]	0.3944994
	Artificial Sweeteners	0.0058393	0.0192322	0.0000735	-0.4800000	0.4548550
	All other materials	0.0003939	0.0028070	0.0000109	0.0000427	-0.0032544
Sweetener Products	Sugars	-0.4800000	0.0400000[f]	0.0015000[f]	0.0005000[f]	0.4380000
	Corn Sweeteners	0.4154983	-0.4800000	0.0015000[f]	0.0005000[f]	0.0625017
	Other Sweeteners	0.2081608	0.0200396	-0.4800000	0.0005000[f]	0.2512996
	Artificial Sweeteners	0.0117254	0.0011288	0.0000845	-0.4800000	0.4670613
	All other materials	0.0539663	0.0007414	0.0002231	0.0024539	-0.0573847
Processed fruits and vegetables	Sugars	-0.4800000	0.3000000[c]	0.0002500[e]	0.0002500[e]	0.1795000
	Corn Sweeteners	0.0851322	-0.4800000	0.0002500[e]	0.0002500[e]	0.3943678
	Other Sweeteners	0.0140309	0.0494438	-0.4800000	0.0002500[e]	0.4162754
	Artificial Sweeteners	0.0041264	0.0145410	0.0000735	-0.4800000	0.4612591
	All other materials	0.0004072	0.0031523	0.0000168	0.0000634	-0.0036397
Condiments / Spices	Sugars	-0.4800000	0.3000000[c]	0.0050000[g]	0.0025000[h]	0.1725000
	Corn Sweeteners	0.4102984	-0.4800000	0.0050000[g]	0.0025000[h]	0.0622016
	Other Sweeteners	0.0049216	0.0035986	-0.4800000	0.0025000[h]	0.4689798
	Artificial Sweeteners	0.0221038	0.0161617	0.0224557	-0.4800000	0.4192788
	All other materials	0.0004851	0.0001279	0.0013399	0.0001334	-0.0020863

Appendix 2.20 Changes for All Households with Tax on the Price of Caloric Sweeteners for Nine Sweetener-Intensive Foods (Reduce the Substitutability between Sweeteners by One Half)

Food	Initial per capita food demand ($)[a]	Price with tax	Food demand change (%)	Tax rate: Sugars	Tax rate: Corn Sweeteners	Tax rate: Other Sweeteners		
				27.234%	42.836%	0.00004%		
				Sweeteners consumption quantity change (%)				
				Sugars	Corn Sweeteners	Other Sweeteners	Artificial Sweeteners	All Sweeteners (sugar equivalent)[b]
Milk	100.44	1.004	-0.368	-1.202	-11.592	0.808	6.652	-7.416
Cheese	65.55	1.000	-0.002	-0.864	-12.793	0.527	0.153	-8.947
Ice cream / yogurt	27.39	1.006	-0.557	-1.414	-9.098	0.935	5.643	-5.244
Breakfast cereal / Bakery	149.78	1.006	-0.231	-7.845	-5.948	0.893	4.642	-6.685
Soft drink	118.41	1.012	-1.179	-2.030	-16.408	3.663	1.878	-14.264
Juice	42.96	1.003	-0.104	-1.025	-14.001	2.681	0.664	-10.716
Sweetener products	87.56	1.030	-1.487	-11.078	-8.343	4.208	-1.275	-10.105
Processed fruits and vegetables	29.39	1.003	-0.578	-1.527	-14.560	1.438	-0.055	-11.328
Condiments / Spices	104.65	1.001	-0.149	-1.251	-7.340	-0.146	0.718	-3.173
Sweeteners	**Initial per capita sweeteners consumption (lbs)**		**Sweeteners consumption quantity change (%)**		**Initial per capita sweeteners consumption ($)**		**Sweeteners consumption value change (%)**	
All Sweeteners (sugar equivalent)[b]		105.69		-10.000		22.66		19.889
Sugars		61.90		-8.880		13.8		17.357
Corn Sweeteners		54.81		-12.405		7.31		28.709
Other Sweeteners		2.86		1.276		0.94		1.296
Artificial Sweeteners		0.54		-0.043		0.61		-0.043
Real expenditure on above nine foods	**Initial per capita real expenditure ($)**				**Real expenditure change (%)**			
				726.13				0.273
Welfare				**Market welfare change**				
EV (million $)								-1668.099
Per capita EV ($)								-5.952
EV/Income (%)								0.032

Note: Elasticities for final products are from USDA/ERS and Chouinard, H.H., D.E. Davis, J.T. LaFrance, and J.M.Perloff. 2010.
a- Initial prices are normalized to $1/unit.
b- See footnote in Table 2.7.

Appendix 2.21 Changes for All Households with Tax on the Price for Individual Sweetener for Nine Sweetener-Intensive Foods (Reduce the Substitutability between Sweeteners by One Half)

Food	Initial per capita food demand ($)[a]	Tax on the price of Sugars		Tax on the price of Corn Sweeteners	
		Tax rate			
		60.879%		154.311%	
		Price with tax	Food demand change (%)	Price with tax	Food demand change (%)
Milk	100.44	1.002	-0.181	1.007	-0.726
Cheese	65.55	1.000	0.100	1.001	-0.137
Ice cream / yogurt	27.39	1.005	-0.485	1.010	-0.816
Breakfast cereal / Bakery	149.78	1.009	-0.328	1.004	-0.169
Soft drink	118.41	1.001	-0.091	1.032	-2.992
Juice	42.96	1.001	0.188	1.007	-0.519
Sweetener products	87.56	1.053	-2.620	1.010	-0.453
Processed fruits and vegetables	29.39	1.001	-0.061	1.007	-1.435
Condiments / Spices	104.65	1.001	-0.142	1.002	-0.202
Sweeteners	**Initial per capita sweeteners consumption (lbs)**	**Sweeteners consumption quantity change (%)**			
All Sweeteners (sugar equivalent)[b]	105.69		-10.000		-10.000
Sugars	61.90		-21.996		7.639
Corn Sweeteners	54.81		7.367		-37.325
Other Sweeteners	2.86		1.130		1.830
Artificial Sweeteners	0.54		-0.886		0.995
Sweeteners	**Initial per capita sweeteners consumption ($)**	**Sweeteners consumption value change (%)**			
All Sweeteners	22.66		20.094		30.939
Sugars	13.80		29.050		7.639
Corn Sweeteners	7.31		7.367		81.137
Other Sweeteners	0.94		1.130		1.830
Artificial Sweeteners	0.61		-0.886		0.995
Real expenditure on nine foods	**Initial per capita real expenditure ($)**	**Real expenditure change (%)**			
	726.13		0.459		0.093
Welfare		**Market welfare change**			
EV (million $)			-1855.917		-1913.940
Per capita EV ($)			-6.622		-6.829
EV/Income (%)			0.035		0.036

Note: Elasticities for final products are from USDA/ERS and Chouinard, H.H., D.E. Davis, J.T. LaFrance, and J.M.Perloff. 2010.

a- Initial prices are normalized to $1/unit.

b- See footnote in Table 2.7.

Appendix 2.22 Computation of Simulations

Computation of Food Price with Sweetener Input Tax

If the tax imposed on the sweeteners inputs is changed, we derived that

$$d\ln P_i = d\ln PP_i = \sum_k s_{ik} d\ln w_k = \sum_k s_{ik} d\ln(1+t_k),$$

By approximation, $\dfrac{P_i^1 - P_i^0}{P_i^0} \approx \exp(d\ln P_i) - 1 = \exp[\sum_k s_{ik} d\ln(1+t_k)] - 1,$

$$P_i^1 \approx P_i^0 \exp[\sum_k s_{ik} d\ln(1+t_k)] \approx P_i^0 \exp[\sum_k s_{ik} \ln(1+t_k)].$$

Computation of Sweetener Input Quantity Change

We derived that $d\ln x_h = d\ln y + \sum_k \delta_{hk} d\ln(1+t_k)$.

The percentage change of the quantity of input h can be approximated as

$$\frac{x_h^1 - x_h^0}{x_h^0} \approx \exp(d\ln x_h) - 1 \approx \exp[(\ln y_1 - \ln y_0) + \sum_k \delta_{hk} \ln(1+t_k)] - 1.$$

Computation of Sweetener Input Value Change

If tax is not imposed on the sweetener h, the percentage change of the value of input h can be approximated as

$$\frac{w_h^0 x_h^1 - w_h^0 x_h^0}{w_h^0 x_h^0} = \frac{x_h^1 - x_h^0}{x_h^0} \approx \exp[(\ln y_1 - \ln y_0) + \sum_k \delta_{hk} \ln(1+t_k)] - 1,$$

If tax is imposed on the sweetener h, the percentage change of the value of input h can be approximated as

$$\frac{w_h^1 x_h^1 - w_h^0 x_h^0}{w_h^0 x_h^0} = \frac{(1+t_h)x_h^1 - x_h^0}{x_h^0} = \frac{(1+t_h)(x_h^1 - x_h^0)}{x_h^0} + t_h \approx (1+t_h)\{\exp[(\ln y_1 - \ln y_0) + \sum_k \delta_{hk} \ln(1+t_k)] - 1) + t_h\}.$$

Appendix 2.23 Changes for All Households with Tax on the price of All Sweeteners for Nine Sweetener-Intensive Foods

Food	Initial per capita food demand ($)[a]	Price with tax	Food demand change (%)	Tax rate: Sugars	Tax rate: Corn Sweeteners	Tax rate: Other Sweeteners	Tax rate: Artificial Sweeteners	
				27.410%	43.073%	0.00006%	0.00012%	
				Sweeteners consumption quantity change (%)				
				Sugars	Corn Sweeteners	Other Sweeteners	Artificial Sweeteners	All Sweeteners (sugar equivalent)[b]
Milk	100.44	1.004	-0.370	-1.219	-11.639	1.982	14.214	-7.448
Cheese	65.55	1.000	-0.002	-0.880	-12.845	1.063	0.310	-8.985
Ice cream / yogurt	27.39	1.006	-0.560	-1.433	-9.130	2.462	12.295	-5.267
Breakfast cereal / Bakery	149.78	1.006	-0.232	-7.892	-5.964	1.982	9.746	-6.645
Soft drink	118.41	1.013	-1.184	-2.052	-16.478	8.784	5.053	-14.225
Juice	42.96	1.003	-0.104	-1.042	-14.060	5.635	1.507	-10.760
Sweetener products	87.56	1.030	-1.496	-11.139	-8.372	10.413	-0.962	-10.133
Processed fruits and vegetables	29.39	1.003	-0.581	-1.546	-14.621	3.609	0.567	-11.374
Condiments / Spices	104.65	1.001	-0.150	-1.269	-7.364	0.101	1.850	-3.126

Sweeteners	Initial per capita sweeteners consumption (lbs)	Sweeteners consumption quantity change (%)	Initial per capita sweeteners consumption ($)	Sweeteners consumption value change (%)
All Sweeteners (sugar equivalent)[b]	105.69	-10.000	22.66	20.143
Sugars	61.90	-8.929	13.80	17.474
Corn Sweeteners	54.81	-12.451	7.31	28.894
Other Sweeteners	2.86	3.223	0.94	3.348
Artificial Sweeteners	0.54	1.325	0.61	1.400

Real expenditure on above nine foods	Initial per capita real expenditure ($)	Real expenditure change (%)
	726.13	0.275

Welfare	Market welfare change
EV (million $)	-1676.919
Per capita EV ($)	-5.983
EV/Income (%)	0.032

Note: Elasticities for final products are from USDA/ERS and Chouinard, H.H., D.E. Davis, J.T. LaFrance, and J.M.Perloff. 2010.

a- Initial prices are normalized to $1/unit.

b- See footnote in Table 2.7.

Appendix 2.24 Changes on All Households and Disaggregated Income Groups with Tax on the price of All Sweeteners for Nine Sweetener-Intensive Foods

Food	All households		Food demand by household quintiles: Lowest 20%		Second 20%		Third 20%		Fourth 20%		Highest 20%	
	Food demand (per capita)											
	Initial value ($)[a]	Change (%)	Initial value ($)[a]	Change (%)	Initial value ($)[a]	Change (%)	Initial value ($)[a]	Change (%)	Initial value ($)[a]	Change (%)	Initial value ($)[a]	Change (%)
Milk	100.44	-0.370	104.98	-0.517	107.31	-0.390	95.18	-0.387	99.59	-0.330	98.18	-0.293
Cheese	65.55	-0.002	60.44	0.000	56.54	-0.002	62.73	-0.002	66.77	-0.003	75.57	-0.003
Ice cream / yogurt	27.39	-0.560	25.26	-0.889	23.62	-0.733	26.21	-0.581	27.90	-0.486	31.58	-0.375
Breakfast cereal / Bakery	149.78	-0.232	150.03	-0.336	141.06	-0.277	138.98	-0.248	148.90	-0.208	164.84	-0.165
Soft drink	118.41	-1.184	114.12	-1.795	109.23	-1.448	112.87	-1.233	120.07	-1.034	129.86	-0.836
Juice	42.96	-0.104	41.98	-0.151	40.55	-0.122	40.33	-0.110	42.70	-0.094	47.40	-0.076
Sweetener products	87.56	-1.496	86.58	-2.209	79.50	-1.858	85.20	-1.526	87.20	-1.330	95.78	-1.059
Processed fruits and vegetables	29.39	-0.581	28.84	-0.858	27.74	-0.691	28.36	-0.597	29.48	-0.514	31.53	-0.423
Condiments / Spices	104.65	-0.150	90.40	-0.252	93.45	-0.188	101.54	-0.153	108.64	-0.128	118.83	-0.103
	Sweeteners consumption quantities (per capita)											
Sweeteners	Initial value (lbs)	Change (%)	Initial value (lbs)	Change (%)	Initial value (lbs)	Change (%)	Initial value (lbs)	Change (%)	Initial value (lbs)	Change (%)	Initial value (lbs)	Change (%)
All Sweeteners (sugar equivalent)[b]	105.69	-10.000	103.83	-10.450	97.85	-10.193	101.28	-10.039	105.85	-9.899	115.37	-9.727
Sugars	61.90	-8.929	61.21	-9.434	56.96	-9.115	59.54	-8.981	61.73	-8.803	67.67	-8.643
Corn Sweeteners	54.81	-12.451	53.41	-12.838	51.24	-12.619	52.26	-12.483	55.22	-12.370	59.63	-12.213
Other Sweeteners	2.86	3.223	2.72	3.068	2.63	3.124	2.71	3.212	2.89	3.258	3.17	3.328
Artificial Sweeteners	0.54	1.325	0.53	0.685	0.49	1.060	0.52	1.244	0.54	1.485	0.59	1.706

Note: Elasticities for final products are from USDA/ERS and Chouinard, H.H., D.E. Davis, J.T. LaFrance, and J.M.Perloff. 2010.
a- Initial prices are normalized to $1/unit.
b- See footnote in Table 2.7.

Appendix 2.24 (continued)

Sweeteners	All households		Food demand by household quintiles									
			Lowest 20%		Second 20%		Third 20%		Fourth 20%		Highest 20%	
	Sweeteners consumption values (per capita)											
	Initial value ($)[a]	Change (%)	Initial value ($)[a]	Change (%)	Initial value ($)[a]	Change (%)	Initial value ($)[a]	Change (%)	Initial value ($)[a]	Change (%)	Initial value ($)[a]	Change (%)
All Sweeteners	22.66	20.143	22.26	19.531	20.95	19.963	21.72	20.064	22.68	20.302	24.75	20.466
Sugars	13.8	17.474	13.64	16.819	12.70	17.247	13.27	17.400	13.76	17.638	15.08	17.838
Corn Sweeteners	7.31	28.894	7.12	28.335	6.84	28.649	6.97	28.847	7.37	29.006	7.95	29.245
Other Sweeteners	0.94	3.348	0.89	3.195	0.87	3.249	0.89	3.338	0.95	3.383	1.04	3.452
Artificial Sweeteners	0.61	1.400	0.59	0.761	0.55	1.137	0.58	1.317	0.61	1.561	0.66	1.782
Real expenditure on nine foods	Real expenditure (per capita)											
	Initial value ($)	Change (%)	Initial value ($)	Change (%)	Initial value ($)	Change (%)	Initial value ($)	Change (%)	Initial value ($)	Change (%)	Initial value ($)	Change (%)
	726.13	0.275	702.64	0.007	679.01	0.154	691.40	0.256	731.26	0.337	793.56	0.434
Welfare	Market welfare change		Market welfare change		Market welfare change		Market welfare change		Market welfare change		Market welfare change	
EV (million $)		-1676.919		-225.008		-275.226		-323.775		-379.654		-473.256
Per capita EV ($)		-5.983		-5.864		-5.537		-5.732		-5.997		-6.537
EV/Income (%)		0.032		0.121		0.059		0.040		0.030		0.019

Appendix 2.25 Changes for All Households with Tax on the price of All Sweeteners for Nine Sweetener-Intensive Foods (Reduce the Sugar Equivalent Quantity of All Sweeteners by 20%)

				Tax rate				
				Sugars	Corn Sweeteners	Other Sweeteners	Artificial Sweeteners	
				80.903%	116.391%	0.000126%	0.000000001%	
				Sweeteners consumption quantity change (%)				
Food	**Initial per capita food demand ($)[a]**	**Price with tax**	**Food demand change (%)**	**Sugars**	**Corn Sweeteners**	**Other Sweeteners**	**Artificial Sweeteners**	**All Sweeteners (sugar equivalent)[b]**
Milk	100.44	1.009	-0.826	-5.888	-22.265	4.519	34.858	-14.803
Cheese	65.55	1.001	0.015	-5.144	-24.875	2.404	0.712	-17.352
Ice cream / yogurt	27.39	1.015	-1.284	-6.377	-16.746	5.693	30.268	-11.038
Breakfast cereal / Bakery	149.78	1.014	-0.549	-19.062	-9.527	4.777	24.734	-14.335
Soft drink	118.41	1.027	-2.584	-7.610	-32.120	19.948	11.218	-25.776
Juice	42.96	1.007	-0.190	-5.444	-27.352	12.917	3.417	-20.296
Sweetener products	87.56	1.075	-3.688	-25.470	-15.170	26.797	-2.436	-21.267
Processed fruits and vegetables	29.39	1.007	-1.261	-6.546	-28.451	8.137	1.268	-21.360
Condiments / Spices	104.65	1.003	-0.344	-6.018	-12.751	0.229	4.295	-6.761

Sweeteners	**Initial per capita sweeteners consumption(lbs)**	**Sweeteners consumption quantity change (%)**	**Initial per capita sweeteners consumption ($)**	**Sweeteners consumption value change (%)**
All Sweeteners (sugar equivalent)[b]	105.69	-20.000	22.66	68.062
Sugars	61.90	-19.627	13.8	58.194
Corn Sweeteners	54.81	-22.331	7.31	99.611
Other Sweeteners	2.86	8.094	0.94	8.957
Artificial Sweeteners	0.54	3.271	0.61	3.796

Real expenditure on above nine foods	**Initial per capita real expenditure ($)**	**Real expenditure change (%)**
	726.13	0.644

Welfare	**Market welfare change**
EV (million $)	-3908.932
Per capita EV ($)	-13.947
EV/Income (%)	0.074

Note: Elasticities for final products are from USDA/ERS and Chouinard, H.H., D.E. Davis, J.T. LaFrance, and J.M.Perloff. 2010.
a- Initial prices are normalized to $1/unit.
b- See footnote in Table 2.7.

Appendix 2.26 Changes for All Households with Tax on the price of All Sweeteners for Nine Sweetener-Intensive Foods (Reduce the Substitutability between Sweeteners by One Half)

Food	Initial per capita food demand ($)[a]	Price with tax	Food demand change (%)	Sugars	Corn Sweeteners	Other Sweeteners	Artificial Sweeteners	All Sweeteners (sugar equivalent)[b]
				Tax rate				
				Sugars	Corn Sweeteners	Other Sweeteners	Artificial Sweeteners	
				27.220%	42.866%	0.0039%	0.00012%	
				Sweeteners consumption quantity change (%)				
Milk	100.44	1.004	-0.368	-1.190	-11.604	0.806	6.654	-7.419
Cheese	65.55	1.000	-0.002	-0.853	-12.803	0.525	0.153	-8.951
Ice cream / yogurt	27.39	1.006	-0.557	-1.403	-9.110	0.933	5.643	-5.245
Breakfast cereal / Bakery	149.78	1.006	-0.231	-7.838	-5.962	0.891	4.641	-6.684
Soft drink	118.41	1.012	-1.179	-2.020	-16.417	3.663	1.879	-14.271
Juice	42.96	1.003	-0.104	-1.014	-14.011	2.680	0.664	-10.721
Sweetener products	87.56	1.030	-1.487	-11.072	-8.356	4.205	-1.275	-10.102
Processed fruits and vegetables	29.39	1.003	-0.579	-1.516	-14.570	1.437	-0.055	-11.333
Condiments / Spices	104.65	1.001	-0.149	-1.239	-7.354	-0.148	0.718	-3.173

Sweeteners	Initial per capita sweeteners consumption (lbs)	Sweeteners consumption quantity change (%)	Initial per capita sweeteners consumption ($)	Sweeteners consumption value change (%)
All Sweeteners (sugar equivalent)[b]	105.69	-10.000	22.66	19.891
Sugars	61.90	-8.874	13.8	17.351
Corn Sweeteners	54.81	-12.414	7.31	28.726
Other Sweeteners	2.86	1.275	0.94	1.299
Artificial Sweeteners	0.54	-0.043	0.61	-0.024

Real expenditure on above nine foods	Initial per capita real expenditure ($)	Real expenditure change (%)
	726.13	0.273

Welfare	Market welfare change
EV (million $)	-1668.119
Per capita EV ($)	-5.952
EV/Income (%)	0.032

Note: Elasticities for final products are from USDA/ERS and Chouinard, H.H., D.E. Davis, J.T. LaFrance, and J.M.Perloff. 2010.
a- Initial prices are normalized to $1/unit.
b- See footnote in Table 2.7.

CHAPTER 3. ACCOUNTING FOR PRODUCT SUBSTITUTION IN THE ANALYSIS OF FOOD TAXES TARGETING OBESITY

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.

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. (See Technical Appendix 3.1 for further detail). 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. For details on added sugars, see Technical Appendix

3.2. 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

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

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

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

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 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

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

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

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

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

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

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*,

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

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 3.3 for detailed listing of foods in the food groups.

The initial consumption of calorie and nutrients from the 25 composite food groups are shown in Table 3.1. 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.

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 listed for the 100 sub-categories in Technical Appendix 3.4 to 3.5 and for selected foods in Table 3.2. In the rest of the paper, we report results for the cut-off decomposition and refer readers to Technical Appendix 3.17 for simulation results using the average decomposition of the four types of goods. Qualitative results are similar.

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.[4]

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 3.3. 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. The cross-price elasticities from the same sources are listed in Technical Appendix 3.6. All the available cross-price elasticities are small in absolute value, which means the substitutability or complementarily among the final products will be limited.

(2) Income I

[4] 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".

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 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 3.4.

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 3.3 and cross-price elasticities from Technical Appendix 3.6. The Marshallian price elasticity matrix for the composite food groups is recovered with the parameters in the LinQuad demand system and shown in Technical Appendix 3.7. 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 3.4 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 provided in Technical Appendix 3.8. The densities 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 3.5. The new composite food prices inclusive of the tax are provided in Technical Appendix 3.13 to 3.14. Table 3.5 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.

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 3.6). 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 calories/gram while added sugars provide 4 calorie/gram (Table 3.7). 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 3.5 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 (see Technical Appendix 3.14 to 3.15). 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 3.5.

More interestingly, Table 3.5 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 (see details in Technical Appendix 3.8 to 3.10). 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 3.6 and 3.7 present the calorie and nutrient intake changes induced by the tax on calories from added sugar.

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 3.6 and 3.7), 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 3.6, 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 3.7, 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 3.7 (0.90% reduction versus 0.87% reduction).

The real expenditure changes under either approach are small. Table 3.8 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).

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.

References

Abdulai, A. and D. Aubert. 2004. “Nonparametric and Parametric Analysis of Calorie Consumption in Tanzania.” *Food Policy* 29, 113-129.

Adamy, J., 2009. “Soda Tax Weighted to Pay for Health Care.” *The Wall Street Journal* 12, May http://online.wsj.com/article/SB124208505896608647.html (accessed June, 2010)

Allais, O., P.Bertail, and V. Nichèle. 2010. “The Effects of a Fat Tax on French Households’ Purchases: A Nutritional Approach.” *American Journal of Agricultural Economics*. 92(1): 228-245.

American Heart Association. 2009. Fats 101 http://www.americanheart.org/ (accessed December 2009)

Andreyeva, T., M.W. Long, and K.D. Brownell. 2010. “The Impact of Food Prices on Consumption: a Systematic Review of Research on the Price Elasticity of Demand for Food.” *American Journal of Public Health*. 100(2): 216-222.

Beghin, J.C., J. Bureau, and S. Drogué. 2004. “The Calibration of Incomplete Demand Systems in Quantitative Analysis.” *Applied Economics* 36(8): 839-847.

Bhattacharya, J. and M.K. Bundorf. 2005. “The Incidence of the Healthcare Costs of Obesity.” NBER Working Paper 11303.

Bhuyan, S. and R.A. Lopez. 1997. “Oligopoly Power in the Food and Tobacco Industries.” *American Journal of Agricultural Economics* 79 (3): 1035-1043.

Boizot-Szantaï C. and F. Etilé. 2005. “The Food Prices / Body Mass Index Relationship: Theory and Evidence from a Sample of French Adults.” Paper prepared for presentation at the Congress of the European Association of Agricultural Economists, Copenhagen, Denmark, 24-27 August.

Bowman, S.A., J.E. Friday, and A.J. Moshfegh. 2008. "MyPyramid Equivalents Database, 2.0 for USDA Survey Foods, 2003-2004: Documentation and User Guide." Food Surveys Research Group, Beltsville Human Nutrition Research Center, Agricultural Research Service, USDA. http://www.ars.usda.gov/ba/bhnrc/fsrg (accessed August, 2009)

Bureau of Labor Statistics. 2010. "Consumer Price Index-Average Price Data & All Urban Consumers (Current series)"http://www.bls.gov/data/#prices (accessed April, 2010)

Cash, S.B., D.L. Sunding, and D. Zilberman. 2005. "Fats Taxes and Thin Subsidies: Prices, Diet, and Health Outcomes." *Acta Agriculturae Scandinavica Section C* 2 (3-4): 167-174

Centers for Disease Control and Protection, National Center for Health Statistics. 2009. "National Health and Nutrition Examination Survey 2003-2004." http://www.cdc.gov/nchs/nhanes/nhanes2003-2004/nhanes03_04.htm (accessed September, 2009)

Chouinard, H.H., D.E. Davis, J.T. LaFrance, and J.M. Perloff. 2010. "Milk Marketing Order Winners and Losers." *Applied Economic Perspectives and Policy* 32(1): 59-76.

French, S.A., R.W. Jeffery, M. Story, K.K. Breitlow, J.S. Baxter, P. Hannan, and M.P. Snyder. 2001. "Pricing and Promotion Effects on Low-Fat Vending Snack Purchases: The CHIPS Study." *American Journal of Public Health* 91(1): 112-117.

Gustavsen, G. 2005. "Public Policies and the Demand for Carbonated Soft Drinks: A Censored Quartile Regression Approach." Paper presented at the Congress of the EAAE (European Association of Agricultural Economists), Copenhagen, Denmark, 24-27 August.

Kuchler, F., A Tegene, and J.M. Harris. 2004. "Taxing Snack Foods: What to Expect for Diet and Tax Revenues." *Agriculture Information Bulletin* No. 747-08, August.

—. 2005. "Taxing Snacks Foods: Manipulating Diet Quality or Financing Information Programs?" *Review of Agricultural Economics* 27 (1): 4-20.

Miao, Z., J. Beghin, and H.H. Jensen. 2010. "Taxing Sweets: Sweetener Input Tax or Final Consumption Tax?" Selected Paper prepared for presentation at the Agricultural & Applied Economics Association 2010 AAEA, CAES & WAEA Joint Annual Meeting, Denver, Colorado, 25-27 July.

National Cancer Institute. 2008. "Usual Dietary Intakes: Food Intakes, US Population, 2001-04." http://riskfactor.cancer.gov/diet/usualintakes/pop/ (accessed November, 2009)

Ogden C.L., M.D. Carroll, M.A. McDowell, K.M. Flegal. 2007. "Obesity Among Adults in the United States— No Statistically Change Since 2003–2004." National Center for Health Statistics Data Brief No. 1. http://www.cdc.gov/nchs/data/databriefs/db01.pdf (accessed October, 2009)

Powell, L.M. and J.F. Chriqui. Forthcoming. "Food Taxes and Subsidies: Evidence and Policies for Obesity Prevention." In J. Cawley (Ed.), *The Handbook of the Social Science of Obesity*. Oxford University Press

Reed, A.J., J.W. Levedahl, and C. Hallahan. 2005. "The Generalized Composite Commodity Theorem and Food Demand Estimation." *American Journal of Agricultural Economics* 87 (1): 28-37.

Reed, A.J., J.W. Levedahl, and J.S. Clark. 2003. "Commercial Disappearance and Composite Demand for Food with an application to U.S. Meats." *Journal of Agricultural and Resource Economics* 28 (1): 53-70.

Richards, T.J., P.M. Patterson, and A. Tegene. 2007. "Obesity and Nutrient Consumption: A Rational Addiction?" *Contemporary Economic Policy*. 25(3): 309-324.

Schroeter, C., J. Lusk, and W. Tyner. 2008. "Determining the Impact of Food Price and Income Changes on Body Weight." *Journal of Health Economics* 27:45-68.

Shankar, B. 2009. "Fat Chance: Modelling the Socio-Economic Determinants of Dietary Fat Intake in China." Contributed paper prepared for presentation at the International Association of Agricultural Economists Conference, Beijing, China, 16-22 August.

Smed, S., J.D. Jensen and S. Denver. 2007. "Socio-economic Characteristics and the Effect of Taxation as a Health Policy Instrument." *Food Policy* 32: 5-6.

Smith, T.A., B.H. Lin, and J.Y. Lee. 2010. "Taxing Caloric Sweetened Beverages: Potential Effects on Beverage Consumption, Calorie Intake, and Obesity." *Economic Research Report* Number 100. U.S. Department of Agriculture, Economic Research Service (USDA/ERS). July.

U.S. Department of Agriculture, Agricultural Research Service. 2006. *USDA Food and Nutrient Database for Dietary Studies, 2.0*. Beltsville, MD: Agricultural Research Service, Food Surveys Research Group.

U.S. Department of Agriculture, Center for Nutrition Policy and Promotion. 2009. "CNPP Food Prices Database, 2003-04." http://www.cnpp.usda.gov/usdafoodplanscostoffood.htm (accessed September, 2009)

U.S. Department of Agriculture, Economic Research Service (USDA/ERS). 2006. "Commodity and Food Elasticities" http://www.ers.usda.gov/Data/Elasticities (accessed October. 2009)

——. 2009. "Food Availability Data System". http://www.ers.usda.gov/Data/FoodConsumption/FoodAvailIndex.htm (accessed October. 2009)

U.S. Department of Agriculture and Department of Health and Human Services (USDA/DHHS). 2005. "Dietary Guidelines for Americans, 2005." http://www.health.gov/dietaryguidelines/dga2005/document/default.htm (accessed October, 2009)

Yaniv, G., O. Rosin, and Y. Tobol. 2009. "Junk-food, Home Cooking, Physical Activity and Obesity: The Effect of the Fat Tax and the Thin Subsidy." *Journal of Public Economics* 93(5-6): 823-830.

Table 3.1 Initial Consumption of Calorie and Nutrients from Composite Food Groups

Composite food groups[a]	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

a- The first 2 or 3 digits of the NHANES 2003-04 food codes are used to group the food items taken by survey participants.

Table 3.2 Calories, Nutrients, and Expenditures of Selected Foods by Cut-off Measure

Composite food groups	Sub-categories[a]	Share of Total Calories	Percent contribution to total calories			Food expenditure ($)
			Discret. Oil[b]	Discret. solid fat[b]	Sugars[b]	
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- Each gram of discretionary oil and of discretionary solid fat provides 9 calories; each gram of added sugars provides 4 calories.

Table 3.3 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 3.4 Elasticity of Substitution 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 3.5 Demand Changes with Tax on Calories from Added Sugars by Cut-off Measure

Composite food groups	Relative change in demand (%)					
	Without CES	With CES[a,b]				
		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 3.6 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 3.7 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 3.8 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

Appendix 3.1 Definition, Example, Health Effect, and Intake Guidelines for Saturated fat, Unsaturated fat, and Trans fat

Fat Type		Definition	Presence in food	Health effects	Intake Guidelines
Saturated fat		Saturated fats are typically solid at room temperature.	The majority of saturated fats come from animal sources, including meat and dairy products. Examples are fatty beef, lamb, pork, poultry with skin, beef fat (tallow), lard and cream, butter, cheese and other dairy products made from whole or reduced-fat (2%) milk. In addition, many baked goods and fried foods can contain high levels of saturated fats. Some plant foods, such as palm oil, palm kernel oil and coconut oil, also contain primarily saturated fats.	Saturated fats increase the cholesterol level in the blood. High level of blood cholesterol increases the risk of heart disease and stroke.	The American Heart Association recommends limiting saturated fats to less than 7% of total daily calories. That means no more than 140 calorie (16 grams) saturated fats for a 2000 calorie need per day.
Unsaturated fat	Monounsaturated fat	Monounsaturated fats are typically liquid at room temperature but start to turn solid when chilled.	Examples of foods high in monounsaturated fats include vegetable oils such as olive oil, canola oil, peanut oil, sunflower oil and sesame oil. Other sources include avocados, peanut butter, and many nuts and seeds.	Monounsaturated and/or polyunsaturated fats can help decrease bad cholesterol levels in the blood and decrease the risk of heart disease and stroke. Monounsaturated fats are also high in vitamin E. Polyunsaturated fats also include essential fats that the body needs such as omega-6 and omega-3.	Limit the total fats to less than 25–35% of the calories intake per day. The majority of those fats should be monounsaturated or polyunsaturated. Have foods containing monounsaturated and/or polyunsaturated fats instead of foods that contain saturated and/or trans fats.
	Polyunsaturated fat	Polyunsaturated fats are typically liquid at room temperature and when chilled.	Foods high in polyunsaturated fat are vegetable oils including soybean oil, corn oil and safflower oil, as well as fatty fish such as salmon, mackerel, herring and trout. Other sources include some nuts and seeds such as walnuts and sunflower seeds.		
Trans fat		Trans fats (trans fatty acids or partially hydrogenated oils) are created in an industrial process that adds hydrogen to liquid vegetable oils to make them more solid.	Trans fats can be found in fried foods like French fries and doughnuts, and baked goods including pastries, pie crusts, biscuits, pizza dough, cookies, crackers, and stick margarines and shortenings	Trans fats increase the bad (LDL) cholesterol levels and decrease the good (HDL) cholesterol levels. Trans fats increase the risk of heart disease and stroke. It's also associated with a higher risk of type 2 diabetes.	The American Heart Association recommends limiting trans fats to less than 1% of total daily calories. That means no more than 20 calories (2 grams) from trans fats for a 2000 calorie need per day. No more industrially manufactured trans fats given the naturally occurring trans fat that have been consumed.

Source: American Heart Association. Fats 101 http://www.americanheart.org/ (accessed December, 2009)

Appendix 3.2 Definition, Source and Example of Discretionary Fats and Added Sugar

Source of discretionary calories	Definition	Subgroup	Definition	Example	Sources
Discretionary fat	The fat above the lowest available fat level	Discretionary liquid oil	Oils are fats that are liquid at room temperature. Foods that are mainly oil include mayonnaise, some salad dressing and soft tub or squeeze margarine.	Vegetable oils used in cooking	Oils from a plant source and not described as "Hydrogenated" or "shortening" Fish Nuts and seeds Margarine described as "tub" or "liquid" types. If the type (stick/tub/liquid) of the margarine is not included in the description, it is classified as an oil if the recipe ingredient is an oil, or if it contains less than 80% total fat
		Discretionary solid fat	Solid fats are fats that are solids at room temperature. Solid fats mainly come from animal sources or from vegetable oils that have been hydrogenated.	Butter, beef tallow, stick margarine, and shortenings	From an animal source other than fish A blend of animal and plant sources (e.g., butter and margarine blend) Described as "hydrogenated" Described as "shortening" Cocoa fat/ fat in chocolate (not liquid) Derived from coconut or palm oil Margarine described as "stick". If the type of margarine (stick/tub/liquid) is not included in the description, or if the recipe ingredient is classified as solid or if the fat content was 80% or greater, it is classified as a solid fat
Added sugar	Added sugars are sugars consumed directly or added to foods at the table, or used as ingredients in processed and prepared foods such as breads, cakes, soft drinks, jams, chocolates, and ice cream. Added sugars do not include naturally occurring sugars such as lactose in milk or fructose in fruit.			White sugar, brown sugar, raw sugar, corn syrup, corn syrup solids, high fructose corn syrup, malt syrup, maple syrup, pancake syrup, fructose sweetener, liquid fructose, honey, molasses, anhydrous dextrose, crystal dextrose, and dextrin	

Source: Bowman, S.A., J.E. Friday, and A.J. Moshfegh. 2008. "MyPyramid Equivalents Database, 2.0 for USDA Survey Foods, 2003-2004: Documentation and User Guide." Food Surveys Research Group, Beltsville Human Nutrition Research Center, Agricultural Research Service, USDA. http://www.ars.usda.gov/ba/bhnrc/fsrg (accessed August, 2009)

Appendix 3.3 Food Groups and Details on Foods Included in the Food Groups

Food Group[a]	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

a- The first 2 or 3 digits of the NHANES 2003-04 food codes are used to group the food items taken by survey participants.

Appendix 3.4 Calories, Nutrients, and Expenditures of Foods by Cut-off Measure

Composite food groups	Sub categories[a]	Calorie distribution within column[b]	Discretionary oil density[c]	Discretionary solid fat density[d]	Added sugars density[e]	Food expenditure ($)
11 Milks and milk drinks	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
12 Creams and cream substitutes	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
13 Milk desserts, sauces, gravies	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
14 Cheeses	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
20-24 Beef & Pork & Lamb, veal, game, other carcass meat & Poultry	Aggregate	7.90%	5.15%	20.98%	0.14%	0.58
	HH	0.07%	0.13%	44.26%	8.84%	0.01
	HL	5.22%	1.43%	30.58%	0.08%	0.34
	LL	2.61%	12.72%	1.16%	0.02%	0.24
25 Organ meats, sausages and lunchmeats, and meat spreads	Aggregate	2.68%	0.19%	43.27%	0.54%	0.16
	HL	1.99%	0.26%	58.26%	0.43%	0.09
	LH	0.04%	0.00%	0.00%	13.31%	0.01
	LL	0.65%	0.01%	0.10%	0.04%	0.07
26 Fish and shellfish	Aggregate	1.27%	9.50%	16.16%	0.56%	0.19
	HL	0.92%	8.37%	21.75%	0.70%	0.12
	LH	0.00%	37.10%	0.00%	11.61%	0.00
	LL	0.35%	12.34%	1.64%	0.18%	0.07
27+28+77 Meat, poultry, fish with nonmeat items & Frozen and shelf-stable plate meals, soups, and gravies with meat, poultry, fish base; gelatin and gelatin-based drinks & Vegetables with meat, poultry, fish	Aggregate	7.37%	9.02%	20.60%	2.44%	0.43
	HH	0.17%	3.55%	17.92%	10.78%	0.01
	HL	5.91%	7.55%	24.95%	2.16%	0.31
	LH	0.08%	19.20%	0.46%	12.38%	0.01
	LL	1.21%	16.31%	0.97%	2.01%	0.11

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- Percentage contribution of discretionary oil to the total calories in the food. Each gram of discretionary oil provides 9 calories.
d- Percentage contribution of discretionary solid fat to the total calories in the food. Each gram of discretionary solid fat provides 9 calories.
e- Percentage contribution of discretionary added sugars to the total calories in the food. Each gram of added sugars provides 4 calories.

Appendix 3.4 (continued)

Composite food groups	Sub categories[a]	Calorie distribution within column[b]	Discretionary oil density[c]	Discretionary solid fat density[d]	Added sugars density[e]	Food expenditure ($)
31-35 Eggs	Aggregate	2.14%	5.68%	36.79%	0.42%	0.07
	HH	0.00%	0.01%	35.70%	12.39%	0.00
	HL	2.10%	5.09%	37.42%	0.36%	0.07
	LH	0.00%	0.00%	0.00%	89.76%	0.00
	LL	0.04%	38.16%	3.49%	0.00%	0.00
41-43 Dry beans, peas, other legumes, nuts, and seeds	Aggregate	3.37%	34.34%	3.92%	3.29%	0.12
	HH	0.16%	0.53%	11.42%	16.95%	0.01
	HL	0.52%	16.95%	18.17%	0.13%	0.01
	LH	0.27%	10.43%	1.38%	24.20%	0.03
	LL	2.42%	42.93%	0.65%	0.77%	0.07
51+52+54 Yeast breads, rolls & Quick breads & Crackers and salty snacks from grain products	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
53+55 Cakes, cookies, pies, pastries & Pancakes, waffles, French toast, other grain products	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
56-57 Pastas, cooked cereals, rice & Cereals, not cooked or ns as to cooked	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
58-59 Grain mixtures, frozen plate meals, soups & Meat substitutes, mainly cereal protein	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
61-67 (excluding 612+641+642+644) Fruits	Aggregate	2.27%	0.16%	0.06%	5.07%	0.23
	HH	0.00%	2.08%	32.37%	24.16%	0.00
	HL	0.00%	0.08%	29.07%	2.81%	0.00
	LH	0.21%	0.56%	0.01%	54.82%	0.01
	LL	2.05%	0.11%	0.00%	0.00%	0.21

Appendix 3.4 (continued)

Composite food groups	Sub categories[a]	Calorie distribution within column[b]	Discretion ary oil density[c]	Discretionary solid fat density[d]	Added sugars density[e]	Food expenditure ($)
612+641+642+644+92 Fruit juices & Nectars & Vinegar & Nonalcoholic beverages (excluding Coffee & Tea & Soft drinks, carbonated)	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
71 White potatoes and Puerto Rican starchy vegetables	Aggregate	4.70%	17.20%	24.79%	0.10%	0.12
	HH	0.00%	0.00%	57.91%	16.92%	0.00
	HL	2.78%	0.01%	41.62%	0.00%	0.07
	LL	1.92%	42.10%	0.39%	0.24%	0.05
72-76 Other vegetables	Aggregate	2.84%	8.87%	15.64%	6.06%	0.40
	HH	0.06%	8.30%	16.16%	31.64%	0.00
	HL	1.19%	4.83%	36.25%	0.29%	0.11
	LH	0.26%	5.25%	0.05%	51.52%	0.02
	LL	1.33%	13.23%	0.24%	0.98%	0.27
81 Fats	Aggregate	1.22%	34.46%	65.63%	0.26%	0.02
	HH	0.01%	0.00%	71.20%	25.40%	0.00
	HL	0.81%	2.18%	98.54%	0.00%	0.01
	LL	0.41%	99.15%	0.10%	0.39%	0.00
82-83 Oils & Salad dressings	Aggregate	2.06%	88.85%	2.39%	5.98%	0.04
	HH	0.01%	6.86%	28.14%	21.48%	0.00
	HL	0.15%	83.18%	9.13%	1.17%	0.00
	LH	0.55%	79.86%	0.48%	16.54%	0.02
	LL	1.34%	94.05%	2.15%	2.01%	0.02
91 Sugars and sweets	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
921-923 Coffee & Tea	Aggregate	1.01%	0.11%	6.57%	61.48%	0.12
	HH	0.13%	0.29%	23.30%	44.96%	0.01
	HL	0.08%	0.47%	40.93%	0.00%	0.01
	LH	0.57%	0.00%	0.00%	98.14%	0.02
	LL	0.22%	0.14%	0.00%	0.01%	0.08
924 Soft drinks, carbonated	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
93 Alcoholic beverages	Aggregate	4.21%	0.05%	0.19%	3.45%	0.68
	HH	0.02%	0.26%	38.65%	11.18%	0.00
	LH	0.60%	0.32%	0.05%	23.39%	0.14
	LL	3.59%	0.00%	0.00%	0.05%	0.53
94 Water	Aggregate	0.00%	0.00%	0.00%	0.00%	0.00
	LL	0.00%	0.00%	0.00%	0.00%	0.00

Appendix 3.5 Calories, Nutrients, and Expenditures of Foods by Average Measure

Composite food groups	Sub categories[a]	Calorie distribution within column[b]	Discretionary oil density[c]	Discretionary solid fat density[d]	Added sugars density[e]	Food expenditure ($)
11 Milks and milk drinks	Aggregate	4.67%	0.85%	26.38%	11.16%	0.22
	HH	0.17%	0.11%	33.53%	27.79%	0.01
	HL	2.40%	0.00%	39.50%	0.00%	0.10
	LH	1.15%	2.52%	14.09%	41.16%	0.05
	LL	0.94%	1.14%	6.57%	0.03%	0.07
12 Creams and cream substitutes	Aggregate	0.68%	6.49%	68.51%	14.48%	0.03
	HH	0.02%	0.10%	72.59%	27.75%	0.00
	HL	0.35%	0.00%	84.34%	0.68%	0.01
	LH	0.24%	0.00%	60.47%	38.67%	0.01
	LL	0.08%	57.57%	19.80%	0.44%	0.00
13 Milk desserts, sauces, gravies	Aggregate	2.12%	0.78%	42.88%	33.31%	0.07
	HH	1.09%	0.02%	48.73%	36.54%	0.03
	HL	0.37%	0.17%	58.97%	21.37%	0.01
	LH	0.36%	1.25%	21.74%	45.75%	0.02
	LL	0.30%	3.72%	27.30%	21.49%	0.01
14 Cheeses	Aggregate	2.74%	0.15%	65.93%	0.31%	0.14
	HH	0.00%	0.00%	87.06%	2.51%	0.00
	HL	1.87%	0.16%	71.47%	0.00%	0.08
	LH	0.23%	0.01%	59.98%	3.64%	0.01
	LL	0.64%	0.16%	51.80%	0.00%	0.04
20-24 Beef & Pork & Lamb, veal, game, other carcass meat & Poultry	Aggregate	7.90%	5.15%	20.98%	0.14%	0.58
	HH	0.28%	3.31%	38.58%	3.35%	0.02
	HL	3.88%	1.05%	35.20%	0.00%	0.23
	LH	0.11%	17.24%	9.28%	1.36%	0.01
	LL	3.63%	9.31%	4.78%	0.00%	0.33
25 Organ meats, sausages and lunchmeats, and meat spreads	Aggregate	2.68%	0.19%	43.27%	0.54%	0.16
	HH	0.65%	0.06%	59.98%	1.19%	0.02
	HL	1.29%	0.36%	58.48%	0.05%	0.07
	LH	0.06%	0.03%	4.44%	10.68%	0.01
	LL	0.67%	0.01%	0.97%	0.00%	0.07
26 Fish and shellfish	Aggregate	1.27%	9.50%	16.16%	0.56%	0.19
	HH	0.35%	5.92%	32.02%	1.41%	0.04
	HL	0.18%	9.23%	27.70%	0.00%	0.02
	LH	0.19%	22.78%	8.16%	1.16%	0.02
	LL	0.55%	7.33%	4.81%	0.00%	0.12

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- Percentage contribution of discretionary oil to the total calories in the food. Each gram of discretionary oil provides 9 calories.
d- Percentage contribution of discretionary solid fat to the total calories in the food. Each gram of discretionary solid fat provides 9 calories.
e- Percentage contribution of discretionary added sugars to the total calories in the food. Each gram of added sugars provides 4 calories.

Appendix 3.5 (continued)

Composite food groups	Sub categories[a]	Calorie distribution within column[b]	Discretionary oil density[c]	Discretionary solid fat density[d]	Added sugars density[e]	Food expenditure ($)
27+28+77 Meat, poultry, fish with nonmeat items & Frozen and shelf-stable plate meals, soups, and gravies with meat, poultry, fish base; gelatin and gelatin-based drinks & Vegetables with meat, poultry, fish	Aggregate	7.37%	9.02%	20.60%	2.44%	0.43
	HH	1.45%	7.14%	29.14%	4.66%	0.05
	HL	2.23%	2.86%	33.18%	0.53%	0.14
	LH	1.70%	21.15%	9.96%	5.16%	0.09
	LL	1.98%	6.89%	9.32%	0.63%	0.16
31-35 Eggs	Aggregate	2.14%	5.68%	36.79%	0.42%	0.07
	HH	0.26%	0.20%	48.03%	1.56%	0.01
	HL	0.57%	2.13%	45.67%	0.00%	0.02
	LH	0.16%	15.16%	23.24%	3.02%	0.01
	LL	1.15%	7.32%	31.80%	0.00%	0.04
41-43 Dry beans, peas, other legumes, nuts, and seeds	Aggregate	3.37%	34.34%	3.92%	3.29%	0.12
	HH	0.23%	0.38%	9.91%	17.24%	0.01
	HL	0.52%	17.05%	18.19%	0.07%	0.01
	LH	0.26%	16.61%	0.05%	21.34%	0.02
	LL	2.37%	43.26%	0.66%	0.72%	0.07
51+52+54 Yeast breads, rolls & Quick breads & Crackers and salty snacks from grain products	Aggregate	12.00%	9.70%	10.63%	5.72%	0.24
	HH	1.43%	1.31%	27.97%	22.32%	0.04
	HL	2.60%	7.11%	26.27%	0.82%	0.05
	LH	3.53%	9.82%	0.52%	7.87%	0.04
	LL	4.44%	13.82%	3.93%	1.52%	0.10
53+55 Cakes, cookies, pies, pastries & Pancakes, waffles, French toast, other grain products	Aggregate	6.43%	3.78%	30.44%	28.45%	0.18
	HH	1.43%	0.86%	35.49%	38.80%	0.03
	HL	2.04%	0.47%	44.83%	20.75%	0.05
	LH	1.50%	6.08%	18.80%	42.53%	0.04
	LL	1.45%	8.95%	17.25%	14.54%	0.05
56-57 Pastas, cooked cereals, rice & Cereals, not cooked or ns as to cooked	Aggregate	4.44%	2.32%	3.20%	11.99%	0.12
	HH	0.64%	1.65%	7.15%	27.50%	0.02
	HL	0.99%	2.92%	9.22%	0.00%	0.01
	LH	1.16%	2.59%	0.16%	27.59%	0.04
	LL	1.65%	2.02%	0.20%	2.15%	0.03
58-59 Grain mixtures, frozen plate meals, soups & Meat substitutes, mainly cereal protein	Aggregate	11.18%	3.52%	28.19%	0.91%	0.53
	HH	0.60%	0.28%	35.83%	4.62%	0.04
	HL	5.58%	0.54%	38.45%	0.35%	0.28
	LH	1.09%	11.22%	13.14%	3.76%	0.05
	LL	3.91%	6.14%	16.58%	0.33%	0.16

Appendix 3.5 (continued)

Composite food groups	Sub categories[a]	Calorie distribution within column[b]	Discretionary oil density[c]	Discretionary solid fat density[d]	Added sugars density[e]	Food expenditure ($)
61-67 (excluding 612+641+642+644) Fruits	Aggregate	2.27%	0.16%	0.06%	5.07%	0.23
	HH	0.00%	3.02%	16.54%	20.51%	0.00
	HL	0.01%	43.61%	13.33%	0.56%	0.00
	LH	0.21%	0.52%	0.00%	54.89%	0.01
	LL	2.05%	0.01%	0.00%	0.00%	0.21
612+641+642+644+92 Fruit juices & Nectars & Vinegar & Nonalcoholic beverages (excluding Coffee & Tea & Soft drinks, carbonated)	Aggregate	3.51%	0.04%	0.08%	41.41%	0.16
	HH	0.02%	0.42%	15.04%	57.78%	0.00
	HL	0.00%	0.81%	3.79%	40.58%	0.00
	LH	1.70%	0.08%	0.00%	82.79%	0.08
	LL	1.79%	0.00%	0.00%	2.11%	0.08
71 White potatoes and Puerto Rican starchy vegetables	Aggregate	4.70%	17.20%	24.79%	0.10%	0.12
	HH	0.00%	0.00%	57.91%	16.92%	0.00
	HL	2.59%	0.01%	43.40%	0.00%	0.06
	LH	0.19%	33.46%	2.93%	2.35%	0.01
	LL	1.91%	38.76%	1.85%	0.00%	0.05
72-76 Other vegetables	Aggregate	2.84%	8.87%	15.64%	6.06%	0.40
	HH	0.05%	0.19%	19.81%	37.92%	0.00
	HL	1.08%	4.33%	38.35%	0.24%	0.10
	LH	0.45%	31.61%	0.85%	32.90%	0.02
	LL	1.26%	4.89%	1.25%	0.21%	0.28
81 Fats	Aggregate	1.22%	34.46%	65.63%	0.26%	0.02
	HH	0.00%	0.00%	77.32%	14.26%	0.00
	HL	0.78%	0.00%	101.35%	0.00%	0.01
	LH	0.06%	83.25%	3.26%	4.33%	0.00
	LL	0.38%	98.25%	1.61%	0.00%	0.01
82-83 Oils & Salad dressings	Aggregate	2.06%	88.85%	2.39%	5.98%	0.04
	HH	0.07%	72.50%	7.68%	10.21%	0.00
	HL	0.79%	91.08%	4.93%	2.87%	0.01
	LH	0.58%	78.33%	0.36%	16.01%	0.02
	LL	0.62%	97.54%	0.48%	0.17%	0.01
91 Sugars and sweets	Aggregate	3.31%	11.23%	7.19%	60.30%	0.10
	HH	0.11%	8.30%	13.43%	72.39%	0.01
	HL	1.26%	25.41%	17.09%	36.40%	0.04
	LH	1.44%	0.40%	0.09%	87.21%	0.03
	LL	0.50%	7.54%	1.37%	39.73%	0.02
921-923 Coffee & Tea	Aggregate	1.01%	0.11%	6.57%	61.48%	0.12
	HH	0.01%	0.00%	25.42%	68.31%	0.00
	HL	0.21%	0.38%	30.39%	25.14%	0.01
	LH	0.57%	0.00%	0.00%	98.14%	0.02
	LL	0.22%	0.14%	0.00%	0.01%	0.08

Appendix 3.5 (continued)

Composite food groups	Sub categories[a]	Calorie distribution within column[b]	Discretionary oil density[c]	Discretionary solid fat density[d]	Added sugars density[e]	Food expenditure ($)
924 Soft drinks, carbonated	Aggregate	5.91%	0.00%	0.00%	95.00%	0.30
	LH	4.87%	0.00%	0.00%	98.03%	0.18
	LL	1.03%	0.00%	0.00%	80.68%	0.12
93 Alcoholic beverages	Aggregate	4.21%	0.05%	0.19%	3.45%	0.68
	HH	0.03%	0.29%	29.41%	14.88%	0.00
	LH	0.62%	0.31%	0.00%	22.61%	0.15
	LL	3.56%	0.00%	0.00%	0.00%	0.52
94 Water	Aggregate	0.00%	0.00%	0.00%	0.00%	0.00
	LL	0.00%	0.00%	0.00%	0.00%	0.00

Appendix 3.6 Cross-Price Elasticities of Composite Foods

Composite food groups	11	12	13	14	20-24	25	26	27+28+77	31-35	41-43	51+52+54	53+55	56-57	58-59	61-67 (excluding 612+641+642+644)	612+641+642+644+92	71	72-76	81	82-83	91	921-923	924	93	94
Milks and milk drinks (11)		-9.E-03	1.E-01	1.E-02	-1.E-02	6.E-02	-2.E-02		4.E-02	-1.E-02			2.E-02		-1.E-02	-1.E-02	6.E-03	8.E-03	2.E-02		-6.E-03	1.E-02		3.E-02	
Creams (12)			6.E-02	7.E-02															-6.E-03						
Milk desserts and sauces (13)				9.E-02															9.E-02						
Cheeses (14)					-8.E-02	5.E-01	7.E-02		6.E-02	2.E-02			8.E-03		6.E-03	-3.E-02	-4.E-03	-7.E-03	-4.E-02		-3.E-02	2.E-02		-1.E-02	
Meats (20-24)						-6.E-03	-7.E-02		-9.E-03	2.E-02	-7.E-02		-5.E-02		4.E-03	5.E-03	4.E-02	1.E-03	-2.E-03		-1.E-02	6.E-03		1.E-02	
Organ meats, sausages and lunchmeats (25)							-1.E-02		-1.E-02	3.E-02	-2.E-01		-8.E-02		1.E-02	-2.E-02	-3.E-03	3.E-02	-2.E-02		-5.E-03	-7.E-03		3.E-03	

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., D.E. Davis, J.T. LaFrance, and J.M.Perloff. 2010.

Appendix 3.6 (continued)

Composite food groups	11	12	13	14	20-24	25	26	27+28+77	31-35	41-43	51+52+54	53+55	56-57	58-59	61-67 (excluding 612+641+642+644)	612+641+642+644+92	71	72-76	81	82-83	91	921-923	924	93	94
Fish and shellfish (26)									-6.E-02	-3.E-02	-1.E-01		-5.E-02		-3.E-02	7.E-03	4.E-02	-2.E-02	-7.E-02		-3.E-02	2.E-03		-3.E-03	
Meat in mixtures (27, 28, 77)																									
Eggs (31-35)										-5.E-03	-2.E-01		-3.E-02		-2.E-02	3.E-02	-2.E-03	-1.E-03	-1.E-02		-2.E-02	8.E-03		9.E-03	
Dry beans, legumes and nuts (41-43)													3.E-02		6.E-03	-2.E-02	-6.E-02	-1.E-03	-1.E-02		2.E-02	-5.E-03		8.E-03	
Breads, Crackers & snacks from grain (51, 52, 54)													2.E-02		-1.E-02	-6.E-03			-3.E-02						
Cakes, pastries & other grain products (53, 55)																									
Pasta and cereals (56-57)															5.E-04	7.E-03	2.E-02	2.E-02	-4.E-02		1.E-01	-4.E-02		1.E-02	
Grain mixtures (58-59)																									
Fruits excluding juice (61-67, excluding 612+641+642+644)																-1.E-02	1.E-02	-8.E-03	2.E-02		-1.E-02	-3.E-03		3.E-04	

Appendix 3.6 (continued)

Composite food groups	11	12	13	14	20-24	25	26	27+28+77	31-35	41-43	51+52+54	53+55	56-57	58-59	61-67 (excluding 612+641+642+644)	612+641+642+644+92	71	72-76	81	82-83	91	921-923	924	93	94
Fruit juices (612, 641, 642, 644, 92)																	-2.E-02	9.E-04	-2.E-02		7.E-02	-2.E-02		1.E-02	
Potatoes (71)																		-3.E-03	-3.E-02		4.E-02	6.E-02		-2.E-02	
Other vegetables (72-76)																			-5.E-02		-3.E-02	1.E-03		4.E-03	
Fats (81)																				6.E-03	2.E-02	4.E-03		3.E-02	
Oils (82-83)																									
Sugars and sweets (91)																						-4.E-02		-3.E-03	
Coffee & Tea (921-923)																								3.E-03	
Soft drinks, carbonated (924)																									
Alcoholic beverages (93)																									
Water (94)																									

Appendix 3.7 Mashallian Elasticities of Composite Foods

Composite food groups	11	12	13	14	20-24	25	26	27+28+77	31-35	41-43	51+52+54	53+55	56-57	58-59	61-67 (excluding 612+641+642+644)	612+641+642+644+92	71	72-76	81	82-83	91	921-923	924	93	94
Milks and milk drinks (11)	-7.E-01	-9.E-03	1.E-01	1.E-02	-1.E-02	6.E-02	-2.E-02	-1.E-04	4.E-02	-1.E-02	-2.E-04	-1.E-04	2.E-02	-2.E-04	-1.E-02	-1.E-02	6.E-03	8.E-03	2.E-02	-2.E-05	-6.E-03	1.E-02	-2.E-04	3.E-02	-1.E-06
Creams (12)	-7.E-02	-4.E-01	6.E-02	7.E-02	5.E-04	1.E-04	6.E-05	5.E-04	1.E-04	4.E-04	6.E-04	4.E-04	2.E-04	6.E-04	2.E-04	3.E-04	2.E-04	8.E-04	-6.E-03	5.E-05	3.E-04	4.E-04	7.E-04	2.E-03	5.E-06
Milk desserts and sauces (13)	3.E-01	2.E-02	-7.E-01	9.E-02	7.E-04	2.E-04	9.E-05	7.E-04	2.E-04	5.E-04	8.E-04	5.E-04	3.E-04	9.E-04	4.E-04	4.E-04	3.E-04	1.E-03	9.E-02	8.E-05	4.E-04	5.E-04	1.E-03	3.E-03	7.E-06
Cheeses (14)	2.E-02	1.E-02	5.E-02	-1.E+00	-8.E-02	5.E-01	7.E-02	3.E-04	6.E-02	2.E-02	4.E-04	2.E-04	8.E-03	4.E-04	6.E-03	-3.E-02	-4.E-03	-7.E-03	-4.E-02	3.E-05	-3.E-02	2.E-02	5.E-04	-1.E-02	3.E-06
Meats (20-24)	-9.E-03	-4.E-04	-1.E-03	-2.E-02	-8.E-01	-7.E-03	-7.E-02	-3.E-03	-9.E-03	2.E-02	-7.E-02	-2.E-03	-5.E-02	-4.E-03	4.E-03	5.E-03	4.E-02	1.E-03	-1.E-03	-3.E-04	-1.E-02	6.E-03	-5.E-03	1.E-02	-3.E-05
Organ meats, sausages and lunchmeats (25)	8.E-02	-5.E-04	-1.E-03	4.E-01	-3.E-02	-8.E-01	-1.E-02	-3.E-03	-1.E-02	3.E-02	-2.E-01	-2.E-03	-8.E-02	-4.E-03	1.E-02	-2.E-02	-3.E-03	3.E-02	-2.E-02	-3.E-04	-5.E-03	-7.E-03	-5.E-03	3.E-03	-3.E-05
Fish and shellfish (26)	-2.E-02	-6.E-04	-2.E-03	5.E-02	-2.E-01	-1.E-02	-5.E-01	-4.E-03	-6.E-02	-3.E-02	-1.E-01	-3.E-03	-5.E-02	-5.E-03	-3.E-02	7.E-03	4.E-02	-2.E-02	-7.E-02	-4.E-04	-3.E-02	2.E-03	-6.E-03	-4.E-03	-3.E-05

Note: Elasticities are from 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., D.E. Davis, J.T. LaFrance, and J.M.Perloff. 2010.

Appendix 3.7 (continued)

Composite food groups	11	12	13	14	20-24	25	26	27+28+77	31-35	41-43	51+52+54	53+55	56-57	58-59	61-67 (excluding 612+641+642+644)	612+641+642+644+92	71	72-76	81	82-83	91	921-923	924	93	94
Meat in mixtures (27, 28, 77)	-2.E-03	-3.E-04	-1.E-03	-2.E-03	-2.E-03	-5.E-04	-3.E-04	-2.E+00	-6.E-04	-2.E-03	-3.E-03	-2.E-03	-1.E-03	-3.E-03	-1.E-03	-1.E-03	-1.E-03	-4.E-03	-1.E-04	-2.E-04	-1.E-03	-2.E-03	-3.E-03	-1.E-02	-2.E-05
Eggs (31-35)	1.E-01	-2.E-04	-6.E-04	1.E-01	-7.E-02	-2.E-02	-2.E-02	-1.E-03	-1.E-01	-5.E-03	-2.E-01	-1.E-03	-3.E-02	-2.E-03	-2.E-02	3.E-02	-2.E-03	-1.E-03	-1.E-02	-1.E-04	-2.E-02	8.E-03	-2.E-03	9.E-03	-1.E-05
Dry beans, legumes and nuts (41-43)	-2.E-02	2.E-04	6.E-04	2.E-02	1.E-01	4.E-02	-5.E-02	1.E-03	-2.E-03	-8.E-01	2.E-03	1.E-03	3.E-02	2.E-03	6.E-03	-2.E-02	-5.E-02	-1.E-03	-1.E-02	2.E-04	2.E-02	-5.E-03	2.E-03	8.E-03	1.E-05
Breads, Crackers & snacks from grain (51, 52, 54)	1.E-05	2.E-06	5.E-06	9.E-06	-2.E-01	-1.E-01	-1.E-01	1.E-05	-7.E-02	1.E-05	-8.E-01	1.E-05	2.E-02	2.E-05	-1.E-02	-6.E-03	6.E-06	2.E-05	-3.E-02	1.E-06	8.E-06	9.E-06	2.E-05	6.E-05	1.E-07
Cakes, pastries & other grain products (53, 55)	-5.E-04	-7.E-05	-2.E-04	-4.E-04	-4.E-04	-1.E-04	-6.E-05	-5.E-04	-1.E-04	-4.E-04	-6.E-04	-7.E-01	-2.E-04	-6.E-04	-2.E-04	-3.E-04	-2.E-04	-8.E-04	-2.E-05	-5.E-05	-3.E-04	-3.E-04	-7.E-04	-2.E-03	-4.E-06
Pasta and cereals (56-57)	4.E-02	-1.E-04	-4.E-04	9.E-03	-2.E-01	-1.E-01	-8.E-02	-9.E-04	-2.E-02	3.E-02	4.E-02	-7.E-04	-6.E-01	-1.E-03	5.E-04	7.E-03	2.E-02	2.E-02	-4.E-02	-1.E-04	1.E-01	-4.E-02	-1.E-03	1.E-02	-8.E-06
Grain mixtures (58-59)	-2.E-03	-3.E-04	-1.E-03	-2.E-03	-2.E-03	-5.E-04	-3.E-04	-2.E-03	-6.E-04	-2.E-03	-3.E-03	-2.E-03	-1.E-03	-2.E+00	-1.E-03	-1.E-03	-1.E-03	-4.E-03	-1.E-04	-2.E-04	-1.E-03	-2.E-03	-3.E-03	-1.E-02	-2.E-05
Fruits excluding juice (61-67, excluding 612+641+642+644)	-2.E-02	-4.E-04	-1.E-03	2.E-03	1.E-02	9.E-03	-2.E-02	-2.E-03	-8.E-03	9.E-04	-1.E-02	-2.E-03	-7.E-04	-3.E-03	-6.E-01	-1.E-02	1.E-02	-8.E-03	2.E-02	-3.E-04	-1.E-02	-3.E-03	-4.E-03	-1.E-04	-2.E-05

Appendix 3.7 (continued)

Composite food groups	11	12	13	14	20-24	25	26	27+28+77	31-35	41-43	51+52+54	53+55	56-57	58-59	61-67 (excluding 612+641+642+644)	612+641+642+644+92	71	72-76	81	82-83	91	921-923	924	93	94
Fruit juices (612, 641, 642, 644, 92)	-2.E-02	-2.E-04	-6.E-04	-2.E-02	2.E-02	-1.E-02	1.E-02	-2.E-03	1.E-02	-1.E-02	-1.E-02	-1.E-03	5.E-03	-2.E-03	-2.E-02	-9.E-01	-2.E-02	8.E-04	-2.E-02	-2.E-04	7.E-02	-2.E-02	-2.E-03	1.E-02	-1.E-05
Potatoes (71)	1.E-02	-2.E-04	-5.E-04	-6.E-03	2.E-01	-3.E-03	7.E-02	-1.E-03	-1.E-03	-6.E-02	-1.E-03	-8.E-04	2.E-02	-1.E-03	2.E-02	-2.E-02	-2.E-01	-3.E-03	-3.E-02	-1.E-04	4.E-02	6.E-02	-2.E-03	-2.E-02	-1.E-05
Other vegetables (72-76)	4.E-03	-1.E-04	-3.E-04	-3.E-03	8.E-03	1.E-02	-6.E-03	-8.E-04	1.E-05	-2.E-03	-9.E-04	-6.E-04	7.E-03	-9.E-04	-3.E-03	9.E-04	-7.E-04	-5.E-01	-5.E-02	-8.E-05	-3.E-02	1.E-03	-1.E-03	4.E-03	-7.E-06
Fats (81)	2.E-01	-9.E-03	3.E-01	-3.E-01	-3.E-02	-1.E-01	-7.E-01	-2.E-03	-6.E-02	-8.E-02	-4.E-01	-2.E-03	-3.E-01	-3.E-03	2.E-01	-1.E-01	-2.E-01	-1.E+00	-4.E-01	6.E-03	2.E-02	4.E-03	-4.E-03	3.E-02	-2.E-05
Oils (82-83)	-2.E-03	-2.E-04	-7.E-04	-1.E-03	-2.E-03	-4.E-04	-2.E-04	-2.E-03	-4.E-04	-1.E-03	-2.E-03	-1.E-03	-8.E-04	-2.E-03	-8.E-04	-9.E-04	-8.E-04	-3.E-03	3.E-03	-8.E-01	-1.E-03	-1.E-03	-3.E-03	-8.E-03	-2.E-05
Sugars and sweets (91)	-1.E-02	1.E-04	3.E-04	-4.E-02	-5.E-02	-5.E-03	-6.E-02	8.E-04	-1.E-02	2.E-02	9.E-04	6.E-04	1.E-01	1.E-03	-2.E-02	1.E-01	5.E-02	-1.E-01	4.E-03	8.E-05	-7.E-01	-4.E-02	1.E-03	2.E-03	7.E-06
Coffee & Tea (921-923)	3.E-02	2.E-04	4.E-04	3.E-02	4.E-02	-6.E-03	8.E-03	1.E-03	6.E-03	-5.E-03	1.E-03	8.E-04	-4.E-02	1.E-03	-2.E-03	-3.E-02	6.E-02	9.E-03	9.E-04	1.E-04	-4.E-02	-6.E-01	2.E-03	3.E-03	1.E-05

Appendix 3.7 (continued)

Composite food groups	11	12	13	14	20-24	25	26	27+28+77	31-35	41-43	51+52+54	53+55	56-57	58-59	61-67 (excluding 612+641+642+644)	612+641+642+644+92	71	72-76	81	82-83	91	921-923	924	93	94
Soft drinks, carbonated (924)	1.E-04	2.E-05	5.E-05	9.E-05	1.E-04	3.E-05	2.E-05	1.E-04	3.E-05	9.E-05	1.E-04	9.E-05	5.E-05	2.E-04	6.E-05	6.E-05	5.E-05	2.E-04	5.E-06	1.E-05	7.E-05	9.E-05	-1.E+00	6.E-04	1.E-06
Alcoholic beverages (93)	1.E-02	3.E-04	8.E-04	-2.E-03	2.E-02	5.E-03	4.E-03	2.E-03	2.E-03	2.E-03	2.E-03	1.E-03	3.E-03	2.E-03	5.E-03	6.E-03	-1.E-03	8.E-03	1.E-03	2.E-04	2.E-04	1.E-03	3.E-03	-9.E-01	2.E-05
Water (94)	8.E-04	1.E-04	3.E-04	6.E-04	7.E-04	2.E-04	1.E-04	8.E-04	2.E-04	6.E-04	9.E-04	6.E-04	4.E-04	1.E-03	4.E-04	4.E-04	3.E-04	1.E-03	3.E-05	9.E-05	5.E-04	6.E-04	1.E-03	4.E-03	-3.E-01

Appendix 3.8 Calorie and Nutrient Densities of Composite Food Groups before Tax

Composite food groups	Calorie/Nutrient Density			
	Calorie (calorie/unit)	Discretionary oil (g/unit)	Discretionary solid fat (g/unit)	Added sugar (g/unit)
Milks and milk drinks (11)	453.60	0.43	13.29	12.66
Creams (12)	558.38	4.03	42.50	20.21
Milk desserts and sauces (13)	626.99	0.55	29.87	52.22
Cheeses (14)	431.13	0.07	31.58	0.34
Meats (20-24)	295.77	1.69	6.90	0.10
Organ meats, sausages and lunchmeats (25)	355.25	0.08	17.08	0.48
Fish and shellfish (26)	143.56	1.52	2.58	0.20
Meat in mixtures (27, 28, 77)	377.55	3.78	8.64	2.30
Eggs (31-35)	629.78	3.97	25.74	0.66
Dry beans, legumes and nuts (41-43)	626.27	23.90	2.73	5.15
Breads, Crackers & snacks from grain (51, 52, 54)	1102.37	11.88	13.02	15.75
Cakes, pastries & other grain products (53, 55)	801.62	3.37	27.11	57.01
Pasta and cereals (56-57)	842.53	2.17	2.99	25.25
Grain mixtures (58-59)	461.44	1.81	14.45	1.05
Fruits excluding juice (61-67, excluding 612+641+642+644)	220.10	0.04	0.01	2.79
Fruit juices (612, 641, 642, 644, 92)	466.92	0.02	0.04	48.33
Potatoes (71)	855.79	16.35	23.57	0.22
Other vegetables (72-76)	153.86	1.52	2.67	2.33
Fats (81)	1386.80	53.09	101.12	0.89
Oils (82-83)	1226.56	121.08	3.26	18.35
Sugars and sweets (91)	708.08	8.84	5.66	106.74
Coffee & Tea (921-923)	187.36	0.02	1.37	28.80
Soft drinks, carbonated (924)	431.83	0.00	0.00	102.56
Alcoholic beverages (93)	136.28	0.01	0.03	1.18
Water (94)	38.88	0.00	0.00	0.00

Appendix 3.9 Calorie and Nutrient Densities of Composite Food Groups with Tax on Calories from Added Sugar by Cut-off Measure

Composite food groups	Calorie/Nutrient Density			
	Calorie	Discretionary oil (g/unit)	Discretionary solid fat (g/unit)	Added sugar (g/unit)
Milks and milk drinks (11)	453.26	0.42	13.35	12.22
Creams (12)	558.84	4.10	42.58	19.78
Milk desserts and sauces (13)	628.11	0.56	30.00	51.57
Cheeses (14)	431.16	0.07	31.59	0.33
Meats (20-24)	295.78	1.69	6.89	0.10
Organ meats, sausages and lunchmeats (25)	355.27	0.08	17.08	0.48
Fish and shellfish (26)	143.56	1.52	2.58	0.20
Meat in mixtures (27, 28, 77)	377.44	3.78	8.64	2.29
Eggs (31-35)	629.73	3.97	25.75	0.63
Dry beans, legumes and nuts (41-43)	627.55	24.00	2.73	5.09
Breads, Crackers & snacks from grain (51, 52, 54)	1095.59	11.85	12.99	15.29
Cakes, pastries & other grain products (53, 55)	797.58	3.40	26.83	56.32
Pasta and cereals (56-57)	848.36	2.19	3.02	24.99
Grain mixtures (58-59)	461.43	1.81	14.46	1.04
Fruits excluding juice (61-67, excluding 612+641+642+644)	218.41	0.04	0.01	2.19
Fruit juices (612, 641, 642, 644, 92)	468.42	0.02	0.04	45.18
Potatoes (71)	855.79	16.35	23.57	0.22
Other vegetables (72-76)	153.42	1.51	2.68	2.24
Fats (81)	1386.72	53.04	101.18	0.87
Oils (82-83)	1231.90	121.70	3.30	18.20
Sugars and sweets (91)	696.32	9.23	5.99	102.17
Coffee & Tea (921-923)	176.24	0.02	1.38	25.76
Soft drinks, carbonated (924)	394.04	0.00	0.00	93.01
Alcoholic beverages (93)	136.41	0.01	0.03	1.16
Water (94)	38.88	0.00	0.00	0.00

Appendix 3.10 Calorie and Nutrient Densities of Composite Food Groups with Tax on Calories from Added Sugar by Average Measure

Composite food groups	Calorie/Nutrient Density			
	Calorie	Discretionary oil (g/unit)	Discretionary solid fat (g/unit)	Added sugar (g/unit)
Milks and milk drinks (11)	453.29	0.42	13.35	12.23
Creams (12)	556.76	4.08	42.45	19.66
Milk desserts and sauces (13)	625.35	0.55	29.76	51.93
Cheeses (14)	431.16	0.07	31.59	0.33
Meats (20-24)	295.77	1.69	6.89	0.10
Organ meats, sausages and lunchmeats (25)	355.22	0.08	17.08	0.48
Fish and shellfish (26)	143.55	1.52	2.58	0.20
Meat in mixtures (27, 28, 77)	377.02	3.77	8.63	2.29
Eggs (31-35)	629.79	3.97	25.74	0.66
Dry beans, legumes and nuts (41-43)	627.57	23.99	2.73	5.10
Breads, Crackers & snacks from grain (51, 52, 54)	1100.10	11.91	13.01	15.42
Cakes, pastries & other grain products (53, 55)	797.85	3.39	26.96	56.14
Pasta and cereals (56-57)	846.75	2.18	3.02	25.02
Grain mixtures (58-59)	461.51	1.80	14.46	1.04
Fruits excluding juice (61-67, excluding 612+641+642+644)	218.43	0.04	0.01	2.20
Fruit juices (612, 641, 642, 644, 92)	468.35	0.02	0.04	45.07
Potatoes (71)	855.79	16.35	23.57	0.22
Other vegetables (72-76)	153.27	1.49	2.68	2.26
Fats (81)	1386.72	53.05	101.18	0.88
Oils (82-83)	1230.31	121.57	3.27	18.19
Sugars and sweets (91)	694.56	9.20	5.89	101.73
Coffee & Tea (921-923)	174.74	0.02	1.37	25.37
Soft drinks, carbonated (924)	412.40	0.00	0.00	97.41
Alcoholic beverages (93)	136.41	0.01	0.03	1.16
Water (94)	38.88	0.00	0.00	0.00

Appendix 3.11 Added Sugar Densities of Composite Food Groups and Sub Categories by Cut-off Measure

Composite food groups	Added sugar per unit of food (g/unit)				
	Composite	HH	HL	LH	LL
Milks and milk drinks (11)	12.66	48.04	0.00	47.79	0.00
Creams (12)	20.21	46.23	0.18	NA	0.00
Milk desserts and sauces (13)	52.22	55.56	1.20	55.24	0.00
Cheeses (14)	0.34	16.50	0.27	NA	0.00
Meats (20-24)	0.10	4.48	0.07	NA	0.01
Organ meats, sausages and lunchmeats (25)	0.48	NA	0.51	4.42	0.02
Fish and shellfish (26)	0.20	NA	0.29	12.20	0.05
Meat in mixtures (27, 28, 77)	2.30	11.06	2.28	9.10	1.24
Eggs (31-35)	0.66	7.42	0.59	219.77	0.00
Dry beans, legumes and nuts (41-43)	5.15	28.55	0.25	14.03	1.40
Breads, Crackers & snacks from grain (51, 52, 54)	15.75	46.41	5.37	81.82	6.00
Cakes, pastries & other grain products (53, 55)	57.01	68.82	2.15	36.53	0.00
Pasta and cereals (56-57)	25.25	53.68	0.05	35.23	0.99
Grain mixtures (58-59)	1.05	9.14	0.86	17.88	1.54
Fruits excluding juice (61-67, excluding 612+641+642+644)	2.79	14.03	4.41	48.34	0.00
Fruit juices (612, 641, 642, 644, 92)	48.33	57.34	NA	90.08	0.00
Potatoes (71)	0.22	29.36	0.01	NA	0.49
Other vegetables (72-76)	2.33	40.04	0.17	46.37	0.26
Fats (81)	0.89	55.73	0.00	NA	2.03
Oils (82-83)	18.35	15.33	3.35	31.48	8.74
Sugars and sweets (91)	106.74	57.70	2.77	175.90	0.05
Coffee & Tea (921-923)	28.80	47.42	0.00	161.43	0.00
Soft drinks, carbonated (924)	102.56	NA	NA	149.07	0.00
Alcoholic beverages (93)	1.18	4.97	NA	5.37	0.02
Water (94)	0.00	NA	NA	NA	0.00

Appendix 3.12 Added Sugar Densities of Composite Food Groups and Sub Categories by Average Measure

Composite food groups	Added sugar per unit of food (g/unit)				
	Composite	HH	HL	LH	LL
Milks and milk drinks (11)	12.66	45.98	0.00	48.25	0.02
Creams (12)	20.21	11.32	0.88	71.19	0.72
Milk desserts and sauces (13)	52.22	72.88	32.11	51.82	26.61
Cheeses (14)	0.34	3.08	0.00	3.50	0.00
Meats (20-24)	0.10	2.29	0.00	0.97	0.00
Organ meats, sausages and lunchmeats (25)	0.48	1.86	0.06	3.94	0.00
Fish and shellfish (26)	0.20	0.71	0.00	0.73	0.00
Meat in mixtures (27, 28, 77)	2.30	7.59	0.48	5.50	0.44
Eggs (31-35)	0.66	2.27	0.00	4.29	0.00
Dry beans, legumes and nuts (41-43)	5.15	17.22	0.14	15.80	1.29
Breads, Crackers & snacks from grain (51, 52, 54)	15.75	46.54	2.15	35.95	3.56
Cakes, pastries & other grain products (53, 55)	57.01	113.19	42.66	82.52	22.23
Pasta and cereals (56-57)	25.25	42.42	0.01	39.25	5.54
Grain mixtures (58-59)	1.05	3.47	0.39	4.47	0.45
Fruits excluding juice (61-67, excluding 612+641+642+644)	2.79	18.11	0.78	48.37	0.00
Fruit juices (612, 641, 642, 644, 92)	48.33	57.34	51.84	94.67	2.52
Potatoes (71)	0.22	29.36	0.01	4.85	0.00
Other vegetables (72-76)	2.33	47.41	0.14	39.26	0.05
Fats (81)	0.89	36.05	0.00	17.44	0.00
Oils (82-83)	18.35	18.57	14.80	31.45	0.56
Sugars and sweets (91)	106.74	46.16	58.49	230.12	54.34
Coffee & Tea (921-923)	28.80	168.24	21.28	161.43	0.00
Soft drinks, carbonated (924)	102.56	NA	NA	149.15	36.70
Alcoholic beverages (93)	1.18	6.26	NA	5.17	0.00
Water (94)	0.00	NA	NA	NA	0.00

Appendix 3.13 New Prices with Tax on Calories from Added Sugar by Cut-off Measure

Composite food groups	New Price with Tax					
	Without CES	With CES				
		Composite	HH	HL	LH	LL
Milks and milk drinks (11)	1.0122	1.0119	1.0461	1.0000	1.0459	1.0000
Creams (12)	1.0194	1.0192	1.0444	1.0002	NA	1.0000
Milk desserts and sauces (13)	1.0501	1.0498	1.0533	1.0012	1.0530	1.0000
Cheeses (14)	1.0003	1.0003	1.0158	1.0003	NA	1.0000
Meats (20-24)	1.0001	1.0001	1.0043	1.0001	NA	1.0000
Organ meats, sausages and lunchmeats (25)	1.0005	1.0005	NA	1.0005	1.0042	1.0000
Fish and shellfish (26)	1.0002	1.0002	NA	1.0003	1.0117	1.0000
Meat in mixtures (27, 28, 77)	1.0022	1.0022	1.0106	1.0022	1.0087	1.0012
Eggs (31-35)	1.0006	1.0006	1.0071	1.0006	1.2110	1.0000
Dry beans, legumes and nuts (41-43)	1.0049	1.0049	1.0274	1.0002	1.0135	1.0013
Breads, Crackers & snacks from grain (51, 52, 54)	1.0151	1.0149	1.0446	1.0052	1.0786	1.0058
Cakes, pastries & other grain products (53, 55)	1.0547	1.0544	1.0661	1.0021	1.0351	1.0000
Pasta and cereals (56-57)	1.0242	1.0241	1.0515	1.0001	1.0338	1.0009
Grain mixtures (58-59)	1.0010	1.0010	1.0088	1.0008	1.0172	1.0015
Fruits excluding juice (61-67, excluding 612+641+642+644)	1.0027	1.0024	1.0135	1.0042	1.0464	1.0000
Fruit juices (612, 641, 642, 644, 92)	1.0464	1.0449	1.0551	NA	1.0865	1.0000
Potatoes (71)	1.0002	1.0002	1.0282	1.0000	NA	1.0005
Other vegetables (72-76)	1.0022	1.0022	1.0384	1.0002	1.0445	1.0002
Fats (81)	1.0009	1.0008	1.0535	1.0000	NA	1.0019
Oils (82-83)	1.0176	1.0175	1.0147	1.0032	1.0302	1.0084
Sugars and sweets (91)	1.1025	1.1002	1.0554	1.0027	1.1689	1.0001
Coffee & Tea (921-923)	1.0276	1.0261	1.0455	1.0000	1.1550	1.0000
Soft drinks, carbonated (924)	1.0985	1.0938	NA	NA	1.1431	1.0000
Alcoholic beverages (93)	1.0011	1.0011	1.0048	NA	1.0052	1.0000
Water (94)	1.0000	1.0000	NA	NA	NA	1.0000

Appendix 3.14 New Prices with Tax on Calories from Added Sugar by Average Measure

Composite food groups	New Price with Tax					
	Without CES	With CES				
		Composite	HH	HL	LH	LL
Milks and milk drinks (11)	1.0122	1.0119	1.0441	1.0000	1.0463	1.0000
Creams (12)	1.0194	1.0191	1.0109	1.0008	1.0684	1.0007
Milk desserts and sauces (13)	1.0501	1.0500	1.0700	1.0308	1.0498	1.0255
Cheeses (14)	1.0003	1.0003	1.0030	1.0000	1.0034	1.0000
Meats (20-24)	1.0001	1.0001	1.0022	1.0000	1.0009	1.0000
Organ meats, sausages and lunchmeats (25)	1.0005	1.0005	1.0018	1.0001	1.0038	1.0000
Fish and shellfish (26)	1.0002	1.0002	1.0007	1.0000	1.0007	1.0000
Meat in mixtures (27, 28, 77)	1.0022	1.0022	1.0073	1.0005	1.0053	1.0004
Eggs (31-35)	1.0006	1.0006	1.0022	1.0000	1.0041	1.0000
Dry beans, legumes and nuts (41-43)	1.0049	1.0049	1.0165	1.0001	1.0152	1.0012
Breads, Crackers & snacks from grain (51, 52, 54)	1.0151	1.0150	1.0447	1.0021	1.0345	1.0034
Cakes, pastries & other grain products (53, 55)	1.0547	1.0543	1.1087	1.0410	1.0792	1.0213
Pasta and cereals (56-57)	1.0242	1.0241	1.0407	1.0000	1.0377	1.0053
Grain mixtures (58-59)	1.0010	1.0010	1.0033	1.0004	1.0043	1.0004
Fruits excluding juice (61-67, excluding 612+641+642+644)	1.0027	1.0024	1.0174	1.0007	1.0464	1.0000
Fruit juices (612, 641, 642, 644, 92)	1.0464	1.0448	1.0551	1.0498	1.0909	1.0024
Potatoes (71)	1.0002	1.0002	1.0282	1.0000	1.0047	1.0000
Other vegetables (72-76)	1.0022	1.0022	1.0455	1.0001	1.0377	1.0000
Fats (81)	1.0009	1.0009	1.0346	1.0000	1.0167	1.0000
Oils (82-83)	1.0176	1.0175	1.0178	1.0142	1.0302	1.0005
Sugars and sweets (91)	1.1025	1.0999	1.0443	1.0562	1.2210	1.0522
Coffee & Tea (921-923)	1.0276	1.0259	1.1615	1.0204	1.1550	1.0000
Soft drinks, carbonated (924)	1.0985	1.0959	NA	NA	1.1432	1.0352
Alcoholic beverages (93)	1.0011	1.0011	1.0060	NA	1.0050	1.0000
Water (94)	1.0000	1.0000	NA	NA	NA	1.0000

Appendix 3.15 Demand Change with Tax on Calories from Added Sugar by Average Measure

Composite food groups	Demand change rate					
	Without CES	With CES				
		Composite	HH	HL	LH	LL
Milks and milk drinks (11)	-0.45%	-0.43%	-3.62%	0.80%	-3.83%	0.80%
Creams (12)	-0.63%	-0.62%	-0.09%	0.56%	-3.63%	0.57%
Milk desserts and sauces (13)	-2.82%	-2.82%	-4.42%	-1.23%	-2.80%	-0.78%
Cheeses (14)	-0.06%	-0.06%	-0.51%	0.00%	-0.58%	0.00%
Meats (20-24)	-0.36%	-0.36%	-0.69%	-0.35%	-0.49%	-0.35%
Organ meats, sausages and lunchmeats (25)	-0.55%	-0.54%	-0.69%	-0.50%	-0.92%	-0.49%
Fish and shellfish (26)	-0.80%	-0.79%	-0.82%	-0.77%	-0.82%	-0.77%
Meat in mixtures (27, 28, 77)	-0.42%	-0.41%	-1.44%	-0.06%	-1.04%	-0.05%
Eggs (31-35)	-0.36%	-0.36%	-0.38%	-0.35%	-0.41%	-0.35%
Dry beans, legumes and nuts (41-43)	-0.17%	-0.17%	-1.48%	0.38%	-1.33%	0.26%
Breads, Crackers & snacks from grain (51, 52, 54)	-1.20%	-1.19%	-4.25%	0.20%	-3.22%	0.05%
Cakes, pastries & other grain products (53, 55)	-3.87%	-3.84%	-8.29%	-2.67%	-5.93%	-0.91%
Pasta and cereals (56-57)	-0.13%	-0.15%	-1.37%	1.68%	-1.15%	1.27%
Grain mixtures (58-59)	-0.23%	-0.23%	-0.73%	-0.10%	-0.94%	-0.11%
Fruits excluding juice (61-67, excluding 612+641+642+644)	-0.46%	-0.44%	-8.32%	0.47%	-21.58%	0.89%
Fruit juices (612, 641, 642, 644, 92)	-3.42%	-3.29%	-4.90%	-4.08%	-10.23%	3.87%
Potatoes (71)	0.48%	0.47%	-0.81%	0.48%	0.26%	0.48%
Other vegetables (72-76)	-0.42%	-0.41%	-3.99%	-0.24%	-3.36%	-0.23%
Fats (81)	0.04%	0.05%	-2.48%	0.12%	-1.16%	0.12%
Oils (82-83)	-1.39%	-1.39%	-1.42%	-1.05%	-2.65%	0.36%
Sugars and sweets (91)	-6.85%	-6.67%	-1.64%	-2.76%	-16.04%	-2.38%
Coffee & Tea (921-923)	-2.17%	-2.05%	-15.37%	-1.43%	-14.81%	0.95%
Soft drinks, carbonated (924)	-9.36%	-9.12%	NA	NA	-16.34%	1.61%
Alcoholic beverages (93)	0.00%	0.00%	-1.24%	NA	-0.97%	0.29%
Water (94)	0.03%	0.03%	NA	NA	NA	0.03%

Appendix 3.16 Elasticity of Substitution by Average Measure of Defining Sub Categories

Composite food groups	Elasticity of substitution Average measure
Milks and milk drinks (11)	1.04
Creams (12)	0.65
Milk desserts and sauces (13)	0.88
Cheeses (14)	1.71
Meats (20-24)	1.56
Organ meats, sausages and lunchmeats (25)	1.14
Fish and shellfish (26)	0.70
Meat in mixtures (27, 28, 77)	2.04
Eggs (31-35)	0.15
Dry beans, legumes and nuts (41-43)	1.15
Breads, Crackers & snacks from grain (51, 52, 54)	1.09
Cakes, pastries & other grain products (53, 55)	0.94
Pasta and cereals (56-57)	0.76
Grain mixtures (58-59)	2.15
Fruits excluding juice (61-67, excluding 612+641+642+644)	5.55
Fruit juices (612, 641, 642, 644, 92)	1.72
Potatoes (71)	0.46
Other vegetables (72-76)	0.86
Fats (81)	0.77
Oils (82-83)	1.04
Sugars and sweets (91)	1.01
Coffee & Tea (921-923)	1.18
Soft drinks, carbonated (924)	1.96
Alcoholic beverages (93)	2.55
Water (94)	[a]

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

Appendix 3.17 Percentage Change in Calories with Tax on Calories from Added Sugar by Average Measure

Composite food groups	Calories consumption		
	Initial consumption (calorie)	Consumption change (%)	
		Without CES	With CES by Average measure
Milks and milk drinks (11)	102.05	-0.45%	-0.50%
Creams (12)	14.83	-0.63%	-0.91%
Milk desserts and sauces (13)	46.39	-2.82%	-3.07%
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%	-0.55%
Fish and shellfish (26)	27.75	-0.80%	-0.79%
Meat in mixtures (27, 28, 77)	161.10	-0.42%	-0.55%
Eggs (31-35)	46.78	-0.36%	-0.36%
Dry beans, legumes and nuts (41-43)	73.62	-0.17%	0.04%
Breads, Crackers & snacks from grain (51, 52, 54)	262.36	-1.20%	-1.39%
Cakes, pastries & other grain products (53, 55)	140.55	-3.87%	-4.29%
Pasta and cereals (56-57)	97.14	-0.13%	0.35%
Grain mixtures (58-59)	244.54	-0.23%	-0.22%
Fruits excluding juice (61-67, excluding 612+641+642+644)	49.60	-0.46%	-1.19%
Fruit juices (612, 641, 642, 644, 92)	76.79	-3.42%	-2.99%
Potatoes (71)	102.70	0.48%	0.47%
Other vegetables (72-76)	62.15	-0.42%	-0.79%
Fats (81)	26.61	0.04%	0.05%
Oils (82-83)	44.98	-1.39%	-1.09%
Sugars and sweets (91)	72.44	-6.85%	-8.46%
Coffee & Tea (921-923)	22.02	-2.17%	-8.65%
Soft drinks, carbonated (924)	129.16	-9.36%	-13.21%
Alcoholic beverages (93)	92.05	0.00%	0.09%
Water (94)	0.06	0.03%	0.03%
Total	2187.06	-1.56%	-1.95%

Appendix 3.18 Percentage Change in Calories from Discretionary Solid Fat and Added Sugar with Tax on Calories from Added Sugar by Average Measure

Composite food groups	Discretionary solid fat consumption			Added sugar consumption		
	Initial consumption (g)	Consumption change rate		Initial consumption (g)	Consumption change rate	
		Without CES	Initial consumption (g)		Without CES	Without CES
Milks and milk drinks (11)	2.99	-0.45%	-0.02%	2.85	-0.45%	-3.81%
Creams (12)	1.13	-0.63%	-0.74%	0.54	-0.63%	-3.35%
Milk desserts and sauces (13)	2.21	-2.82%	-3.19%	3.86	-2.82%	-3.35%
Cheeses (14)	4.39	-0.06%	-0.05%	0.05	-0.06%	-0.57%
Meats (20-24)	4.03	-0.36%	-0.37%	0.06	-0.36%	-0.66%
Organ meats, sausages and lunchmeats (25)	2.81	-0.55%	-0.56%	0.08	-0.55%	-0.78%
Fish and shellfish (26)	0.50	-0.80%	-0.80%	0.04	-0.80%	-0.82%
Meat in mixtures (27, 28, 77)	3.69	-0.42%	-0.55%	0.98	-0.42%	-1.05%
Eggs (31-35)	1.91	-0.36%	-0.36%	0.05	-0.36%	-0.40%
Dry beans, legumes and nuts (41-43)	0.32	-0.17%	0.05%	0.61	-0.17%	-1.13%
Breads, Crackers & snacks from grain (51, 52, 54)	3.10	-1.20%	-1.26%	3.75	-1.20%	-3.27%
Cakes, pastries & other grain products (53, 55)	4.75	-3.87%	-4.38%	10.00	-3.87%	-5.32%
Pasta and cereals (56-57)	0.34	-0.13%	0.65%	2.91	-0.13%	-1.06%
Grain mixtures (58-59)	7.66	-0.23%	-0.18%	0.55	-0.23%	-0.61%
Fruits excluding juice (61-67, excluding 612+641+642+644)	0.00	-0.46%	-3.72%	0.63	-0.46%	-21.49%
Fruit juices (612, 641, 642, 644, 92)	0.01	-3.42%	-4.86%	7.95	-3.42%	-9.81%
Potatoes (71)	2.83	0.48%	0.47%	0.03	0.48%	0.23%
Other vegetables (72-76)	1.08	-0.42%	-0.34%	0.94	-0.42%	-3.33%
Fats (81)	1.94	0.04%	0.11%	0.02	0.04%	-1.38%
Oils (82-83)	0.12	-1.39%	-1.07%	0.67	-1.39%	-2.26%
Sugars and sweets (91)	0.58	-6.85%	-2.74%	10.92	-6.85%	-11.05%
Coffee & Tea (921-923)	0.16	-2.17%	-2.10%	3.38	-2.17%	-13.69%
Soft drinks, carbonated (924)	0.00	0.00%	0.00%	30.67	-9.36%	-13.68%
Alcoholic beverages (93)	0.02	0.00%	-1.24%	0.79	0.00%	-0.98%
Water (94)	0.00	0.00%	0.00%	0.00	0.00%	0.00%
Total	46.58	-0.90%	-0.88%	82.33	-5.53%	-9.47%

Appendix 3.19 Calorie Sources with Tax on Calories from Added Sugar (Calories)

	Total calories	Calories from discretionary solid fat and added sugar[a]	Calories from discretionary oil[b]	Calories from discretionary solid fat[b]	Calories from Added sugar[b]
Initial consumption	2187.06 (100%)	748.55 (34.23%)	178.64 (8.17%)	419.24 (19.17%)	329.31 (15.06%)
After tax (Without CES)	2152.98 (100%)	726.59 (33.75%)	176.87 (8.22%)	415.48 (19.30%)	311.11 (14.45%)
After tax (With CES by Cut-off measure)	2139.70 (100%)	709.39 (33.15%)	177.54 (8.30%)	415.59 (19.42%)	293.80 (13.73%)
After tax (With CES by Average measure)	2144.51 (100%)	713.65 (33.28%)	177.38 (8.27%)	415.54 (19.38%)	298.11 (13.90%)

Note: Numbers in parentheses are share of total calories in row.
a- This column is the summation of the last two columns in the table.
b- Each gram of discretionary oil and discretionary solid fat are assumed to provide 9 calories, each gram of added sugar is assumed to provide 4 calories.

Appendix 3.20 Welfare Loss per Unit of Nutrient Consumption Reduced with Tax on Calories from Added Sugar by Average Measure

	Without CES	With CES by Average measure
EV/Calorie reduction ($/calorie)	0.0023	0.0018
EV/Discretionary oil reduction ($/g)	0.3905	0.5360
EV/Discretionary solid fat reduction ($/g)	0.1842	0.1827
EV/Added sugar reduction ($/g)	0.0169	0.0096

Note: EV is equivalent variation.

CHAPTER 4. REDUCING CALORIES INTAKE: WHICH FOOD TAXES ARE MOST EFFECTIVE?

Abstract

We analyze a series of food taxes, including the popular soda tax, and their impact on calorie intake, welfare and tax revenue generation. For a given calorie reduction target, we provide ranking of these tax instruments based on the welfare loss induced and their ability to raise tax revenues (the social cost of public funds). Our investigation is based on the methodology developed in essay 2 which accounts for the ability of consumers to substitute away from fatty, sweet food to low-fat, low-sugar substitutes within the same food group and among food groups. Simulations show that choosing the right food group is much more import than whether the tax is applied on total calories or calories from some particular nutrients (sugar, fats) for the welfare evaluation. Taxes on fat goods such as butter and on calorie-dense bakery goods such as breads, muffins, rolls, and crackers minimize the welfare loss of the calorie reduction. Taxes on carbonated soft drinks are a good way to raise revenue although the associated welfare loss is not the lowest one. A tax applied on all calories in all foods is the instrument that has the lowest social cost of public fund.

Keywords: soda tax, food tax, fat, added sugar, food demand, low-fat, low-sugar substitute, health policy, nutrition, obesity.

Introduction

Soda tax proposals have received attention recently because of concerns about obesity and high-calorie diets. Sweetened beverages contribute significantly to total calorie intake. According to the 1999-2004 NHANES, half of the added sugar intake by the American consumers comes from soft drinks (Smith, Lin, and Lee, 2010). Some literature also suggests that soda consumption is directly associated with weight gain and obesity (Babey, Jones, Yu, and Goldstein, 2009). Soft drinks contain a large amount of so-called empty calories but little valuable nutrition. Although the production and consumption of caloric soft drinks has dropped somewhat in the last ten years (Center for Science in the Public Interest (CSPI), 2010), the consensus view among policymakers is that consumers are still consuming sweetened beverages excessively.

Many states have considered policies to curb the consumption of soft drink and other calorie-laden "disfavored" foods. As of 2009, over 30 states had some form of tax on sodas. The existing state soda taxes tend to be small, several are the same as the tax applied to food, and they have not reduced consumption substantially (Fletcher, Frisvold, and Tefft, 2010). Health advocates are urging larger tax rates. The federal government could levy a larger tax to discourage soda consumption and raise a substantial amount of money earmarked for health promotion. The Senate Finance Committee included a new sugary drinks tax in its list of possible health care reform funding mechanisms (CSPI, 2009). The debate on the application of soda tax is clearly not settled yet.

Is a soda tax the most efficient way to reduce calorie intake and thus the best way to fight the obesity epidemic? This essay investigates several tax instruments targeting foods, nutrients and calories and compares their efficiency in terms of the welfare loss induced by the taxes. We use the framework developed in the previous chapter of the dissertation to analyze an extensive set of tax instruments targeting a similar given calorie reduction and estimate and compare their welfare impact. We also investigate the revenue raising consequences of these instruments. The latter dimension is often discussed in the obesity debate as a way to fund education programs (Kuchler, Tegene, and Harris, 2004).

Tax instruments can vary on several dimensions. Taxes can target goods, nutrients and be expressed in specific or ad valorem form. One way to apply the tax is adding an ad valorem tax as a percentage of the prices of food products on selected sub categories within composite food groups, such as high-sugar “Soft drinks, carbonated” foods or high-fat “Fats”. Under the ad valorem tax scenarios, only the prices of the sub categories that are taxed change while the prices of other sub categories remain constant. The sub categories are targeted in the tax design because they rank high in the calorie per dollar of food and have relatively large cost shares within their composite food groups. Soda tax proposals mostly focus on “regular” soda and exempt diet soda from the taxed product list. Although diet soda has little or no nutritive value and it may contain caffeine and teeth-decaying acids, it has lower calorie content. An alternative instrument is to impose a tax proportional to the calorie content or nutrient content of selected foods or of all food products. Under these scenarios, the prices of most sub-categories are more or less affected unless they do not have any of the targeted nutrients at all. As example, for a calorie tax, the tax rate is set at the calorie unit level. The prices of foods with high total calories are targeted the most as the tax is imposed proportionally to the total calories contained in the foods. The prices of foods with high solid fat or added sugar content are targeted most if taxes are imposed proportional to these nutrients contained in the foods.

The methods and results presented in this essay extend the model and methods developed in essay 2. As done there, all foods are organized into 25 composite food groups. Sub-categories within food groups are distinguished by the discretionary solid fat and added sugar content of these goods to capture the possible substitution by consumers within the food groups as well as among composite food groups. The incorporation of sub-category food products provides the possibility to explore the tax effects of targeting only some particular foods, such as taxing the non-diet soda as proposed in some state bills. The data are used to calibrate a model corresponding to a two-stage budgeting process by combining a LinQuad demand system for the composite groups and a Constant Elasticity of Substitution aggregator for each group made of four types of substitutes (high/low fat and high/low added sugar).

We first establish the basis of equivalence to compare all tax scenarios. The application of the one-cent-per-ounce tax on high-sugar “Soft drinks” is set as the calorie reduction basis for the comparison. In each individual tax case, the total calorie consumption reduction from all 25 composite food groups is designed to be equal to the basis of the soda tax scenario (2.19% of total calories or 47.9 calories per day). The choice of the one-cent-per-ounce tax rate on the high-sugar carbonated soft drink is well within the range of soda tax rates proposed in different states.

We show that taxing fats (butter, margarine); bread, crackers, muffins, and salty snacks; soda; and candies are good choices for reducing the total calorie consumption and minimizing the consumer welfare loss. Taxing soda is not the most efficient one. Targeting particular food groups cause less welfare loss than targeting all the food groups. Once the targeted food group is determined, an ad valorem tax on the individual sub category and a proportional tax on calories or calories from specific nutrients cause similar magnitudes of welfare losses. So targeting the right food is much more important than the way the tax is imposed. Taxing soda is a good way to reduce added sugar consumption but it misses the opportunity to reduce discretionary solid fat consumption. We also show that a soda tax is a better way to raise revenue than taxing other food subcategories. Targeting all the calories from all the foods has the lowest social cost to raising each dollar of public fund.

The chapter is organized as follows. The background section provides information on state level taxes and recent tax proposals on soda and other calorie-intensive foods and beverages. The following section summarizes related existing studies. The model section provides a succinct presentation of the framework developed in essay 2, that is, the LinQuad incomplete food demand system extended by allowing the substitution within food groups for components delineated by low/high fat and sweetener levels. The data section summarizes the data and calibration steps that are detailed in essay 2. Next we present the results on the tax simulations and policy implications. The last section provides a summary and discussion.

Background

States vary considerably in the tax rates imposed on foods and selected "disfavored" foods. The MayaTech Corporation for the Bridging the Gap Program at the University of Illinois at Chicago compiled the sales tax rates on sodas and selected snack foods including candy, gum, chips/pretzels, ice cream, popsicle, and milkshakes and baked goods sold in grocery stores and vending machines for all the states (MayaTech Corporation for the Bridging the Gap Program at the University of Illinois at Chicago, 2009). The information on tax rates is summarized in Appendix 4.1. As of 2009, the existing sales taxes on sodas range from 0% tax rate in 18 states to 7% in Indiana, Mississippi, New Jersey, and Rhode Island. In 29 states, the tax on soda drinks was the same rate as applied to food products; in the other 21 states, the tax rate was greater than that on food products. Other state and city sugar sweetened beverages tax bills identified for the period 2010-March, 2011 are provided in Appendix 4.2 (Yale Rudd Center for Food Policy and Obesity, 2011).

Among the proposed tax bills, a relatively large number propose to impose an excise tax on sugar sweetened beverages. The rates of the tax range from 1¢ on each 19 oz container (West Virginia) to 2¢/oz (Mississippi and Philadelphia). The most popular tax rate is 1¢/oz as proposed in California, Connecticut, Washington D.C. New York, Rhode Island, Tennessee, Texas, and Vermont. Other states (California and Kansas) propose a tax on the sugar sweetened beverage at the rate of 1¢ per teaspoon of added sugar or sweeteners (equivalent to 0.8333¢/oz). In contrast, others (e.g., Mississippi) would tax the soft drink whether it contains sweeteners or not (i.e., is non-caloric). Some bills propose tax rates that depend on container volume. In Hawaii, the proposed tax is 10¢ per container if the container is less than or equal to 12 oz and 25¢ per container if container is greater than 12 oz. Rhode Island would tax 5¢ for bottled soft drinks up to 20 oz and 10¢ for bottled soft drinks larger than 20 oz. In contrast, Mississippi proposes to set the same tax regardless of the size or capacity of the bottle (1¢ per bottle). In addition to sales through retail food outlets, some states would direct the tax to other outlets: in New York, a tax is proposed on beverages sold through vending machine; in Texas, the tax on artificial sweetened and sugar sweetened beverages would not apply to beverages sold in a restaurant, lunch counter, cafeteria or hotel, but would apply to other retail outlets. Some states would apply a tax on syrup, concentrate, and powders or other base products used to produce soft drinks in their bills (e.g., New York and

West Virginia) (Yale Rudd Center for Food Policy and Obesity, 2011). Hence, the proposals vary widely in the definition of taxed good.

Some states that currently exempt food from a sales tax, or assess food at a relative low rate, would eliminate the state sales tax exemption on soft drinks. The extension of sales tax to soft drinks is equivalent to a sales tax rates of 2.9% (equivalent to 0.0556¢/oz[5]) in Colorado, 6.25% (equivalent to 0.1198¢/oz) in Massachusetts, and 6% (equivalent to 0.1150¢/oz) in Vermont. Several other states and cities are actively considering imposing a tax on sugar-sweetened beverages and excluding sodas from the favored (lower) food sales tax rate (e.g., Arizona, Baltimore, New Hampshire, New Mexico, Oregon, Virginia). Although there is some variation in the levels and method of the tax imposed, as this short review indicates, most of the proposed taxes are in the range of 0.05 to 2.08 cents per ounce. In addition to health objectives, the taxes are seen as a source of revenue to help the state and city fund health education budgets (Yale Rudd Center for Food Policy and Obesity, 2011).

A few recent studies have examined the relative effects of imposing the soda and snack taxes. A study by Smith, Lin and Lee (2010) incorporated eight beverages distinguished by calorie content (caloric sweetened beverages, diet drinks, whole milk, low-fat milk, skim milk, 100% fruit and vegetable juice, coffee/tea, and bottled water) to examine the effects of taxing sweetened drinks. An AIDS subsystem of the beverages was estimated using the 2003-06 NHANES and 1998-2007 Nielsen Homescan data. They showed that a hypothetical ad valorem 20% increase in the price of caloric sweetened beverages (caloric sweetened sodas, fruit drinks, sports and energy drinks, and powdered mixes) can reduce the

[5] Each 12 oz of soft drink contains 40 grams (10 teaspoons) of added sugar. The price of Carbonated Soft Drinks is 1.9169 ¢/oz based on our calculations using 2003-04 NHANES data.

daily calorie intake from beverages by 37 calories for adults – a reduction that would lead adults lose 3.8 pounds in weight per year. An earlier paper of the same authors (Lin, Smith and Lee, 2010) revealed that the 20% effective tax rate on the beverages (or about 0.44-0.47 cents per ounce) would be regressive based on their estimation of two demand systems, one for high and the other for low income households.

Several other studies examine the tax effect on other high fat or disfavored foods and the results suggest some general conclusions. Jacobson and Brownell (2000) argue that tax rates should be established on the whole group of food instead of based on the saturated fat level. They argue that although food categories are not consistent with nutrition values, it is more practical to impose tax on the well-recognized foods for the legislative agencies. They proposed to tax 1 cent per 12-ounce on soft drinks and 1 cent per pound on candy, chips, other snack foods, fats and oils. Kuchler, Tegene, and Harris (2004) examined 0.4%, 1%, 10%, and 30% ad valorem taxes on snack foods. The 0.4% tax is nearly equivalent to the proposed 1 cent per pound tax by Jacobson and Brownell (2000). They assumed that other foods would not substitute for salty snacks and find that the annual reduction in calories consumed ranges from 28 calories to 139 calories per capita depending on the values of price elasticity. Chouinard et al. (2007) analyzed how a 10% tax on fat content in dairy products takes effect. They found that this fat tax would only reduce the fat consumption by less than 1% but it is a good way to raise revenue.

Smed, Jensen, and Denver (2007) investigated potential tax and subsidy scenarios aimed at a single nutrient and targeting several nutrients. They include a tax on foods with large content of saturated fat (fatty meat, butter, and cheese); a value-added tax reduction on fresh fruit and vegetable, potatoes, and grain-based products; a tax directly applied to the content of saturated fats in foods; taxing sugar; a subsidy on fibers; and the combination of the above scenarios. Different tax scenarios are comparable since their welfare losses are scaled equally. Their study is based on the Danish food consumption data of 23 food categories from 1997 to 2000. They find that taxing a single nutrient or food may cause unwanted effects on the demand of other nutrients. Taxes on a combination of the nutrients can avoid the undesired effects when targeting a single nutrient and are more appropriate tax design. We examine these aspects through variations on the taxed foods and food components in this essay too.

Modeling Approach

We follow the methodology developed in essay 2 which is based a calibrated LinQuad food demand system as in Beghin, Bureau, and Drogué (2004). The demand system is augmented to account for the explicit substitution possibilities among close substitutes with low and high contents of sugar and fat. The within food group substitution is incorporated using the Armington constant elasticity of substitution (CES) function form for each composite group. In addition the demand system incorporates nutrient information linking food intakes to nutrient intake via a matrix of fixed conversion factors.

To summarize the methodology of the previous essay, let $D = [D_1,...,D_n]'$ be the vector of demands for the target sweet and fatty composite foods, $P = [P_1,...P_n]'$ be the corresponding price vector. The LinQuad Marshallian demand equations are

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

where $\chi, \varepsilon,$ and V are preference parameters. Properties of this demand system are described in essay 2.

Each food group (any element of vector *D*) is further disaggregated 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 its added sugar and discretionary solid fat content. The elasticity of substitution between any two sub-categories within each composite food group is constant and remains the same across any pair of sub-categories within a given composite group. The CES composite form for each food group *i* is

$$D_i = (\alpha_{iHH} D_{iHH}^{-\rho_i} + \alpha_{iHL} D_{iHL}^{-\rho_i} + \alpha_{iLH} D_{iLH}^{-\rho_i} + \alpha_{iLL} D_{iLL}^{-\rho_i})^{-\frac{1}{\rho_i}}, \tag{2}$$

where $\alpha_{iHH}, \alpha_{iHL}, \alpha_{iLH}, \alpha_{iLL}$ represent consumers' preferences among the sub-categories within the group. The elasticity of substitution within each composite food group σ_i satisfies $\sigma_i = 1/(1+\rho_i)$. The price of each composite food group is function of the price of the sub-categories within that composite food group as follows

$$P_i = (\alpha_{iHH}^{\sigma_i} P_{iHH}^{1-\sigma_i} + \alpha_{iHL}^{\sigma_i} P_{iHL}^{1-\sigma_i} + \alpha_{iLH}^{\sigma_i} P_{iLH}^{1-\sigma_i} + \alpha_{iLL}^{\sigma_i} P_{iLL}^{1-\sigma_i})^{\frac{1}{1-\sigma_i}}. \tag{3}$$

The demand for each sub-category *K* within a particular composite food group *i* is

$$D_{iK} = \alpha_{iK}^{\sigma_i} D_i (\frac{P_{iK}}{P_i})^{-\sigma_i}, \; K = HH, HL, LH, LL. \tag{4}$$

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

$$s_{iK} = \frac{D_{iK} P_{iK}}{D_i P_i} = \frac{\alpha_{iK}^{\sigma_i} D_i (\frac{P_{iK}}{P_i})^{-\sigma_i} P_{iK}}{D_i P_i} = \alpha_{iK}^{\sigma_i} (\frac{P_{iK}}{P_i})^{-\sigma_i + 1}, \; K = HH, HL, LH, LL. \tag{5}$$

The CES structure leads to

$$\eta_{iK} = -\sigma_i(1 - s_{iK}),\ K = HH, HL, LH, LL. \tag{6}$$

or eventually, for calibration purposes to $\sigma_i = \eta_{iK} / (s_{iK} - 1)$. Parameter η is the corresponding own-price elasticity of demand for that composite good.

A conversion matrix converts the food consumption implied by D to the nutrients in food component consumption

$$D'C = N\ , \tag{7}$$

where $N = [N^F, N^S, N^{cal}]$ is the vector of aggregate nutrients and calories contained in the final products *D*. The superscripts *F, S, cal* represent discretionary solid fat, added sugar, and calories contained. Matrix $C = [C^F, C^S, C^{cal}]$ is the conversion matrix between food and nutrients and calories with similar superscripts.

In the policy analysis, the vector of prices of targeted food groups changes from P^0 to P^1, and the welfare effect from this change in price is measured by the equivalent variation, EV, with

$$EV = (I - \varepsilon' P^1 - \frac{1}{2} P^1{}' V P^1)\exp(\chi P^0 - \chi P^1) - (I - \varepsilon' P^0 - \frac{1}{2} P^0{}' V P^0)\ , \tag{8}$$

If the food tax is imposed on the added sugar at the tax rate t^S, then $P^1 = P^0 + C^S t^S$. Then P^1 can be substituted into the EV equation to obtain the corresponding welfare change. Essay 2 provides further details on the model building, data and calibration procedures.

Data

Food groups and components

Several national level data sources are used in developing the underlying parameters used in the estimates and calculations. Detailed data descriptions, sources and statistics are provided in essay 2. This section provides a summary.

The National Health and Nutrition Examination Survey (NHANES) 2003-04 (Centers for Disease Control and Protection, 2009), a nationally representative survey of reported food intakes (24-hour recall) data, is used to develop the estimates of consumption of food and beverage intakes for individuals age 20 years and older. In addition to the food intake amounts, detailed information on nutrients and other food components in the foods are available. The survey data and accompanying files provide the information on food intakes (by foods and food groups) and associated calories, fat, added sugar and sweeteners. The My Pyramid Equivalence Database (MPED) 2.0 (Bowman, Friday, and Moshfegh, 2008) is used to convert the amounts of food intake into the respective amount of "discretionary" solid fat and added sugar. The term discretionary is applied to mean an amount that is added in processing (sugar or fat) or available through selection of foods in levels (of solid fat) greater than the amounts in comparable, leaner varieties (such as fatter meat cuts or choice of full-fat milk over skim). The foods were grouped into 25 food groups, and within each food group, into categories based on the relative amount of discretionary solid fat and of added sugar (HH, HL, LH and LL). The detailed composite food group description is shown in Appendix 4.3. Appendix 4.4 provides the calories, nutrients, and expenditures of food and their sub categories. The food groups and initial consumption of calories, discretionary solid fat and added sugar are listed in Table 4.1.

Food expenditure (by day) is estimated by using the amounts of reported food intake and prices from the USDA Center for Nutrition and Policy Promotion (CNPP) Food Price database (USDA/CNPP, 2009). The initial distribution of food expenditure cost shares within composite food groups are displayed in Table 4.2.

Table 4.3 provides the calories per dollar of food sub categories can bring. The calories per dollar of food product measure how expensive the calorie sources are. Although in some food groups, the calorie-dense options (HH) offer the most calories per dollar spent (e.g., "Milks and milk drinks" and "Cakes, cookies, pies and pastries"), this is not always the case.

Demand parameters

The parameter values used in the LinQuad demand system are recovered from various sources. The measures of the income elasticity η_{iI} , own-price elasticity η_{ii}^{M} , cross-price elasticity η_{ij}^{M} , and the elasticity of substitution, σ_i were from available estimates and obtained from the USDA/ERS Commodity and Food Elasticity dataset (USDA/ERS 2006) as well as other recent studies as described in essay 2.

Income, *I*, is developed from data reported in the NHANES 2003-04 survey data file. Food prices come from the CNPP Food Prices Database (and assume foods observed for food items in the "as consumed" form from "at home" sources). These prices are used to estimate food expenditures. 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 leads to results that are independent of this normalization.

Implementation of Policy Reforms and Results

Based on the calibrated model of essay 2, we implement several tax scenarios with ad-valorem tax on selected food sub-categories or with taxes proportional to calorie or nutrient content of selected food groups and finally a similar tax on all food groups.

One-cent-per-ounce tax on high-sugar carbonated soft drinks

We first look at the impact of levying an ad-valorem tax on high-sugar carbonated soft drinks. Based on our 2003-04 data, a representative consumer expends 5.25 dollars 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 average unit price of calories consumed. This is approximate of course but a transparent way to derive the calorie price. Our classification of sub-categories leaves 6 sub-categories vacant. There are big variations in the daily expenditures on the remaining 94 sub-categories. Each sub-category within the composite food groups has its own calorie and nutrient densities.

Among all the composite food groups, “Soft drinks, carbonated” (924) contributes the most (37.25%) to the total added sugar consumption. The current soda tax proposals focus on the non-diet soda which could be easily matched to the LH “Soft drinks, carbonated” (924). The simulated 1-cent-per-ounce soda tax can be converted to a 35.71% ad-valorem tax on the LH “Soft drinks, carbonated” (924) since a regular 12-ounce can of soda contains 140 calories and our approximated calorie price is 0.24 cents per calorie. The calorie price of the LH “Soft drinks, carbonated” (924) is a little bit lower (0.16 cents per calorie or equivalent to 1.92 ¢/oz). So the converted ad-valorem tax is 52% on the LH “Soft drinks, carbonated” (924). The ad-valorem tax rate is displayed in Table 4.4.

This 52% ad-valorem tax on the LH “Soft drinks, carbonated” (924) decreases the consumption of composite food group “Soft drinks, carbonated” (924) by 24%. Meanwhile, it leads consumers to switch between the LH and LL carbonated soft drinks since all the beverages in “Soft drinks, carbonated” (924) are classified as low fat. As a consequence, the demand for the LH carbonated soft drink decreases by 48% while the demand of the LL carbonated soft drink increases by 18%. The prices of all the other food groups remain constant as their individual sub-group prices do not change. The between-group substitution causes negligible changes (near 0%) in the demands of these composite food groups as well as their sub-categories.

The initial calorie consumption from the “Soft drinks, carbonated” (924) contributed nearly 6% to the total calorie consumption from all the foods and beverages. The simulated soda tax reform causes a roughly 2% decrease in the total calorie consumption from all 25 food groups, or 48 calories per capita per day. This 48-calorie decrease comes mostly (99%) from the “Soft drinks, carbonated” (924), whose calories decrease by 47 calories per capita per day. All the other food groups have negligible calorie changes.

Since “Soft drinks, carbonated” (924) is dense in added sugar and has no discretionary solid fat, the total discretionary solid fat from all the food groups only have negligible changes (near 0% decrease). If we assume that each gram of added sugar provide 4 calories, the total added sugar consumption decreases 14%, which is equivalent to nearly 12 grams of sugar, or 47 calories per capita per day as shown in Table 4.5. Again, most of the decrease in the total added sugar consumption comes from the reduction in “Soft drinks, carbonated” (924) whose added sugar decreases 38%. This is equivalent to nearly 12 grams (47 calories) per capita, and takes almost all of the total added sugar consumption reduction. Other composite food groups exhibit small increases or decreases in the added sugar consumption, but their total effect is negligible. Aggregated over all the foods and beverages, the initial contributions of discretionary solid fat and added sugar to the total calorie consumption are 19% and 15%. With the ad-valorem soda tax reform, their contributions become nearly 20%, and 13%. So consumers switch their calories source from added sugar to discretionary solid fat in some degree.

The welfare loss for the soft drinks (LH) measured by EV is $24.24 per capita per year (Table 4.4) and it represents 0.13% of the annual average income. The annual revenue generated from this soda tax brings 5.34 billion dollars nationally (in 2003-04 dollars). This is comparable to the $7.76 billion dollars revenue from taxing regular soft drinks estimated by Yale Rudd Center for Food Policy and Obesity for 2010 (Yale Rudd Center for Food Policy and Obesity, 2010). The tax revenue measures the welfare transfer from consumers to the government achieved by the tax policy; the EV measures how much is the consumer loss from the tax policy. The net deadweight loss of the tax is the revenue generated net of the absolute value of EV. It measures the excess burden of the tax and the net welfare effect to society caused by the tax. The ratio of deadweight loss to revenue is interpreted as the social cost of raising public fund. The social cost of each dollar of public fund raised by the one-cent-per-ounce soda tax is $0.40 (Table 4.4). The tax "calorie abatement efficiency" is measured by the EV per calorie reduction and it shows that for each unit calorie reduction, the EV is reduced by14 cents as shown in Table 4.6.

Ad-valorem taxes on other selected food sub-categories

Besides the ad-valorem tax on LH "Soft drinks, carbonated" (924), it is also interesting to investigate the impact of ad-valorem taxes imposed on other food sub-categories. To make different tax schemes comparable, all the scenarios are set to reach the same policy target of reducing the total calorie consumption by roughly 2% or 48 calories per capita per day. We simulate the impact of ad-valorem taxes on each individual food sub-category once at the time and find that among the 94 available food sub-categories, 43 can reach the policy target with a tax rate lower than a arbitrarily chosen high rate (5000%); 17 cannot reach the policy target with tax rates lower than 5000%; while the remaining 34 can never reach the policy target no matter how large the tax rates are because consumption fall to zero before the calorie reduction can be achieved. The arbitrary 5000% ad-valorem tax bound is set to avoid computationally feasible but extremely high tax rates impossible to implement in reality. The ad-valorem tax rates and the associated welfare losses for taxing individual sub-category are provided in Appendix 4.5 while the 43 feasible tax schemes are shown in Appendix 4.6.

The 43 feasible tax schemes designed to reach the policy target are sorted by their associated welfare losses to compare the calorie abatement efficiencies. The annual per capita EV ranges from rounded amounts of \$8 to \$107, with the median value of \$35. Ad-valorem taxes on HL or LL “Fats” (81) have the smallest EV. They include taxes on butters, margarines, animal fat or drippings, and margarine-like spreads etc. The calories contained in HL “Fats” (81) come majorly from discretionary solid fat while the calories contained in LL “Fats” (81) come majorly from discretionary liquid oil. Taxes on LH, LL, or HL “Yeast breads, rolls, quick breads, crackers” (51+52+54) also have small EV. These subgroups include various breads, rolls, bread sticks, muffins, crackers, popcorns, bagels, salty snacks and pretzels etc. The LL subgroup of “Grain mixtures” (58-59) is another sub-category that has smaller EV than LH “Soft drinks, carbonated” (924). Taxes on LL “Dry beans, peas, other legumes, nuts, and seeds” (41-43), LH and HL “Sugars and sweets” (91), HL “Grain mixtures” (58-59), and HH “Yeast breads, rolls, quick breads, crackers” (51+52+54) also have their corresponding annual per capita EV less than \$30.

The major implication from this simulation exercise is that a tax on soft drinks is not the most efficient tax scheme to abate calories in terms of the welfare cost per abated calorie. HL and LL "Fats" (81) or LH, LL, or HL "Yeast breads, rolls, quick breads, crackers" (51+52+54), as well as LL "Grain mixtures" (58-59) are better choices than the soda tax if EV of a given calorie reduction is the metric used to select the "best" tax scheme. Taxing the HL and LL "Fats" (81) sub groups has a third of the welfare loss of taxing the LH "Soft drinks, carbonated" (924) subgroup. This is a major difference in efficiency in calorie abatement. Finally, we note that numerous combinations of food sub-categories could also be the basis of the tax policy and their EV losses will be smaller than targeting only one sub-category. Since there are 94 food sub-categories in our demand system, too many potential combinations exist and we do not investigate these in details.

A few results are surprising. When the ad-valorem tax applies to the subgroups of "Yeast breads, rolls, quick breads, and crackers" (51+52+54), the ranking of the absolute values of their EV is LH, LL, HL, and HH in order of increasing EV. The HH sub-category ranks last while the LL sub-category ranks ahead of HL. The policy mechanism is that when only one sub-category within a composite food group is taxed, consumers decrease the consumption of this particular sub-category and switch to the other three sub-categories within the same composite food group. Consumers also substitute from the targeted composite group to other composite food groups, but these effects are smaller in magnitude than the within group substitution effects.

The total effect of a food tax on welfare is determined by both the calories density per dollar of food product and the initial cost shares of each sub-category within its group. When the ad-valorem tax is imposed on the sub-category with high calories per dollar of food, consumers substitute to sub-categories with low calorie density per dollar of food. The consumer welfare loss is relatively small compared to the scenario targeting a sub-category with low calorie density per dollar of food. In the latter case, consumers substitute to sub-categories with high calories per dollar of food. So within the same composite food group, the ranking of the welfare losses is expected to be consistent with the ordering of the calorie density per dollar of food. The relative size of the sub-categories within the same composite food group allows the potential substitution within group. The initial within group food expenditures are sometimes relatively large for sub-categories with low calories per dollar of food and limit the extent to which consumers can substitute to sub-categories with high calories per dollar of food. The cost shares of food with high calorie density per dollar are not high enough to accommodate the substitution so the welfare loss under this case is also relatively small.

The most efficient ad-valorem tax rates on single sub-categories needed to reach the 48- calorie reduction are shown in Table 4.4. There are big within group variations of the tax rates for “Fats” (81) and “Yeast breads, rolls, quick breads, crackers” (51+52+54). The price of each sub-category is weighted by its within-group cost share to obtain the new price of the composite food group; the new prices of the same composite food group with various tax rates on individual sub-categories turn out to be quite close and are not particularly insightful. By design, the calorie reductions are the same across all the ad-valorem tax scenarios. However, the sources of the calorie reductions vary as displayed in Table 4.5. All the scenarios except the ad-valorem tax on “Fats” (81) exhibit decreases in both discretionary solid fat and added sugar consumption. Almost all the calorie reduction comes from added sugar reduction for the soft drink tax scenario. Taxing “Sugars and sweets” (91) also has a large share of total calorie reduction (over 70%) from added sugar reduction and a small share from discretionary solid fat. But for other food groups, the total calorie reduction is composed of calories from all nutrients including proteins.

From the revenue perspective, the ad-valorem soda tax generates the highest revenue ($5.34 billion) among the top ten tax schemes taxing food sub-category candidates with low EVs. The other schemes have the same order of magnitude of revenues except LL "Fats" (81), LH or LL "Sugars and sweets" (91) whose revenues are one order of magnitude smaller (less than $1 billion). The latter result is caused by the high ad-valorem tax rates in these two scenarios. They are over 600% and reduce their after tax consumer demand to very small values.

The social costs of public funds raised by these ad-valorem taxes on individual food sub-categories vary dramatically. From $0.30 for the LL "Yeast breads, rolls, quick breads, crackers" (51+52+54) to $13 for LH "Sugars and sweets" (91). Many taxes exhibit a social cost of less than one dollar such as the taxes on LH, or LL, or HL "Yeast breads, rolls, quick breads, crackers" (51+52+54), or LL "Grain mixtures" (58-59), or LH "Soft drinks, carbonated" (924). Our analysis suggests that although a soda tax is not the most efficient way to reduce calorie intake, in terms of consumer welfare evaluation, it is a good way to decrease the bad nutrient consumption without sacrificing better nutrients and it is an effective way to raise public fund with a relatively low social cost.

A tax proportional to the calorie or nutrients contained in selected food groups

The previous analysis of the taxes on individual sub-category revealed that "Fat" (81), "Yeast breads, rolls, quick breads, crackers" (51+52+54), "Soft drinks, carbonated" (924), and "Sugars and sweets" (91) are the food groups to be targeted if the policymaker wants to minimize consumer welfare loss for a given calorie reduction. Once the food groups to be targeted are determined, it is also worth considering the way that the tax could be applied. The tax could be applied in an ad-valorem form on sub-categories as we discussed above. The tax could also be applied proportionally on the calorie or nutrient contents in these foods. The sub-categories within the composite food groups are themselves composed of several food items. Each food item has its own calorie and nutrient density. They are classified into the same sub-category because of their similarities in calorie and nutrient contents. For simplicity, we assume that all the food items belonging to a sub-category have identical calorie and nutrient densities.

All the scenarios are designed to reach the same policy target of reducing total calorie consumption by roughly 2% or 48 per capita per day. We consider a tax imposed proportionally to the total calories contained in the selected food group, or a tax proportional to the calories from specific sources (discretionary solid fat, added sugar, or discretionary solid fat and added sugar) in the selected food group. The taxes are set under the assumption that each gram of discretionary solid fat provides 9 calories and each gram of added sugar provides 4 calories. So the more calories or nutrients contained in the sub-category, the more tax is imposed.

Table 4.7 show the tax rates per calorie required to reach the policy target under all 16 sub-cases when the tax is imposed on selected food groups. When the tax is imposed proportionally to all calories rather than to calories from specific nutrients, the tax rate is smaller as expected since the abatement of calories is larger. One exception of course is the soda tax for which tax rates are close no matter the tax rate is on all calories or calories from sweeteners.

The annual per capita consumer welfare losses have ranges around \$8, \$14 to \$18, \$28, and \$25 for taxes on "Fats" (81), "Yeast breads, rolls, quick breads, crackers" (51+52+54), "Soft drinks, carbonated" (924), and "Sugars and sweets" (91). There is little variation in the EV for the different forms of taxation (levied on all calories or subset of calories of the food group). Taxes on "Fats" (81) exhibit the smallest EV, followed by "Yeast breads, rolls, quick breads, crackers" (51+52+54). The EV per abated calorie are displayed in Table 4.6.

The welfare implications of the calorie based taxes and the ad-valorem tax on the same food group are quite close too. It is worth noticing that ad-valorem tax on LH "Soft drinks, carbonated" (924) has a lower EV than the proportional tax on the whole group. This is because that the only two available sub-categories within this composite food group LH and LL "Soft drinks, carbonated" (924) have relatively even share of expenditure, 59% versus 41% (Table 4.2). Imposing a tax on both LH and LL sub-categories limits the possibility to substitute to the LL sub-category. The obvious policy implication is that diet soda could be exempted from the soda tax scheme to reduce the consumer welfare loss.

All the sub cases with calorie-based taxes have annual revenues between \$0.84 billion and \$6.92 billion (Table 4.7). As discussed, there are limited differences regarding consumer welfare loss between the ad-valorem tax on food and the calorie-based taxes once the targeted food groups are set, the difference between their revenue generations are not striking. We note that a calorie-based tax on "Soft drinks, carbonated" (924) and "Sugars and sweets" (91) generates higher revenues than their corresponding ad-valorem taxes. The social costs of calorie-based taxes are less than one dollar except when calories from "Fats" (81) or "Sugars and sweets" (91) are targeted. Not surprisingly within each food group, the social cost of each dollar of public fund is lower if all the calories are targeted rather than calories from specific nutrients. The calorie-based taxes have lower social cost than the corresponding ad-valorem consumer taxes. This advantage is especially apparent for the "Sugars and sweets" (91) group whose social cost of public fund from a calorie-based tax is about 3 times smaller than that of the ad-valorem consumer tax.

A tax based on the calories or nutrients contained in all the foods

We finally consider four sub-cases with tax levied on all food groups: a tax imposed proportionally to the total calories contained in each of the foods or proportionally to the calories from specific sources (discretionary solid fat, added sugar, or discretionary solid fat and added sugar) in all foods. To reach the policy target of reducing total calorie consumption by 48 calories per day, tax rates are 0.0039 cents per calorie (all calories), 0.0216 cents per calorie (calories from fat), 0.0272 cents per calorie (calories from sweeteners), and 0.0118 cents per calorie (calories from fat and sweeteners) as shown in Table 4.7. The tax rates are smaller than those obtained when targeting selected food groups.

With the tax imposed on all calories, the demand for composite food groups decreases the most in "Fats" (81) (6%), followed by "Yeast breads, rolls, quick breads, crackers" (51+52+54) (4%), and "Oils & Salad dressings" (82-83) (nearly 4%). The corresponding calorie reductions in these three composite food groups are the highest among all reductions. With the tax imposed on calories from discretionary solid fat, the demand for composite food groups decreases the most for "Fats" (81) (nearly 11%) too. Demand changes for the other food groups are all less than 5%. In several composite food groups such as "Fat" (81), demands for HH and HL sub-categories increase while demands for LH and LL sub-categories decrease as expected. Calories and discretionary solid fat from "Fats" (81) decrease the most (roughly 9% and 16%) but the highest decrease in added sugar comes from "Cakes, cookies, pies, pastries" (53+55).

With the tax imposed on calories from added sugar, demand decreases the most in "Soft drink, carbonated" (924) (10%) and "Sugars and sweets" (91) (nearly 8%). Consumers decrease their demand of LH "Soft drink, carbonated" (924) by 18% and switch to LL "Soft drink, carbonated" (924) whose demand increases by about 2%. Demand changes for other composite food groups are all less than 5%. Calorie intake from "Soft drink, carbonated" (924), "Coffee & Tea" (921-923), and "Sugars and sweets" (91) decrease the most. With the tax imposed on calories from discretionary solid fat and added sugar, demands for composite food groups still decrease the most in "Fats" (81) (nearly 6%). There are also relatively high decreases in "Soft drinks, carbonated" (924) (nearly 5%), "Cakes, cookies, pies, pastries" (53+55) (4%) and "Sugars and sweets" (91) (4%). Consumers substitute from the high-fat, high-sugar sub-categories to the low-fat, low-sugar sub-categories. Calorie intake from "Soft drinks, carbonated" (924), "Fats" (81), "Sugars and sweets" (91), "Coffee & Tea" (921-923), and "Cakes, cookies, pies, pastries" (53+55) exhibits relatively high decreases. In summary, the demand changes, the calorie changes, and the nutrients changes are more spread out when taxing all the calories contained in the foods than only taxing calories from specific nutrient source. The calorie and nutrient changes from each composite food group are the combined results of demand changes and the mixture of the sub-categories changes. When consumers substitute from high-fat sub-categories to low-fat sub-categories within the composite food groups, the decrease in discretionary solid fat from this composite food group is higher than the demand change of the composite food group and vice versa. The same principle applies to added sugars.

The composition of nutrients changes with these four tax schemes although they achieve the same 48-calorie reduction. Taxing all the calories contained in the foods have relatively even changes in total discretionary solid fat and total added sugar by roughly 2%. Taxing calories from discretionary solid fat reduces discretionary solid fat by roughly 4% but sugar by less than 1%. Taxing calories from added sugar causes a significant decrease in added sugar (roughly 11%) but a minor decrease in discretionary solid fat (1%). So many food items intensive in added sugar have relatively little discretionary solid fat in them. When calories from discretionary solid fat and added sugar are both targeted, there changes are more even as expected (3% decrease in discretionary solid fat and 5% decrease in added sugar).

The annual tax revenues generated from these 4 taxes all foods are over $9 billion. They are higher than those from the ad-valorem consumption taxes and those from calorie based taxes on selected food groups. It is the most effective revenue raising tax instrument per calorie abated. The social costs of raising each dollar of public fund range from 1.1 cents to 5.73 cents and are also much lower than those from ad-valorem consumption taxes and those from calorie-based taxes on selected food groups. The lowest one is proportional tax on all the calories from all the foods, which is only 1.1 cents.

Summary and Discussion

This essay investigated tax design targeting highly caloric, fat and sugar intensive food and the associated welfare and tax revenue implications using a methodology developed in essay 2. The methodology uses an explicit CES nesting of 4 sub-categories classified by the fat and sugar content which is incorporated into a LinQuad incomplete demand system composted of 25 composite food groups. The augmented demand system is calibrated using consumption data from NHANES, nutrient data from MPED 2.0, and estimate of price and income elasticities available in the literature.

The two major types of taxes that we considered in the paper are ad-valorem consumption taxes on individual sub-categories within composite food group and calorie taxes on selected foods or all the foods. All the tax scenarios are designed to achieve the policy target of reducing the total calorie reduction consumption by 48 calories per capita per day (corresponding to the impact of a soda tax). All calories are treated equally regardless of their sources. For tax efficiency consideration, “Fat” (81), “Yeast breads, rolls, quick breads, crackers” (51+52+54), “Soft drinks” (924), “Sugars and sweets” (91) are the major food groups that should be targeted. Our analysis shows that to reduce the total calorie consumption and minimize the consumer welfare loss, taxing butter, margarine, bread, crackers, muffins, salty snacks, soda, candies are good choices. Taxing sodas has moderate welfare losses, proceed but it is not the most efficient scheme.

Once the targeted food groups were determined, we found that the form of the tax does not matter much in terms of its welfare impact. Ad-valorem consumption tax on the individual sub-category and tax on calories or calories from specific nutrients in the same sub-category causes welfare losses of similar magnitudes. So targeting the “right” food is more important than the way the tax is imposed. The advantage of ad-valorem tax is that the administration cost will be comparatively lower than for calorie based taxes, because the calorie taxes affect more food items, differ by food sub-categories, and are relatively complicate to apply.

In our analysis, all the calories are treated equally. For health concerns, it could be argued that some sources of nutrients such as discretionary solid fat and added sugar are worse than others. So the composition of the calorie reduction could influence the tax instrument that policy makers choose since some calories may be deemed better than others. If added sugar is more of a concern, then taxing “Soft drinks, carbonated” (924) can be chosen. But taxing “Soft drinks, carbonated” (924) almost only reduces added sugar consumption and misses the opportunity to reduce discretionary solid fat consumption. Taxing “Sugars and sweets” (91) reduces both discretionary solid fat and added sugar and these two nutrients composed most of the total calorie reduction.

The consumer welfare loss throughout our analysis is measured by the EV and the total calorie consumption reduction is set as the basis of equivalence across all the policy scenarios. A more exhaustive welfare analysis should incorporate the health benefits from the total calorie reduction. The total calorie reduction should also be further distinguished by its composition. The social health and medical costs could be incorporated in such analysis.

We also showed that soda tax is a better way to raise revenue than taxing other food sub-categories. But the taxes on calories tend to be more effective at raising revenues than ad-valorem taxes, although their consumer welfare evaluations are quite similar. With comparable welfare losses and more revenues collected, calorie-based taxes have smaller social costs of public funds. Targeting all foods has much lower social cost of public fund than targeting selected other food groups. So policymakers can trade off nutrient consumption changes, consumers’ health condition improvement, consumer welfare loss, and revenue collection with the design of obesity taxes.

References

Armington, P.S. 1969. “A Theory of Demand for Products Distinguished by Place of Production.” IMF Staff Papers 16: 159–178.

Babey, S.H., M. Jones, H. Yu, H. Goldstein. 2009. “Bubbling Over: Soda Consumption and its Link To Obesity in California” http://healthpolicy.ucla.edu/pubs/Publication.aspx?pubID=375 (accessed August, 2010)

Beghin, J.C., J. Bureau, and S. Drogué. 2004. “The Calibration of Incomplete Demand Systems in Quantitative Analysis.” *Applied Economics* 36(8): 839-847.

Bowman, S.A., J.E. Friday, and A.J. Moshfegh. 2008. “MyPyramid Equivalents Database, 2.0 for USDA Survey Foods, 2003-2004.” Food Surveys Research Group, Beltsville Human Nutrition Research Center, Agricultural Research Service, USDA. http://www.ars.usda.gov/ba/bhnrc/fsrg (accessed August, 2009)

Centers for Disease Control and Protection, National Center for Health Statistics. 2009. National Health and Nutrition Examination Survey 2003-2004 (accessed September, 2009). http://www.cdc.gov/nchs/nhanes/nhanes2003-2004/nhanes03_04.htm

Center for Science in the Public Interest. 2009. “Soda Taxes Can Help Fund Health Coverage and Prevention Programs, Say Experts.” http://www.cspinet.org/new/200906171.html (accessed July, 2010).

—.2010. “Health Advocates Cheer Decline in Soda Drinking.” http://www.cspinet.org/new/201004141.html (accessed July, 2010).

Chouinard, H.H., D.E. Davis, J.T. LaFrance, and J.M.Perloff. 2007. “Fat Taxes: Big Money for Small Change” http://www.bepress.com/cgi/viewcontent.cgi?article=1071&context=fhep (accessed May, 2009).

Fletcher, J.M., D. Frisvold, and N. Tefft. "Can Soft Drink Taxes Reduce Population Weight?"*Contemporary Economic Policy* 28(1), 2010, 23-35.

Jacobson, M.F. and K.D. Brownell. 2000. "Small Taxes on Soft Drinks and Snack Foods to Promote Health." American Journal of Public Health. 90 (6): 854-857.

Kuchler, F., A Tegene, and J.M. Harris. 2004. "Taxing Snack Foods: What to Expect for Diet and Tax Revenues." *Agriculture Information Bulletin* No. 747-08, August.

Lin, N.H., T.A. Smith, and J.Y. Lee. 2010. "The Effects of a Sugar-Sweetened Beverage Tax: Consumption, Calorie Intake, Obesity, and Tax Burden By Income." Selected Paper prepared for presentation at the Agricultural & Applied Economics Association 2010 AAEA, CAES & WAEA Joint Annual Meeting, Denver, Colorado, 25-27 July.

MayaTech Corporation for the Bridging the Gap Program at the University of Illinois at Chicago. 2009. "State Snack and Soda Sales Tax Data" http://www.impacteen.org/obesitystatedata.htm (accessed September, 2010)

Smed, S., J.D. Jensen and S. Denver. 2007. "Socio-economic Characteristics and the Effect of Taxation as a Health Policy Instrument." *Food Policy* 32: 5-6.

Smith, T.A., B.H. Lin, and J.Y. Lee. 2010. "Taxing Caloric Sweetened Beverages: Potential Effects on Beverage Consumption, Calorie Intake, and Obesity." Economic Research Report Number 100. U.S. Department of Agriculture, Economic Research Service (USDA/ERS). July 2010.

U.S. Department of Agriculture, Center for Nutrition Policy and Promotion (USDA/CNPP). 2009. "CNPP Food Prices Database, 2003-04."

http://www.cnpp.usda.gov/usdafoodplanscostoffood.htm (accessed September, 2009).

U.S. Department of Agriculture, Economic Research Service (USDA/ERS). 2006. "Commodity and Food Elasticities" http://www.ers.usda.gov/Data/Elasticities/ (accessed October. 2009).

Yale Rudd Center for Food Policy and Obesity. 2010. Revenue calculator for soft drinks taxes. http://www.yaleruddcenter.org/sodatax.aspx (accessed September, 2010).

———. "Legislation Database". 2011. http://www.yaleruddcenter.org/legislation/ (accessed March, 2011).

Table 4.1 Initial Consumption of Calorie and Nutrients from Composite Food Groups

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

a- The first 2 or 3 digits of the NHANES 2003-04 food codes are used to group the food items taken by survey participants.

Table 4.2 Initial Food Expenditure Cost Shares within Composite Food Groups

Composite food groups		Initial Cost Shares within Composite Food Groups (%)[a]			
Food Code[b]	**Food Group**	**HH**	**HL**	**LH**	**LL**
11	Milks and milk drinks	2.56	43.08	23.78	30.58
12	Creams and cream substitutes	8.00	56.19	26.33	9.49
13	Milk desserts, sauces, gravies	40.47	18.06	23.36	18.12
14	Cheeses	0.08	58.65	9.45	31.82
20-24	Beef, pork, poultry and other meats	3.87	39.08	1.42	55.64
25	Organ meats, sausages, lunchmeats	13.85	39.93	5.15	41.08
26	Fish and shellfish	19.81	10.55	8.53	61.11
27+28+77	Meat, poultry, fish mixtures	11.40	31.74	20.47	36.40
31-35	Eggs	12.99	27.51	8.47	51.04
41-43	Dry beans, peas, other legumes, nuts, and seeds	10.53	12.42	16.03	61.02
51+52+54	Yeast breads, rolls, quick breads, crackers	15.74	22.88	17.74	43.63
53+55	Cakes, cookies, pies, pastries	15.33	30.95	24.08	29.64
56-57	Pastas, cereals, rice	19.68	11.19	38.78	30.35
58-59	Grain mixtures	8.29	52.16	9.43	30.13
61-67	Fruits (excluding juices)	0.10	0.09	5.73	94.08
612+641+642+644+92	Fruit juices	0.60	0.10	49.30	49.99
71	White potatoes	0.02	54.05	4.29	41.64
72-76	Other vegetables	0.50	24.84	5.15	69.51
81	Fats	0.41	67.49	4.27	27.83
82-83	Oils & Salad dressings	5.51	22.87	43.81	27.80
91	Sugars and sweets	9.51	41.80	29.26	19.43
921-923	Coffee & Tea	0.24	11.39	16.09	72.28
924	Soft drinks, carbonated	NA	NA	58.56	41.44
93	Alcoholic beverages	0.53	NA	22.10	77.37
94	Water	NA	NA	NA	100.00

a- The initial cost shares within each composite food group sum to 100%.
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.
NA = not available, i.e., No food item is classified into the particular sub-category.
b- The first 2 or 3 digits of the NHANES 2003-04 food codes are used to group the food items taken by survey participants.

Table 4.3 Calories per Dollar of Food Sub Categories

Composite Food Groups		Calorie per dollar (calorie/$)[a]			
Food Code[b]	**Food Group**	**HH**	**HL**	**LH**	**LL**
11	Milks and milk drinks	661.71	542.02	468.90	299.72
12	Creams and cream substitutes	163.15	513.49	736.43	663.21
13	Milk desserts, sauces, gravies	797.93	601.07	453.04	495.34
14	Cheeses	490.95	500.98	385.29	315.84
20-24	Beef, pork, poultry and other meats	273.64	371.44	285.11	244.43
25	Organ meats, sausages, lunchmeats	626.61	430.33	147.63	216.85
26	Fish and shellfish	201.74	194.54	250.22	101.01
27+28+77	Meat, poultry, fish mixtures	652.00	360.47	426.46	279.01
31-35	Eggs	582.54	610.28	568.61	662.46
41-43	Dry beans, peas, other legumes, nuts, and seeds	399.58	772.72	296.22	722.27
51+52+54	Yeast breads, rolls, quick breads, crackers	833.86	1043.99	1826.63	935.32
53+55	Cakes, cookies, pies, pastries	1166.74	822.39	776.17	611.76
56-57	Pastas, cereals, rice	617.05	1673.72	569.18	1031.54
58-59	Grain mixtures	300.04	441.42	476.07	535.94
61-67	Fruits (excluding juices)	353.12	554.97	352.50	211.57
612+641+642 +644+92	Fruit juices	396.96	510.99	457.43	477.03
71	White potatoes	693.95	871.91	825.36	838.07
72-76	Other vegetables	500.16	236.32	477.32	97.93
81	Fats	1011.40	1312.49	1609.66	1538.36
82-83	Oils & Salad dressings	727.82	2063.32	785.91	1331.37
91	Sugars and sweets	255.05	642.74	1055.54	547.13
921-923	Coffee & Tea	985.11	338.65	657.97	56.16
924	Soft drinks, carbonated	NA	NA	608.62	181.95
93	Alcoholic beverages	168.33	NA	91.43	148.88
94	Water	NA	NA	NA	38.88

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.
NA = not available, i.e., No food item is classified into the particular sub-category.
b- The first 2 or 3 digits of the NHANES 2003-04 food codes are used to group the food items taken by survey participants.

Table 4.4 Ad Valorem Tax Rates, Welfare Losses, and Revenues to Reduce Total Calorie Consumption by 2.19%

Selected food sub categories	Ad valorem tax rates	Welfare Loss (Annual per capita EV)[a] ($)	Annual Revenue from population [a,b] (billion $)	Social cost of each dollar of public fund[a] ($)
Fats (81), HL	308.47%	-7.8258	1.01	-1.4003
Fats (81), LL	1766.66%	-7.9912	0.67	-2.6790
Yeast breads, rolls, quick breads, crackers (51+52+54), LH	132.67%	-12.7284	2.57	-0.5245
Yeast breads, rolls, quick breads, crackers (51+52+54), LL	67.02%	-19.3560	4.57	-0.3050
HL "Yeast breads, rolls, quick breads, crackers" (51+52+54)	199.49%	-21.1493	3.76	-0.7333
Grain mixtures (58-59), LL	64.88%	-22.7750	4.16	-0.6898
Soft drinks, carbonated (924)[c], LH	52.17%	-24.2409	5.34	-0.4009
Dry beans, peas, other legumes, nuts, and seeds (41-43), LL	186.00%	-24.7298	3.10	-1.4578
Sugars and sweets (91), LH	1540.73%	-25.0766	0.55	-13.0016
Sugars and sweets (91), HL	613.95%	-25.1230	0.628	-11.4788

a- 2003-04 US dollars are used in the calculation.
b- US population is 308400408 in 2010 (Bureau Labor of Statistics).
c- Tax rate is equivalent to 1 cent/oz based on the assumption that each 12 ounce can of carbonated soft drinks contained 140 calories. Converted ad valorem tax is 52.17%.

Table 4.5 Nutrients Change Rates to Reduce Total Calorie Consumption by 2.19%

Tax scenarios	Taxed nutrients/food components	Nutrient/ change rates	
		Discretionary solid fat change rate	Added sugar change rate
Ad valorem tax on selected food sub categories	Fats (81), HL	-4.23%	0.06%
	Fats (81), LL	-2.73%	0.06%
	Yeast breads, rolls, quick breads, crackers (51+52+54), LH	-0.56%	-1.02%
	Yeast breads, rolls, quick breads, crackers (51+52+54), LL	-1.31%	-0.10%
	Yeast breads, rolls, quick breads, crackers (51+52+54), HL	-3.57%	-0.02%
	Grain mixtures (58-59), LL	-1.58%	-0.03%
	Soft drinks, carbonated" (924), LH	-0.04%	-14.27%
	Dry beans, peas, other legumes, nuts, and seeds (41-43), LL	-0.46%	-0.08%
	Sugars and sweets (91), LH	-1.28%	-11.16%
	Sugars and sweets (91), HL	-1.46%	-10.48%
Tax proportional to calories or nutrient content on "Fats" (81)	All calories	-3.72%	0.05%
	Discretionary solid fat	-4.21%	0.06%
	Added sugar	NA[a]	NA[a]
	Discretionary solid fat Added sugar	-4.20%	0.06%
Tax proportional to calories or nutrient content on "Yeast breads, rolls, quick breads, crackers" (51+52+54)	All calories	-1.58%	-0.71%
	Discretionary solid fat	-3.09%	-0.80%
	Added sugar	-1.65%	-1.43%
	Discretionary solid fat Added sugar	-2.47%	-1.02%
Tax proportional to calories or nutrient content on "Soft drinks, carbonated" (924)	All calories	-0.05%	-13.94%
	Discretionary solid fat	NA[a]	NA[a]
	Added sugar	-0.05%	-13.99%
	Discretionary solid fat Added sugar	-0.05%	-13.99%
Tax proportional to calories or nutrient content on "Sugars and sweets" (91)	All calories	-1.33%	-10.71%
	Discretionary solid fat	-1.46%	-10.46%
	Added sugar	-1.30%	-10.85%
	Discretionary solid fat Added sugar	-1.31%	-10.80%
Tax proportional to calories or nutrient content on all the foods	All calories	-2.11%	-2.19%
	Discretionary solid fat	-4.41%	-0.96%
	Added sugar	-1.00%	-10.61%
	Discretionary solid fat Added sugar	-2.88%	-5.40%

a- NA = not available, i.e., It is not feasible to reach the policy target of reducing total calorie consumption by 2.19% with tax rate less than $50 per calorie.

Table 4.6 Welfare Loss per Unit of Nutrient Consumption Reduction to Reduce Total Calorie Consumption by 2.19%

Tax scenarios	Taxed nutrients/food components	EV per unit of nutrient consumption reduction[a]			
		EV/Calorie reduction (cents/calorie)	EV/Discretionary oil reduction (cents/g)	EV/Discretionary solid fat reduction (cents/g)	EV/Added sugar reduction (cents/g)
Ad valorem tax on selected food sub categories	Fats (81), HL	0.0004	0.0302	0.0109	-0.4299
	Fats (81), LL	0.0005	0.0172	0.0172	-0.4247
	Yeast breads, rolls, quick breads, crackers (51+52+54), LH	0.0007	0.0655	0.1348	0.0415
	Yeast breads, rolls, quick breads, crackers (51+52+54), LL	0.0011	0.0730	0.0871	0.6731
	Yeast breads, rolls, quick breads, crackers (51+52+54), HL	0.0012	0.1387	0.0348	4.2547
	Grain mixtures (58-59), LL	0.0013	0.1731	0.0845	2.5755
	Soft drinks, carbonated (924)[c], LH	0.1386	1050.9190	339.2458	0.5652
	Dry beans, peas, other legumes, nuts, and seeds (41-43), LL	0.0014	0.0307	0.3162	1.0811
	Sugars and sweets (91), LH	0.1434	12.1057	11.5291	0.7479
	Sugars and sweets (91), HL	0.0014	0.0997	0.1009	0.0080
Tax proportional to calories or nutrient content on "Fats" (81)	All calories	0.0004	0.0200	0.0121	-0.5032
	Discretionary solid fat	0.0004	0.0291	0.0109	-0.4468
	Added sugar	NA[b]	NA[b]	NA[b]	NA[b]
	Discretionary solid fat Added sugar	0.0004	0.0289	0.0109	-0.4555
Tax proportional to calories or nutrient content on "Yeast breads, rolls, quick breads, crackers" (51+52+54)	All calories	0.0008	0.0736	0.0530	0.0666
	Discretionary solid fat	0.0010	0.1243	0.0341	0.0747
	Added sugar	0.0008	0.0939	0.0522	0.0341
	Discretionary solid fat Added sugar	0.0009	0.1061	0.0377	0.0517
Tax proportional to calories or nutrient content on "Soft drinks, carbonated" (924)	All calories	0.1625	1050.0250	338.9555	0.6783
	Discretionary solid fat	NA[b]	NA[b]	NA[b]	NA[b]
	Added sugar	0.1589	1050.1640	339.0007	0.6613
	Discretionary solid fat Added sugar	0.1589	1050.1640	339.0007	0.6613
Tax proportional to calories or nutrient content on "Sugars and sweets" (91)	All calories	0.1420	10.9932	11.0122	0.7722
	Discretionary solid fat	0.1435	10.0138	10.1330	0.7986
	Added sugar	0.1421	11.3879	11.2507	0.7625
	Discretionary solid fat Added sugar	0.1421	11.1990	11.1220	0.7656
Tax proportional to calories or nutrient content on all the foods	All calories	0.176	14.072	8.579	4.675
	Discretionary solid fat	0.185	46.394	4.310	11.222
	Added sugar	0.177	53.097	18.201	0.969
	Discretionary solid fat Added sugar	0.180	51.544	6.443	1.948

a- 2003-04 US dollars are used in the calculation.
b- NA = not available, i.e., It is not feasible to reach the policy target of reducing total calorie consumption by 2.19% with tax rate less than $50 per calorie.

Table 4.7 Proportional Tax Rates, Welfare Loss, and Revenues to Reduce Total Calorie Consumption by 2.19%

Tax scenarios	Taxed nutrients/food components	Tax rates on calories from nutrients/food component (cents/kcal)	Welfare Loss (Annual per capita EV)[a] ($)	Annual Revenue from population[a,b] (billion $)	Social cost of each dollar of public fund (EV/Revenue+1)[a] ($)
Tax proportional to calories or nutrient content on "Fats" (81)	All calories	0.1185	-7.6687	1.19	-0.9922
	Discretionary solid fat	0.2227	-7.8082	1.03	-1.3399
	Added sugar	NA[c]	NA[c]	NA[c]	NA[c]
	Discretionary solid fat Added sugar	0.2204	-7.8042	1.03	-1.3261
Tax proportional to calories or nutrient content on "Yeast breads, rolls, quick breads, crackers" (51+52+54)	All calories	0.0161	-14.2430	4.03	-0.0884
	Discretionary solid fat	0.2136	-17.8972	4.57	-0.2078
	Added sugar	0.3254	-14.6653	3.77	-0.2011
	Discretionary solid fat Added sugar	0.1159	-15.8377	4.27	-0.1443
Tax proportional to calories or nutrient content on "Soft drinks, carbonated" (924)	All calories	0.0749	-28.4135	6.92	-0.2665
	Discretionary solid fat	NA[c]	NA[c]	NA[c]	NA[c]
	Added sugar	0.0779	-27.7971	6.72	-0.2755
	Discretionary solid fat Added sugar	0.0779	-27.7971	6.72	-0.2755
Tax proportional to calories or nutrient content on "Sugars and sweets" (91)	All calories	0.1731	-24.8453	1.67	-3.5906
	Discretionary solid fat	3.7170	-25.1005	0.84	-8.2571
	Added sugar	0.3202	-24.8520	1.59	-3.8163
	Discretionary solid fat Added sugar	0.2725	-24.8434	1.63	-3.6886
Tax proportional to calories or nutrient content on all the foods	All calories	0.0039	-30.7695	9.39	-0.0110
	Discretionary solid fat	0.0216	-32.3025	9.74	-0.0225
	Added sugar	0.0272	-30.9155	9.01	-0.0573
	Discretionary solid fat Added sugar	0.0118	-31.5725	9.55	-0.0204

a- 2003-04 US dollars are used in the calculation.
b- US population is 308,400,408 in 2010 (Bureau Labor of Statistics).
c- It is not feasible to reach the policy target of reducing total calorie consumption by 2.19% with tax rate less than $50 per calorie.

Appendix

Appendix 4.1 Summary of State Level Foods/Beverages Tax Rates, 2009

State/ City	Disfavored Foods	Tax Rate (%)			Equivalent soda tax per ounce[a] (cents/oz)
		Food	Other Disfavored	Soda	
AK	NA[b]	0.000	NA	0.00	0.0000
AL	Candy, gum, chips/pretzels, ice cream, popsicle, milkshakes and baked goods, soda	4.000	4.00	4.00	0.0767
AR	Candy, gum, chips/pretzels, ice cream, popsicle, milkshakes and baked goods, soda	3.000	3.00	3.00	0.0575
AZ	NA[b]	0.000	NA	0.00	0.0000
CA	Soda	0.000	NA	6.25	0.1198
CO	Gum	0.000	2.91	0.00	0.0000
CT	Candy, gum, soda	0.000	6.00	6.00	0.1150
DC	NA[b]	0.000	0.00	0.00	0.0000
DE	NA[b]	0.000	0.00	0.00	0.0000
FL	Candy, ice cream, popsicle, soda	0.000	6.00	6.00	0.1150
GA	NA[b]	0.000	0.00	0.00	0.0000
HI	Candy, gum, chips/pretzels, ice cream, popsicle, milkshakes and baked goods, soda	4.000	4.00	4.00	0.0767
IA	Candy, gum, soda	0.000	6.00	6.00	0.1150
ID	Candy, gum, chips/pretzels, ice cream, popsicle, milkshakes and baked goods, soda	6.000	6.00	6.00	0.1150
IL	Candy, gum, chips/pretzels, ice cream, popsicle, milkshakes and baked goods, soda	1.000	1.00	6.25	0.1198
IN	Candy, gum, soda	0.000	7.00	7.00	0.1342
KS	Candy, gum, chips/pretzels, ice cream, popsicle, milkshakes and baked goods, soda	5.300	5.30	5.30	0.1016
KY	Candy, gum, soda	0.000	6.00	6.00	0.1150
LA	NA[b]	0.000	0.00	0.00	0.0000
MA	NA[b]	0.000	0.00	0.00	0.0000
MD	Candy, gum, ice cream, popsicle, soda	0.000	6.00	6.00	0.1150
ME	Candy, gum, soda	0.000	5.00	5.00	0.0958

Source: "State Snack and Soda Sales Tax Data" MayaTech Corporation for the Bridging the Gap Program at the University of Illinois at Chicago. 2009. http://www.impacteen.org/obesitystatedata.htm

a- Price of average LH "924 Soft Drinks, Carbonated" is ($0.1752/106.6071 kcal)*140 kcal/12 oz= 1.9169 ¢/oz.

b- Disfavored foods are not among "Candy, gum, chips/pretzels, ice cream, popsicle, milkshakes and baked goods, and soda".

Appendix 4.1 (continued)

State/ City	Disfavored Foods	Tax Rate (%)			Equivalent soda tax per ounce[a] (cents/oz)
		Food	Other Disfavored	Soda	
MI	NA[b]	0.000	0.00	0.00	0.0000
MN	Candy, gum, soda	0.000	6.50	6.50	0.1246
MO	Candy, gum, chips/pretzels, ice cream, popsicle, milkshakes and baked goods, soda	1.225	1.23	1.23	0.0235
MS	Candy, gum, chips/pretzels, ice cream, popsicle, milkshakes and baked goods, soda	7.000	7.00	7.00	0.1342
MT	NA[b]	0.000	0.00	0.00	0.0000
NC	Candy, soda	0.000	4.50	4.50	0.0863
ND	Candy, gum, soda	0.000	5.00	5.00	0.0958
NE	NA[b]	0.000	0.00	0.00	0.0000
NH	NA[b]	0.000	0.00	0.00	0.0000
NJ	Candy, gum, soda	0.000	7.00	7.00	0.1342
NM	NA[b]	0.000	0.00	0.00	0.0000
NV	NA[b]	0.000	0.00	0.00	0.0000
NY	Candy, gum, soda	0.000	4.00	4.00	0.0767
OH	Soda	0.000	5.50	5.50	0.1054
OK	Candy, gum, chips/pretzels, ice cream, popsicle, milkshakes and baked goods, soda	4.500	4.50	4.50	0.0863
OR	NA[b]	0.000	0.00	0.00	0.0000
PA	Ice cream, soda	0.000	6.00	6.00	0.1150
RI	Candy, gum, soda	0.000	7.00	7.00	0.1342
SC	NA[b]	0.000	0.00	0.00	0.0000
SD	Candy, gum, chips/pretzels, ice cream, popsicle, milkshakes and baked goods, soda	4.000	4.00	4.00	0.0767
TN	Candy, gum, chips/pretzels, ice cream, popsicle, milkshakes and baked goods, soda	5.500	7.00% on candy 5.50% on gum, chips/pretzels, ice cream, popsicle, milkshakes and baked goods	5.50	0.1054
TX	Candy, gum, soda	0.000	6.25	6.25	0.1198
UT	Candy, gum, chips/pretzels, ice cream, popsicle, milkshakes and baked goods, soda	1.750	1.75	1.75	0.0335
VA	Candy, gum, chips/pretzels, ice cream, popsicle, milkshakes and baked goods, soda	1.500	1.50	1.50	0.0288
VT	NA[b]	0.000	0.00	0.00	0.0000
WA	Soda	0.000	0.00	6.50	0.1246
WI	Candy, gum, ice cream, soda	0.000	5.00	5.00	0.0958
WV	Candy, gum, chips/pretzels, ice cream, popsicle, milkshakes and baked goods, soda	3.000	3.00	6.00	0.1150
WY	NA[b]	0.000	0.00	0.00	0.0000

Appendix 4.2 Summary of State Level Sugar Sweetened Beverages Tax Bills 2010-2011

State/ City	Year	Bill[a]	Disfavored Drinks	Bill Summary	Equivalent sugar sweetened beverage tax[b]
AZ	2011	AZ HB 2643 - Tax on sweetened beverages	Sweetened beverage	Charge 40% of the tax base for the business of people participating in the retail sweetened beverage business. The tax base is the gross proceeds of sales or gross income derived from the business.	
	2010	AZ HB 2727 - Transaction Privilege Tax: Soft Drinks	Soft drinks, and syrups and powders from which soft drinks are made	A tax on soft drinks, and syrups and powders from which soft drinks are made	
	2010	AZ HB 2759 - Temporary Soft Drink Tax	All soft drinks, soft drink syrup, simple syrup and powders or other base products used to produce a liquid soft drink	A tax on all soft drinks, soft drink syrup, simple syrup and powders or other base products used to produce a liquid soft drink July 1, 2010-June 30, 2013	
CA	2011	CA HB 669 - Tax on sugar-sweetened beverages	Sugar-sweetened beverages	A 1¢/oz tax on distributors of sugar-sweetened beverages	1¢/oz
	2010	CA HB 2100 - Sugar Sweetened Beverage Tax: Pediatric Obesity Fund	Sugar-sweetened beverages or concentrate	An excise tax of 1¢ per teaspoon of added sweetener to sugar-sweetened beverages or concentrate	1¢ per teaspoon added sweetener = 0.8333¢/oz
	2010	CA SB 1210 - Taxation: sweetened beverage tax	Sweetened beverage, concentrate	A tax upon sweetened beverage manufacturer, concentrate manufacturer, or other person who makes the first sale of a sweetened beverage or concentrate of a rate of 1¢ per teaspoon of sugar placed into the sweetened beverage or equivalent amount of concentrate	1¢ per teaspoon of sugar = 0.8333¢/oz
CO	2010	CO HB 1191 - Eliminate Candy and Soda Sales Tax Exemption	Soft drinks	Candy and soft drinks are no longer exempt from the state sales tax and use taxes.	2.9% sales tax = 0.0556¢/oz
CT	2011	CT SB 256 - Proposed bill to impose tax on soft drinks	Soft drinks	A tax on soft drinks	
	2010	CT SB 38 - Imposing a Tax on Soft Drinks	All carbonated soft drinks in liquid form	A tax of 1¢/oz on all carbonated soft drinks in liquid form	1¢/oz
D.C.	2010	DC Healthy Schools Sweetened Beverage Tax	All sugar-sweetened beverages	A 1¢/oz excise tax on all sugar-sweetened beverages	1¢/oz

Source: "Legislation Database". Yale Rudd Center for Food Policy and Obesity. 2011. http://www.yaleruddcenter.org/legislation/

a- Federal (FD): HR=House of Representatives Bill, SB=Senate Bill; State: HB=House Bill, SB=Senate Bill, AB=Assembly Bill

b- Price of average LH "924 Soft Drinks, Carbonated" is ($0.1752/106.6071 kcal)*140 kcal/12 oz= 1.9169 ¢/oz. Each 12 oz of soft drink contains 40 grams (10 teaspoon) of added sugar.

Appendix 4.2 (continued)

State/ City	Year	Bill[a]	Disfavored Drinks	Bill Summary	Equivalent sugar sweetened beverage tax[b]
HI	2011	HI HB 1062 - Sugar-sweetened beverage tax	Sugar-sweetened beverages	Tax on sugar-sweetened beverages: a 10¢ tax per deposit container less than or equal to 12 fl oz and 25¢ per deposit container greater than 12 fl oz	10¢ tax per deposit container less than or equal to 12 fl oz and 25¢ per deposit container greater than 12 fl oz = 0.8333-2.0833¢/oz
	2011	HI HB 1188 - Imposing tax on sugar-sweetened beverages	Sugar-sweetened beverages	Tax on distributors of sugar-sweetened beverages: a 10¢ tax per deposit container less than or equal to 12 fl oz and 25¢ per deposit container greater than 12 fl oz.	10¢ tax per deposit container less than or equal to 12 fl oz and 25¢ per deposit container greater than 12 fl oz = 0.8333-2.0833¢/oz
	2011	HI HB 1216 - Establish a sugar-sweetened beverage tax	Sugar-sweetened beverage	A per gallon tax on sugar-sweetened beverages	
	2011	HI SB 1179 - Establishes a tax on sugar-sweetened beverages	Sugar-sweetened beverage	A per gallon tax on sugar-sweetened beverages	
	2010	HI HB 1505 - Tax on Soft Drinks and Syrup	Soft drinks and syrup	A tax on soft drinks and syrup	
	2010	HI HB 438 - Taxation of Soft Drinks	All soft drinks	A surcharge on all soft drinks	
	2010	HI SB 185 - Taxation of Soft Drinks	All soft drinks	A surcharge on all soft drinks	
	2010	HI SB 2238 - Excise Taxes on Sweetened Beverages	Sweetened beverages	An additional general excise tax on sweetened beverages that is in addition to the existing 4% rate and the county surcharge of 0.5%	
KS	2010	KS SB 567 - Sugar Sweetened Beverage and Concentrate Tax	Sweetened beverages or concentrate	An excise tax, on the manufacturer, of 1¢ per teaspoon of sugar on sweetened beverages or the equivalent amount of concentrate	1¢ per teaspoon of sugar = 0.8333¢/oz
MA	2011	MA HB 1697 - Regarding tax exemption for sugared beverages and candy	Sugared beverages.	Eliminate sales tax exemption for sugared beverages and candy	6.25% sales tax = 0.1198 ¢/oz
MD-Baltimore	2010	BALTIMORE MD Ordinance 10-0474 Beverage container tax	All beverages except dairy, juice, and bottles larger than two liters	An excise tax on distributors who supply beverages in non-reusable containers: all beverages except dairy, juice, and bottles larger than two liters	

Appendix 4.2 (continued)

State/ City	Year	Bill[a]	Disfavored Drinks	Bill Summary	Equivalent sugar sweetened beverage tax[b]
MS	2011	MS HB 414 - Sweetened beverages and syrups tax law	Sweetened beverages	An excise tax of 2¢/oz on certain sweetened beverages	2¢/oz
	2011	MS SB 2678 - Enact Sweetened Beverages and Syrups Tax Law	Sweetened beverages	An excise tax of 2¢/oz on certain sweetened beverages	2¢/oz
	2010	MS HB 1606 - Sweetened Beverages and Syrups Tax Law; enact.	Sweetened beverage	An excise tax on distributor for the privilege of selling certain sweetened beverage products	
	2010	MS HB 1691 - Additional One Cent Levy on Soft Drinks	Soft drinks	An additional sales tax on retail sales of soft drinks in the amount of 1¢ per bottle containing a soft drink; without regard to the size or volume capacity of the bottle and without regard to whether the soft drink contains a caloric or non caloric sweetener	1¢ per bottle
	2010	MS SB 3109 - The Sweetened Beverages and Syrups Tax Law	Sweetened beverage	An excise tax on distributor for the privilege of selling certain sweetened beverage products	
NH	2010	NH HB 1679 - Establishing a Soft Drinks Tax	Soft drinks	A soft drinks tax	
NM	2011	NM SB 288 - Excise tax on sugar-sweetened beverages	Sugar-sweetened beverages	A 0.5¢/oz tax on sugar-sweetened beverages	0.5¢/oz
	2010	NM SB 243 - Sweetened Beverage Excise Tax	Sweetened beverage	An excise tax on the sweetened beverage	
NY	2010	NY Governor Paterson budget recommendation re: sugar-sweetened beverage taxes	Sugar sweetened beverages	Tax 1¢/oz on sugar sweetened beverages, and exempt bottled water and beverages with fewer than 10 calories per 8 oz from state and local sales taxes, and expand the sales tax base to include coffee and tea drinks with more than 10 calories in 8 ounces.	1¢/oz
	2010	NY HB 41004 Imposing a tax on beverage syrups and soft drinks	Syrup; bottled soft drinks; and soft drink made from powder or product base	An excise tax of $7.68/gal of syrup; $1.28/gal of bottled soft drinks; and $1.28/gal of soft drink made from powder or product base	$7.68/gal of syrup; $1.28/gal of bottled soft drinks; and $1.28/gal of soft drink made from powder or product base = 1¢/oz
	2010	NY HB 7679 - Exempts Vending Machines from Sales and Use Tax	Beverages sold from vending machines	A tax for food and beverages sold from vending machines	
	2010	NY SB 67004 Imposing a tax on beverage syrups and soft drinks.	Syrup; bottled soft drinks; and soft drink made from powder or product base	An excise tax of $7.68/gal of syrup; $1.28/gal of bottled soft drinks; and $1.28/gal of soft drink made from powder or product base.	$7.68/gal of syrup; $1.28/gal of bottled soft drinks; and $1.28/gal of soft drink made from powder or product base = 1¢/oz
OR	2011	OR HB 2644 – Relating to the taxation of sugar-sweetened beverages	Sugar-sweetened beverages and concentrates	An excise tax of a 0.5¢/oz on the sale of sugar-sweetened beverages and concentrates	0.5¢/oz
	2011	OR SJR 29 – Create excise tax on sugar-sweetened beverages and candy	Sugar-sweetened beverages	An excise tax on sugar-sweetened beverages and candy	

Appendix 4.2 (continued)

State/ City	Year	Bill[a]	Disfavored Drinks	Bill Summary	Equivalent sugar sweetened beverage tax[b]
PA-Philadelphia	2010	PHILADELPHIA PA Sugar Sweetened Beverage Tax; Healthy Philadelphia Initiative	Sugar-sweetened beverages	A 2¢/oz tax on retailers based on their annual sales volume of sugar-sweetened beverages	2¢/oz
RI	2011	RI HB 5432 - Establishes tax on sugar-sweetened beverages	Bottled soft drink	A tax of 1¢/oz on bottled soft drink distributors, manufacturers, and wholesalers	1¢/oz
	2011	RI SB 295 - Establishes a tax on sugar-sweetened beverages	Bottled soft drink	A tax of 1¢/oz on bottled soft drink distributors, manufacturers, and wholesalers	1¢/oz
	2010	RI HB 7368 - Soft Drink Taxes	Bottled soft drink	A tax upon each bottled soft drink at a rate of 5¢ for bottled soft drinks up to 20 oz and 10¢ for bottled soft drinks larger than 20 oz	5¢ for bottled soft drinks up to 20 oz and 10¢ for bottled soft drinks larger than 20 oz = 0.25-0.5¢/oz
	2010	RI SB 2199 - Soft Drinks Tax	Bottled soft drink	A tax upon each bottled soft drink at a rate of 5¢ for bottled soft drinks up to 20 oz and 10¢ for bottled soft drinks larger than 20 oz	5¢ for bottled soft drinks up to 20 oz and 10¢ for bottled soft drinks larger than 20 oz = 0.25-0.5¢/oz
	2010	RI SB 2779 - Local Sales and Use Tax on Sugar Sweetened Beverages	Sugar sweetened beverages	An additional local sales tax on sugar sweetened beverages not to exceed 20%	
TN	2011	TN HB 537 - Sugar-sweetened beverage tax	Bottled, sugar-sweetened beverages	A 1¢/oz tax on bottled, sugar-sweetened beverages.	1¢/oz
	2011	TN SB 521 - Sugar-sweetened beverage tax	Bottled soft drinks containing sugar	A 1¢/oz tax on bottled soft drinks containing sugar	1¢/oz
	2010	TN HB 3657 Extends temporary excise tax on bottles of soft drinks and barrels of beer. Companion bill is SB 3372	Carbonated beverages and barrels of beer	Extends the excise tax on carbonated beverages and barrels of beer until June 30, 2015.	
	2010	TN SB 3372 Temporary tax on soft drinks until June 2015	Bottles of soft drinks and barrels of beer	Extend a temporary tax on bottles of soft drinks and barrels of beer until June 30, 2015, or sooner upon state or federal law enacted imposing mandatory deposits on beverage containers.	
TX	2011	TX HB 2209 - Imposing tax on sweetened beverages and ingredients	Sweetened beverage, sweetened beverage powder, or sweetened beverage syrup	A 1¢/12 oz increment of sweetened beverage, sweetened beverage powder, or sweetened beverage syrup	1¢/12 oz = 0.0833¢/oz
	2011	TX HB 2213 - Imposing a tax on sweetened beverages	Sweetened beverage, sweetened beverage powder, or sweetened beverage syrup	A 5¢/12 oz increment of sweetened beverage, sweetened beverage powder, or sweetened beverage syrup	5¢/12 oz = 0.4167¢/oz
	2011	TX HB 2214 - Imposing a tax on sugar-sweetened beverages	Sweetened beverage, sweetened beverage powder, or sweetened beverage syrup	A 1¢/oz tax on sweetened beverage, sweetened beverage powder, or sweetened beverage syrup	1¢/oz
	2011	TX HJRes 10 - Regarding revenue from sweetened beverage tax	Sweetened beverages	A tax on certain sweetened beverages	
	2011	TX SB 1004 - Imposition of a tax on certain beverages	Artificially-sweetened and sugar-sweetened beverages	A 1¢/oz tax on artificially-sweetened and sugar-sweetened beverages except those sold by or in restaurants, lunch counters, cafeterias, hotel and other businesses	1¢/oz
VA	2010	VA SB 525 - Soft Drink Excise Tax	Soft drink	Soft drink excise tax	

Appendix 4.2 (continued)

State/ City	Year	Bill[a]	Disfavored Drinks	Bill Summary	Equivalent sugar sweetened beverage tax[b]
VT	2011	VT HB 151 - Imposing an excise tax on sugar-sweetened beverages	Sugar-sweetened beverages	An excise tax of 1¢/oz on sugar-sweetened beverages	1¢/oz
	2010	VT HB 149 - Sales Tax on Soft Drinks	Soft drinks	Sales tax on soft drinks	6% sales tax = 0.1150 ¢/oz
WV	2011	WV HB 2968 - Increasing the soft drinks tax	Sugar-sweetened beverage	An excise tax on sugar-sweetened beverage: On each bottled soft drink, an additional tax of 1¢ on each 16 and 19 fl oz, or on each 0.5 liter. On each gallon of soft drink syrup, an additional tax of 80¢, or on each 4 liters of soft drink syrup an additional tax of 84¢	1¢/16oz = 0.0625¢/oz 1¢/19oz = 0.0526¢/oz 1¢/0.5liter = 0.0592¢/oz

Appendix 4.3 Composite Food Group Description

Food Code[a]	Food group	Detailed food group description
11	Milks and milk drinks	Milks and milk drinks
12	Creams and cream substitutes	Creams and cream substitutes
13	Milk desserts, sauces, gravies	Milk desserts, sauces, gravies
14	Cheeses	Cheeses
20-24	Beef, pork, poultry and other meats	Beef & Pork & Lamb, veal, game, other carcass meat & Poultry
25	Organ meats, sausages, lunchmeats	Organ meats, sausages and lunchmeats, and meat spreads
26	Fish and shellfish	Fish and shellfish
27+28+77	Meat, poultry, fish mixtures	Meat, poultry, fish with nonmeat items & Frozen and shelf-stable plate meals, soups, and gravies with meat, poultry, fish base; gelatin and gelatin-based drinks & Vegetables with meat, poultry, fish
31-35	Eggs	Eggs
41-43	Dry beans, peas, other legumes, nuts, and seeds	Dry beans, peas, other legumes, nuts, and seeds
51+52+54	Yeast breads, rolls, quick breads, crackers	Yeast breads, rolls & Quick breads & Crackers and salty snacks from grain products
53+55	Cakes, cookies, pies, pastries	Cakes, cookies, pies, pastries & Pancakes, waffles, French toast, other grain products
56-57	Pastas, cereals, rice	Pastas, cooked cereals, rice & Cereals, not cooked or ns as to cooked
58-59	Grain mixtures	Grain mixtures, frozen plate meals, soups & Meat substitutes, mainly cereal protein
61-67	Fruits (excluding juices)	Fruits
612+641+ 642+644+ 92	Fruit juices	Fruit juices & Nectars & Vinegar & Nonalcoholic beverages (excluding Coffee & Tea & Soft drinks, carbonated)
71	White potatoes	White potatoes and Puerto Rican starchy vegetables
72-76	Other vegetables	Other vegetables
81	Fats	Fats
82-83	Oils & Salad dressings	Oils & Salad dressings
91	Sugars and sweets	Sugars and sweets
921-923	Coffee & Tea	Coffee & Tea
924	Soft drinks, carbonated	Soft drinks, carbonated
93	Alcoholic beverages	Alcoholic beverages
94	Water	Water

a- The first 2 or 3 digits of the NHANES 2003-04 food codes are used to group the food items taken by survey participants.

Appendix 4.4 Calories, Nutrients, and Expenditures of Foods by Average Measure

Composite food groups	Sub categories[a]	Calorie distribution within column	Discretionary solid fat density[b]	Added sugars density[c]	Food expenditure ($)
11 Milks and milk drinks	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
12 Creams and cream substitutes	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
13 Milk desserts, sauces, gravies	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
14 Cheeses	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
20-24 Beef, pork, poultry and other meats	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
25 Organ meats, sausages, lunchmeats	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
26 Fish and shellfish	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
27+28+77 Meat, poultry, fish mixtures	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

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- Percentage contribution of discretionary solid fat to the total calories in the food. Each gram of discretionary solid fat provides 9 calories.
c- Percentage contribution of discretionary added sugars to the total calories in the food. Each gram of added sugars provides 4 calories.

Appendix 4.4 (continued)

Composite food groups	Sub categories[a]	Calorie distribution within column	Discretionary solid fat density[b]	Added sugars density[c]	Food expenditure ($)
31-35 Eggs	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
41-43 Dry beans, peas, other legumes, nuts, and seeds	Aggregate	3.37%	3.92%	3.29%	0.12
	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
51+52+54 Yeast breads, rolls, quick breads, crackers	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
53+55 Cakes, cookies, pies, pastries	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
56-57 Pastas, cereals, rice	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
58-59 Grain mixtures	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
61-67 Fruits (excluding juices)	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
612+641+642+644+92 Fruit juices	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

Appendix 4.4 (continued)

Composite food groups	Sub categories[a]	Calorie distribution within column	Discretionary solid fat density[b]	Added sugars density[c]	Food expenditure ($)
71 White potatoes	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
72-76 Other vegetables	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
81 Fats	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
82-83 Oils & Salad dressings	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
91 Sugars and sweets	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
921-923 Coffee & Tea	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
924 Soft drinks, carbonated	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
93 Alcoholic beverages	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
94 Water	Aggregate	0.00%	0.00%	0.00%	0.00
	LL	0.00%	0.00%	0.00%	0.00

Appendix 4.5 Ad Valorem Tax on Single Sub Category to Reduce Total Calorie Consumption by 2.19%

Food groups	HH sub category			HL sub category			LH sub category			LL sub category		
	Tax rate	Total calorie reduction	Annual per capita EV ($)	Tax rate	Total calorie reduction	Annual per capita EV ($)	Tax rate	Total calorie reduction	Annual per capita EV ($)	Tax rate	Total calorie reduction	Annual per capita EV ($)
11 Milks and milk drinks	NA[a]	NA[a]	NA[a]	492%	-2.19%	-53.57	3198%	-2.19%	-54.48	1380%	-2.19%	-54.58
12 Creams and cream substitutes	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[b]	NA[b]	NA[b]
13 Milk desserts, sauces, gravies	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]
14 Cheeses	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[b]	NA[b]	NA[b]
20-24 Beef, pork, poultry and other meats	NA[a]	NA[a]	NA[a]	82%	-2.19%	-45.36	NA[a]	NA[a]	NA[a]	82%	-2.19%	-65.93
25 Organ meats, sausages, lunchmeats	NA[b]	NA[b]	NA[b]	482%	-2.19%	-34.57	NA[b]	NA[b]	NA[b]	519%	-2.19%	-35.62
26 Fish and shellfish	512%	-2.19%	-34.58	1764%	-2.19%	-35.94	2734%	-2.19%	-35.77	104%	-2.19%	-35.12
27+28+77 Meat, poultry, fish mixtures	NA[b]	NA[b]	NA[b]	209%	-2.19%	-33.32	NA[b]	NA[b]	NA[b]	193%	-2.19%	-36.97
31-35 Eggs	2089%	-2.19%	-51.54	864%	-2.19%	-50.26	3457%	-2.19%	-52.03	418%	-2.19%	-48.64
41-43 Dry beans, peas, other legumes, nuts, and seeds	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	186%	-2.19%	-24.73
51+52+54 Yeast breads, rolls, quick breads, crackers	835%	-2.19%	-28.10	199%	-2.19%	-21.12	133%	-2.19%	-12.75	67%	-2.19%	-19.35

a- It is not feasible to reach the policy target of reducing total calorie consumption by 2.19%.
b- It is not feasible with ad valorem tax rate less than 5000% to reach the policy target of reducing total calorie consumption by 2.19%.
c- Sub categories are vacant by CES average classification measure.

Appendix 4.5 (continued)

Food groups	HH sub category			HL sub category			LH sub category			LL sub category		
	Tax rate	Total calorie reduction	Annual per capita EV ($)	Tax rate	Total calorie reduction	Annual per capita EV ($)	Tax rate	Total calorie reduction	Annual per capita EV ($)	Tax rate	Total calorie reduction	Annual per capita EV ($)
53+55 Cakes, cookies, pies, pastries	2304%	-2.19%	-33.50	370%	-2.19%	-31.67	736%	-2.19%	-34.00	498%	-2.19%	-34.78
56-57 Pastas, cereals, rice	1981%	-2.19%	-33.69	NA[b]	NA[b]	NA[b]	477%	-2.19%	-32.87	638%	-2.19%	-30.98
58-59 Grain mixtures	NA[a]	NA[a]	NA[a]	33%	-2.17%	-25.25	NA[a]	NA[a]	NA[a]	65%	-2.19%	-22.80
61-67 Fruits (excluding juices)	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]
612+641+642+644+92 Fruit juices	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	533%	-2.19%	-32.44	476%	-2.19%	-32.18
71 White potatoes	NA[a]	NA[a]	NA[a]	672%	-2.19%	-83.33	NA[a]	NA[a]	NA[a]	1042%	-2.19%	-85.32
72-76 Other vegetables	NA[b]	NA[b]	NA[b]	791%	-2.19%	-96.61	NA[b]	NA[b]	NA[b]	153%	-2.20%	-104.17
81 Fats	NA[b]	NA[b]	NA[b]	308%	-2.19%	-7.82	NA[b]	NA[b]	NA[b]	1767%	-2.19%	-7.99
82-83 Oils & Salad dressings	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]
91 Sugars and sweets	NA[a]	NA[a]	NA[a]	614%	-2.19%	-25.12	1541%	-2.19%	-25.08	NA[b]	NA[b]	NA[b]
921-923 Coffee & Tea	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[b]	NA[b]	NA[b]	NA[a]	NA[a]	NA[a]
924 Soft drinks, carbonated	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	52%	-2.19%	-24.19	NA[b]	NA[b]	NA[b]
93 Alcoholic beverages	NA[a]	NA[a]	NA[a]	NA[c]	NA[c]	NA[c]	NA[a]	NA[a]	NA[a]	102%	-2.19%	-107.34
94 Water	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[a]	NA[a]	NA[a]

Appendix 4.6 Ad Valorem Tax on Single Sub Category to Reduce Total Calorie Consumption by 2.19%

Composite food groups	Sub categories[a]	Tax rate	Total calorie reduction	Annual per capita EV ($)[b]
81 Fats	HL	308.47%	-2.19%	-7.82
81 Fats	LL	1766.66%	-2.19%	-7.99
51+52+54 Yeast breads, rolls, quick breads, crackers	LH	132.67%	-2.19%	-12.75
51+52+54 Yeast breads, rolls, quick breads, crackers	LL	67.02%	-2.19%	-19.35
51+52+54 Yeast breads, rolls, quick breads, crackers	HL	199.49%	-2.19%	-21.12
58-59 Grain mixtures	LL	64.88%	-2.19%	-22.80
924 Soft drinks, carbonated	LH	52.17%	-2.19%	-24.19
41-43 Dry beans, peas, other legumes, nuts, and seeds	LL	186.00%	-2.19%	-24.73
91 Sugars and sweets	LH	1540.73%	-2.19%	-25.08
91 Sugars and sweets	HL	613.95%	-2.19%	-25.12
58-59 Grain mixtures	HL	33%	-2.17%	-25.25
51+52+54 Yeast breads, rolls, quick breads, crackers	HH	835%	-2.19%	-28.10
56-57 Pastas, cereals, rice	LL	638%	-2.19%	-30.98
53+55 Cakes, cookies, pies, pastries	HL	370%	-2.19%	-31.67
612+641+642+644+92 Fruit juices	LL	476%	-2.19%	-32.18
612+641+642+644+92 Fruit juices	LH	533%	-2.19%	-32.44
56-57 Pastas, cereals, rice	LH	477%	-2.19%	-32.87
27+28+77 Meat, poultry, fish mixtures	HL	209%	-2.19%	-33.32
53+55 Cakes, cookies, pies, pastries	HH	2304%	-2.19%	-33.50
56-57 Pastas, cereals, rice	HH	1981%	-2.19%	-33.69
53+55 Cakes, cookies, pies, pastries	LH	736%	-2.19%	-34.00
25 Organ meats, sausages, lunchmeats	HL	482%	-2.19%	-34.57
26 Fish and shellfish	HH	512%	-2.19%	-34.58
53+55 Cakes, cookies, pies, pastries	LL	498%	-2.19%	-34.78
26 Fish and shellfish	LL	104%	-2.19%	-35.12
25 Organ meats, sausages, lunchmeats	LL	519%	-2.19%	-35.62
26 Fish and shellfish	LH	2734%	-2.19%	-35.77
26 Fish and shellfish	HL	1764%	-2.19%	-35.94
27+28+77 Meat, poultry, fish mixtures	LL	193%	-2.19%	-36.97
20-24 Beef, pork, poultry and other meats	HL	82%	-2.19%	-45.36
31-35 Eggs	LL	418%	-2.19%	-48.64
31-35 Eggs	HL	864%	-2.19%	-50.26
31-35 Eggs	HH	2089%	-2.19%	-51.54
31-35 Eggs	LH	3457%	-2.19%	-52.03
11 Milks and milk drinks	HL	492%	-2.19%	-53.57
11 Milks and milk drinks	LH	3198%	-2.19%	-54.48
11 Milks and milk drinks	LL	1380%	-2.19%	-54.58
20-24 Beef, pork, poultry and other meats	LL	82%	-2.19%	-65.93
71 White potatoes	HL	672%	-2.19%	-83.33
71 White potatoes	LL	1042%	-2.19%	-85.32
72-76 Other vegetables	HL	791%	-2.19%	-96.61
72-76 Other vegetables	LL	153%	-2.20%	-104.20
93 Alcoholic beverages	LL	102%	-2.19%	-107.30

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- 2003-04 US dollars are used in the calculation.

ACKNOWLEDGEMENTS

I want to take this opportunity to thank all people who helped me during my Ph.D. study. First and foremost, I would like to express my deepest appreciation to my two major professors, Dr. Helen H. Jensen and Dr. John C. Beghin for their guidance, patience and support. My whole dissertation has benefited enormously from my two advisors' sharp insights in scientific research and from their extensive knowledge in Economics. I would also like to thank my committee members Dr. John R. Schroeter, Dr. Peter F. Orazem and Dr. Ulrike Genschel for their advice and comments to my paper and faculty and staff of the Department of Economics for their assistance throughout my graduate studies. Finally, I would like to give my special thanks to my family and friends for their love and support all these years.