Taxing Sweets: Sweetener Input Tax or Final Consumption Tax?

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Abstract

In order to reduce obesity and associated costs, policymakers are considering various policies, including taxes, to change consumers' high-calorie consumption habits. We investigate two sweet tax policies aimed at reducing added sweetener consumption. Both a consumption tax on sweet goods and a sweetener input tax can reach the same policy target of reducing added sweetener consumption. Both tax instruments are regressive but the associated surplus losses are limited. The tax on sweetener inputs targets sweeteners directly and causes about five times less surplus loss than the final consumption tax. Previous analyzes have overlooked this important point.

Keywords: consumption tax, sugar, added sweeteners, demand, health policy, soda tax

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Introduction

Obesity has become a major public health concern in the United States as well as throughout the world. In 2007-08, 32.2% of men and 35.5% of women (20 years of age and older) were obese (Flegal et al., 2010). Although the rate for women has not increased over the last decade, and the rate for men has been constant during the last several years, obesity rates indicate a major and continuing public health problem. Obesity is most often a result of imbalance between excess calorie intake and reduced physical activity. In the last three decades, on average, American consumers have consumed more calories, especially in the form of refined grains, total fats and added sugars. From 1970 to 2003 the per capita average daily calorie intake grew by 523 calories. The main contributors to the increase were fats and oils (216 calories), refined grains (188 calories) and all sweeteners (76 calories) (Farah and Buzby, 2005).

In order to reduce the costs of obesity, policymakers have debated and tried various policies and programs to change the consumption of high-calorie foods and reduce the prevalence of obesity. The current (2005) dietary guidelines issued by the Department of Health and Human Services (HHS) and USDA recommend limiting the intake of trans-fats and added sugar (DHHS and USDA 2005). 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 long-run health cost of unhealthy food (O'Donoghue and Rabin, 1999). Because fats and oils, refined grains, sugar and sweeteners are the major contributors to the higher calorie consumption, proposals to tax these products are popular ways to reduce their intake (Kuchler, Tegene, and Harris, 2004 and 2005; Gustavsen, 2005; Schroeter, Lusk, and Tyner, 2005; Cash, Sunding, and Zilberman, 2005; Smed, Jensen, and Denver, 2007; Richards, Patterson, and Tegene, 2007; and Chouinard et al., 2007).

We focus on sweet tax policies targeted to reduce added sweetener consumption and investigate the effect of alternative policies to reduce the sweetener intake. Taxing added sweeteners is often discussed but less often thoroughly analyzed than policies to reduce consumption of high fat foods. Taxing sweets can be undertaken at two levels: the consumption or production level. Applying a tax to a specific type of sweetened food directly changes the food price and thus likely reduces the consumer demand for the sweetened food.

Alternatively, policymakers can induce manufacturers to reduce the use of sweetener-intensive ingredients in food processing by imposing a tax on sweetener ingredients. Manufacturers chose among available technologies and ingredients, and to some extent, the manufacturers can substitute among different sweeteners and away from them in the production process. A tax on sweetener inputs increases their marginal cost and hence the price of final food products offered. Faced with a higher price, consumers reduce their consumption of final products. The extent to which the extra costs are transmitted along the food chain affects the final market price and ultimately determines the effectiveness of the tax imposed on manufacturers as a means to reduce consumption of the sweetener-intensive final food products.

Both a final consumption tax and a tax on manufacturer ingredients can reach the same policy target of reducing the consumption of added sweeteners and associated added calories. The objective of our research is to explore the effect of taxes on inputs and on final goods designed to reduce consumption of sweeteners. We evaluate the levels of a tax required on each to achieve a given reduction in sweeteners. An empirical model along with data from industry and recent research studies are used to evaluate the magnitude of the effects the policy instruments on consumption, on welfare, as well as distributional effects of across income groups. We compare the allocative efficiency of both instruments (the tax on final consumption and the tax on manufacturing ingredients) and conclude that although they are both regressive and of small magnitude, taxes on sweetener inputs cause a smaller loss in welfare (about 5 times less) than does a tax on final products, such as a soda tax.

Almost all previous studies that have focused on a consumption tax have found such a tax to be regressive. In our investigation, we fix a 10% reduction in sugar equivalent added sweetener consumption (around 13.13 grams per capita daily sugar equivalent which contain 52.54 calories) as the policy target and minimize the associated welfare loss. The following section summarizes several related studies directed at tax policy on high-calorie foods. Next, the model section presents the model of the food sector we use to evaluate the response of industry and consumers to prices of sweeteners and sweetened goods. The data section introduces the 2002 Economic Census Manufacturing report data, the Food Availability data, the Commodity and Food Elasticity data and the data in Consumer Expenditure Survey that we use in this paper. The calculation of the LinQuad incomplete food demand system and the welfare analysis are discussed in the results section. The last section provides a brief summary and conclusions. Information on derivations, computations details and additional analyses is available in appendices to an extended version of this paper (Miao, Beghin, and Jensen, 2010).

Literature review

The food industry uses sweeteners as ingredients in the manufacturing process. Agricultural technical progress has lowered the cost of both corn and high fructose corn syrup (HFCS) more than the cost of sugar by increasing productivity in corn production over time relatively more than that in sugar production (Beghin and Jensen, 2008). In addition, the price of sugar in the US has long been above the average world level because trade restrictions have kept the cost of using sugar well above its opportunity cost. Conversely, corn subsidies have lowered the price of corn sweeteners. As a result of these two effects, corn-based sweeteners are relatively cheaper compared to sugar and have experienced a sharp rise in use by manufacturers. HFCS is widely used in the beverage, breakfast cereal and bakery, and dairy industries (Beghin and Jensen, 2008).

The effectiveness of taxing high-calorie foods has been analyzed previously. The general findings are that the market intervention can change consumers' dietary choices, but the effects of tax policy are limited and the tax on select foods is often regressive. Santarossa and Mainland (2003) found that consumers tend to replace harmful foods with healthier ones when there is a price increase for unhealthy high-energy foods. In an empirical study based on household consumption data from 1989 to 1999, Gustavsen (2005) showed that a tax on soft drinks may efficiently reduce demand and the decrease is more significant in heavy drinkers than in light drinkers because heavy drinkers are more price and expenditure elastic. Richards, Patterson, and Tegene (2007) found that the craving for different foods is rational and argued that a tax on high-energy foods may be more efficient in reducing their consumption than information-based policies.

Although it is expected that price interventions will induce consumers to choose diets with fewer calories and to move to a healthier eating style, the effects of these policies depend on which foods are affected, to what extent the final price changes, the availability of close, healthy substitutes on the market, and finally how different consumers respond to the adjusted market (Schmidhuber, 2004; Cash, Sunding and Zilberman, 2005). In practice, the effectiveness of tax policy could be complicated by other factors or could be limited. For example, Kuchler, Tegene, and Harris (2004; 2005) studied the possible consumption impact and health outcome associated with a simulated tax on snack foods. Under the assumption that no substitutable foods were available, they found that although a relatively small tax rate of 1% could generate some revenue for public health education, it did not reduce purchases by much and therefore had relatively little influence on diet quality and health outcomes.

Chouinard et al. (2007) analyzed supermarket scanner data to characterize the effects of a fat tax on dairy products. They showed that a 10% tax on fat content would reduce fat consumption by less than 1%, a 50% tax would cause a 3% intake reduction. They concluded that the limited effects of the taxes on demand are due to the fact that dairy product demand is not price elastic. Thus, a fat tax on dairy is best used to enhance revenue. This investigation only included dairy products, which contain fats and did not take non-fat substitute foods into account.

A few studies have considered the effect of substitution related to taxing specific foods and find that the ultimate effect on total calorie consumption (and hence on body weight) would depend on substitutability and complementarity among products with different calorie intensities. Boizot-Szantaï and Etilé (2005) used French food-at-home expenditure data and analyzed the price effects of various foods on Body Mass Index (BMI). They show that the resulting price effect on weight was affected by the possibility of substitution between similar or diverse foods, and suggest that in the short term the effectiveness of a nutritional tax may be limited. Taxing one of the food components may cause substitutions that reduce the effectiveness of the policies to reduce overall calories intake.

A study based on weekly shopping records of 23 food categories in Denmark is one study that considers several food components – sweeteners, fiber and fat – at the same time. Smed, Jensen and Denver (2007) utilized the Almost Ideal Demand (AID) model to show if a sugar tax is applied, sugar demand is reduced but demand for saturated fat increases. If a tax on saturated fat as well as a subsidy on fiber is imposed, the demand of saturated fat will go down but the sugar demand will go up. The unwanted increase in sugar demand disappears when combining the saturated fat tax and fiber subsidy with tax on sugar (Smed, Jensen, and Denver, 2007).

Another issue is that the expenditure shares of food and consumption behaviors may differ among different socio-economic groups. In order to most effectively apply policies to reduce consumption of high calorie, high fat or sweetener intensive foods, policy analysts thus need to disaggregate food specific demand estimates according to socio-economic status, and assess the possible impact of policy changes on food consumption and welfare outcomes at a more disaggregated level in addition to the total effects. The estimated disaggregated effects can provide policymakers information on the direction and extent of possible tax changes, and identify those who stand to benefit or lose from the policy changes.

Differences in consumption across income groups have implications for the incidence and distributional effects of the taxes. Consumers at different income levels spend different portion of their income on foods. The share spent on foods is relatively large for consumers with lower income. Thus, tax policy that increases food prices will be regressive (Cash, Sunding, and Zilberman, 2005). From the investigation of the 2000 U.K. National Food Survey, Leicester and Windmeijer (2004) showed that the proportion of income spent on a “fat tax” for the poorest households is seven times that of richest households. Chouinard et al. (2007) showed that although there was little price elasticity variation for dairy products among different demographic groups, differences across income groups do occur due to different income elasticities and budget shares. A fat tax would be regressive with the tax being borne almost exclusively by low-income consumers. The loss of welfare for households with $20,000 annual income is twice that of households with $100,000 income in terms of dollar values while ten times in terms of fraction of equivalent variation in annual income.

In summary, most existing studies focused on the consumption tax on the snack foods or fat foods and found it is regressive although the magnitude of the welfare loss to consumers is small. It is important to note, however, that the findings on the regressive nature of these taxes may be overstated because low-income groups benefit the most – in a relative sense -- from the reduced consumption of caloric food via improvements in their health status. The use of a food tax is based on the assumption that the current food price involves only the direct cost of consumption but does not capture the potential future health-care cost that consuming high-calorie food might bring. Obesity imposes social costs related to health care. In order to fully account for the social costs of increased future health care, a food price should reflect and include both the direct food production costs as well as future potential medical care costs of treating obesity-related diseases. If the free market fails to incorporate all the costs, a food tax could be introduced to set the price faced by consumers to a level that also reflects future costs.

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 et al. 2004; and Sumner and Wohlgenant, 1985; among others). These added sweeteners are inputs used in food processing industries. We assume that there is infinite supply in the added sweeteners markets so that the added sweeteners’ prices (before tax) 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 they 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 corresponding to the price changes. By doing this, we abstract from the fact that health condition is an important component of consumers' 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 is 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 extent to which the cost 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 to 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.

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 function of pre-tax input price $\tilde{w}_{ik}$ and 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. 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, s_{ik} is the cost share of input k in total cost and whose input price is w_{ik}. We assume that final food producer prices PP_i are set above marginal cost with constant markup coefficient θ_i such that

$$\theta_i = \frac{PP_i - MC_i}{PP_i}, \qquad (2)$$

The producer price setting for the final product in food manufacturing industry i, PP_i is

$$PP_i = \frac{MC_i}{1-\theta_i}, \qquad (3)$$

The model from the producers' side captures the food processors' response to the change of the input prices. But by assuming the markup coefficient θ_i to be constant, we are abstracting away from the retailing sector, which act between the food processors and consumers. When the input price changes, the retailing sector may also adjust their pricing strategy to maximize their profit so that the markup is not always constant. An increase in the markup will cause the final price of the food to increase in addition to the impact of the input price changes and a decrease in the markup will cause the final price of the food to decrease in addition to the impact of the input price changes. For simplicity, we assume the markup does not change and only account for food processors' response to the change of the input prices. A variable markup could be accommodated without difficulty but inducing some clutter.

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 a s_{ik} increase in final food prices. Under the assumption of constant markup, the tax on sweetener prices is transmitted to consumers of sweetener-intensive foods through higher input prices and thus output prices. If a tax rate t_{ik} is applied to sweetener k , the input price of sweetener k is effectively $\tilde{w}_{ik}(1+t_{ik})$, then any change in the input tax rate changes the input price and output price by

$$d\ln w_{ik} = d\ln \tilde{w}_{ik}(1+t_{ik}) = d\ln(1+t_{ik})\,, \tag{4}$$

and

$$d\ln PP_i = d\ln\frac{MC_i}{1-\theta_i} = d\ln MC_i = \sum_k s_{ik} d\ln w_{ik} = \sum_k s_{ik} d\ln(1+t_{ik})\,. \tag{5}$$

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 food. The change of the usage of sweetener h caused by a tax on sweeteners k can be expressed as

$$d\ln x_{ih} = d\ln y_i + \sum_k s_{ik}\sigma_{ihk} d\ln w_{ik} = d\ln y_i + \sum_k \delta_{ihk} d\ln(1+t_{ik}). \tag{6}$$

where x_i is the quantity of the sweetener input 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

$$\delta_{ihk} = s_{ik}\sigma_{ihk} \text{ and } \delta_{ikk} = s_{ik}\sigma_{ikk}. \tag{7}$$

Consumer's side

On the consumer's side, we are mostly interested in the sweetener-intensive foods because sweetener consumption and consumer level effects are our main research focus. The LinQuad incomplete demand systems approach developed by LaFrance (LaFrance, 1998) is adopted to derive consumer demand equations and welfare evaluations. LinQuad system is linear in income and quadratic in price. This incomplete demand system fits well here because only a subset of all the foods is relevant to our analysis. It has a more common form than complete systems do 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 price vector for all the remaining foods $O=[O_1,...,O_z]'$, and I be the income level. These prices can include an ad valorem consumption tax. In this case, then 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 instrument we consider to abate sweetener consumption.

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

$$\underset{D,O}{Max}\ U(D,O) \quad s.t.\ P'D + P_O'O \le I \tag{8}$$

where U represents the utility function. The Marshallian demands $D = D(P', P_O', I)$ satisfying the above maximization problem have the following properties: (a) demands are positive, $D = D(P', P_O', I) > 0$; (b) demands are homogeneous of degree zero in prices and income, (c) the Slutsky substitution matrix $S = \frac{\partial D}{\partial P'} + \frac{\partial D}{\partial I} D'$ is symmetric and negative semi-definite; (d) income is strictly bigger than expenditures on the subset of the target foods, $P'D(P', P_O', I) < I$.
The LinQuad Marshallian demand equations are

$$D = \varepsilon + VP + \chi(I - \varepsilon' P - \frac{1}{2} P'VP), \tag{9}$$

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 fact that the expenditure on target foods is smaller than income is always guaranteed. The Marshallian own- and cross-price elasticities are

$$\begin{cases} \eta_{ii}^M = [v_{ii} - \chi_i(\varepsilon_i + \sum_k v_{ik} P_k)] \dfrac{P_i}{D_i} \\ \eta_{ij}^M = [v_{ij} - \chi_i(\varepsilon_j + \sum_k v_{jk} P_k)] \dfrac{P_j}{D_i} \end{cases} \tag{10}$$

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

Welfare

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. For example, instead of normal soft drink, consumers may drink non-sugar and low-calorie drinks if the caloric sweeteners are taxed. In this paper 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 health condition is an important component of consumers' utility function.

In the following policy simulations, we set a certain targeted decrease in added sweeteners consumption as the target of the tax policy and look for the optimal tax designs to achieve the desired goal. That is, we fix the reduction of added sweetener use and evaluate how the changes in sweetener intake are determined across foods and across income groups. In this way, we fix the health effects to be achieved through reduced intake of added sweetener as the equivalence basis of the policy target. Although this will overstate the negative welfare changes on final consumers, the positive health effect is hard to measure in the short run. We gauge the decrease of sweeteners consumption and measure the EV of the policy target. Most previous studies have overstated the regressive nature of tax because they do not measure the health effects on consumers. This is also true for us. In our paper, we also measure the upper bound on the regressive nature of different taxes. In addition, the narrow focus on EV is not comprehensive because we do not address the impacts on producers' surplus and the government tax revenue.

Suppose the prices of target foods change from P^0 to P^1 because of changes in either inputs or final goods taxes. Then the equivalent variation, EV, derived from equation (9), shows the amount of money that the consumers need to pay before a price increase to keep their utility level constant. That is:

$$EV = (I - \varepsilon' P^1 - \frac{1}{2} P^1 ' V P^1) \exp(\chi P^0 - \chi P^1) - (I - \varepsilon' P^0 - \frac{1}{2} P^0 ' V P^0) . \qquad (11)$$

If the tax on the final products τ_i is changed then

$$P_i^1 = PP_i^0 (1 + \tau_i) , \qquad (12)$$

and

$$d \ln P_i = d \ln(1 + \tau_i) . \qquad (13)$$

If the tax imposed on the sweeteners inputs is changed, we have derived from the analysis of the food processing industry that $d \ln PP_i = \sum_k s_{ik} d \ln w_{ik} = \sum_k s_{ik} d \ln(1 + t_{ik})$, so

$$d \ln P_i = d \ln PP_i = \sum_k s_{ik} d \ln w_{ik} = \sum_k s_{ik} d \ln(1 + t_{ik}) \qquad (14)$$

Then P^1 can be substituted into the *EV* equation to get the welfare changes.

We apply the LinQuad demand systems for all households and disaggregated income groups respectively to evaluate how to achieve the policy target of reducing the added sweeteners consumption by a fixed amount and minimize the consumer welfare loss. Two alternative approaches are used: taxing final sweetener-intensive goods and taxing sweetener inputs. The consumption tax affects consumers through the price changes of final products. In contrast, the input tax, affects the mix of inputs used by food processors, and, ultimately, the final goods consumed.

Disaggregated Income Groups

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 effects on the food demand for each of the n disaggregated income group, that is the partial derivatives of demand with respective to income, χ, are equal across the income groups.

The disaggregated food demands for each income group are

$$\begin{cases} D_1 = \varepsilon_1 + V_1 P + \chi(I_1 - P' \varepsilon_1 - \frac{1}{2} P' V_1 P) \\ D_2 = \varepsilon_2 + V_2 P + \chi(I_2 - P' \varepsilon_2 - \frac{1}{2} P' V_2 P) \\ \vdots \\ D_n = \varepsilon_n + V_n P + \chi(I_n - P' \varepsilon_n - \frac{1}{2} P' V_n P) \end{cases} . \qquad (15)$$

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:

$$\eta_{ijAll}^{M} = \frac{D_{i1}}{D_{iAll}}\eta_{ij1}^{M} + \frac{D_{i2}}{D_{iAll}}\eta_{ij2}^{M} + \cdots + \frac{D_{in}}{D_{iAll}}\eta_{ijn}^{M}. \qquad (16)$$

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. They can be expressed as equation (10).

Under the assumptions that $V_1 = V_2 = \cdots = V_n = V$, equations (15) and (16) 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 in income levels. So with the common component in ε and the assumption that the 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 evaluated as in equation (11) for each of the income groups. The differences across disaggregated income groups come from differences in income and the value of parameters.

Data and Calibration

Data used come from several sources. Estimates for input cost shares are from the 2002 Economic Census Industry Series Reports. Other data are on consumption (food availability) and the demand parameters used to calculate the LinQuad demand system. The data calculations are described in more detail in the following sections.

Production of sweetener-intensive foods

To measure the cost share of sweeteners in the food production process, we use data on the materials consumed by each industry from the Economic Census Industry Series Report (U.S. Department of Commerce, 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.

Material Cost Shares

Data in our study are based on the 2002 Economic Census. All dollar values presented are expressed in 2002 dollars. From the Economic Census Industry report, we identify four sweeteners, which are used in the food processing industries: Sugars (sugar from cane and beet); Corn Sweeteners; Other (caloric) Sweeteners; and Artificial Sweeteners. Table 1 provides the material code categories used in the classification into the four sweetener groups.

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. In doing so, some caveats are in order.

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. Table 2 presents categories of sweetener-intensive intermediate materials. In the table, the major sweetener-intensive intermediate materials are aggregated into eight groups: Fluid milk; Cheese; Dry, condensed and evaporated milk; Ice cream and yogurt mix; Prepared mixes; Flour; Liquid beverage base; and Chocolate. As example, the manufacturing industry "Fluid milk manufacturing" (NAICS 311511) uses as inputs the sweetener-intensive intermediate materials ice cream mix, sherbet mix, yogurt mix and chocolate. These sweetener-intensive intermediate materials contain relatively large amounts of sugar, corn sweetener, artificial sweetener and other sweeteners. When calculating the cost share of sweeteners in the fluid milk manufacturing industry, the sweeteners' value contained in these sweetener-intensive intermediate materials is included in addition to the direct use of the sweeteners in Table 1.

To approximate what kind of sweeteners and how much of each are contained in the sweetener-intensive intermediate materials, we matched the eight aggregated intermediate materials groups to the NAICS industries by using a representative industry among the NAICS industries for each of the intermediate materials products. The matched intermediate materials product groups and representative industries are shown in Table 2. Once the sweeteners ingredient shares in each of the eight intermediate materials groups were calculated, they were applied to all other industries which have the specific intermediate materials as ingredient. For example, the sweeteners share of the "Fluid milk manufacturing" product group (NAICS 311511) was used as proxy for the sweeteners ratio of fluid milk used as ingredient input in other industries.

Targeted Sweetener Intensive Foods

Next, we calculate the value of sweetener inputs in food industries and determined the most sweetener-intensive food industries. The products of the industries, the foods, are the focus of our analysis. Table 3 lists the nine target sweetener-intensive foods and the food industries to which they are matched. Some foods could only be matched to part of a food industry group. This partial matching leads to the decomposition of these industries used in the later analysis. For example, the final product group "Juice" is matched to the segment of "Frozen juices, aides, drink, and cocktail" in the "Frozen fruit, juice, and vegetable manufacturing" (NAICS 311411) industry sector and the segment of "Canned fruit juices, nectars, and concentrates and fresh fruit juices and nectars" in the "Fruit and vegetable canning" (NAICS 311421) industry sector.

Proportion of Products to Direct Consumption

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 3. The eight corresponding representative industries of the sweetener-intensive intermediate materials have proportions less than 100%. For example, only 16.42% of the output of the manufacturing industry "Flavoring syrup and concentrate manufacturing" (NAICS 311930) is consumed directly by consumers, the remaining 83.58% of the output goes to the manufacturing industry "Soft drink manufacturing" industry as ingredients. For refined sugar, the manufacturing industry Cane sugar refining" (NAICS 311312) and "Beet sugar manufacturing" (NAICS

311313) plus the import of refined sugar make the total refined sugar supply. Consumers consume refined sugar directly and indirectly when manufacturers in other industries use refined sugar as ingredients. The proportion of refined sugar that consumers consume directly is estimated as 58.02% (U.S. Department of Commerce, Census Bureau, 2004). Other sweetener-intensive food industries have none or only small proportion of their outputs used as inputs.

Value of Sweeteners and Cost Share

Table 4 provides the data for the values and shares of the sweeteners in the nine target sweetener-intensive foods (those listed in Table 3). 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 contained in the nine target sweetener-intensive foods is taken by the final food product group "Soft drink"; and 44.93% of the Other Sweeteners contained in the nine target sweetener-intensive foods 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 "sweetest" (most sweetener intensive) foods. The quantities of sweeteners in the nine target sweetener-intensive foods are the result of dividing the values of the sweeteners by their prices. Table 5 provides the calculated cost shares of the four sweeteners in the nine target foods.

Consumption

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, 2008b) needed 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 use the adjustment ratio λ to convert the value of shipments from production y to consumption D.

$$D = \lambda y \tag{17}$$

The values of the adjustment ratio λ are listed in Table 3. For food groups which do not have matches in the food availability dataset, the adjustment ratios were set to be one. Values greater than one imply imports to the sector. The sweeteners usage in the manufacturing sector can also be converted to sweeteners consumption by the consumers using the same adjustment ratio λ.

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 households by disaggregated income groups, data for these two sets of household aggregates are discussed separately.

Data for all households:

(1) Income elasticities η_{iI} and price elasticities η_{ii}^M, η_{ij}^M

The income and price elasticities were obtained from two sources: the USDA/ERS Commodity and Food Elasticity Database 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. (2010) provides detailed elasticities for the dairy. We take the average of the elasticities for each of the food groups, after removing those elasticities which 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 6. 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 which indicate that they are inferior goods.

The cross-price elasticities from the same sources are listed in Table 7. All the available cross-price elasticities are very small in absolute value, which means the substitutability or complementarily among the final products will be limited.

(2) Income I

The 2002 Consumer Expenditure Survey (CEX) (Bureau of Labor of Statistics (BLS), 2008) reports the total number of households represented in the survey as 112,108 thousand, and the average household income level after taxes as $46,934. Based on these values, the annual income for all the households is $5.26 trillion.

(3) Price P_i

All final food prices are initially set at $1 per unit. The consumption units are unknown but results are independent of the price normalization.

(4) Marshallian demands D_i

As all the prices are set at $1 per unit, we can use the adjusted value of shipment of the foods in dollar values as physical quantities.

Data for disaggregated income groups:

The 2002 Consumer Expenditure Survey (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 8). The values of at home food expenditures in the CEX were used to distribute the total adjusted industry level value of shipments in 2002 Economic Census Industry Series Reports (Manufacturing) across the five income groups. The matchup between the food categories in the two surveys is detailed in the footnote to Table 8. Although there are some differences between the composition of food at home and food away from home across the food categories, we assumed that the expenditure distribution on these nine target food groups are the same for at home and away from home expenditures. There are no data for food away from home at a disaggregated (food group) level in the CEX. All the food prices are initially set at $1 per unit as what we did in the "all households" scenario.

Production technology in food industries

As shown in Table 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%

(except for the “Sweetener products” industry for which they account for 12.37%) of the total costs of production. We integrate all other materials used in the manufacturing process into one group called “All Other Inputs”. For most sweetener-intensive food industries, this aggregate represents more than 96% of the total costs. 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 industry estimates provided by Goodwin and Brester (1995). The diagonal elements, which represent the own-price elasticity of sweeteners are set to be -0.48. In the upper triangle elements, the cross-price elasticity of Sugars with respect to Corn Sweeteners is set to be 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 be 0.01; and the cross-price elasticities of Sugars, Corn Sweeteners, and Other Sweeteners with respect to Artificial Sweeteners are all set to be 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 Hessian matrix in the production. Miao, Beghin and Jensen, Appendix D provides a table that summarizes the values.

Once the first four columns of the input price elasticity matrix are set, the last column which represents 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. The concavity curvature of the cost function requires that the Hessian matrix be negative semi-definite. The above rules constrain elasticity values when some sweeteners’ cost shares are very small or equal to zero. In this situation, the corresponding elements in upper-triangle of the input price elasticity matrix need to be set to smaller values to satisfy the homogeneity condition.

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. For “Ice cream / yogurt”, these two numbers are set to be 0.0002 and 0.0004. 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. Although some sweeteners are not used in the manufacturing process, their cross-price elasticities are set to non-zero values because manufacturers’ choice of the sweeteners are determined by the relative price of inputs. All the sweeteners have the potential to be used once the relative prices of inputs reach some levels. Besides that, the fact that the integrated “All Other Inputs” take a large proportion of the total cost leads to the outcome that its own-price elasticity is very small.

Results

Calibration of demand systems

We calibrate six LinQuad demand systems. One is for all households with nine sweetener-intensive foods using elasticities from Table 6 and 7. The other five systems for quintile income groups are solved by utilizing the partial derivative of demand to income for all household and setting the parameter matrix of quadratic price term to be equal among different income groups. Based on equations (9)-(10) and equations (15)-(16), we get the results of parameter values for the six LinQuad demand systems. The parameter for the income term in the demand, χ, is the same for all households and quintile 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. The parameter matrix for the quadratic term of the price for all households V_{All} is five times that for quintile income group V, also by construction, so consumers behave the same way in terms of price and income preferences across the quintile income groups on an individual basis.

With these parameters, the Marshallian price elasticity matrix for all households and disaggregated income groups are recovered. The one for all households is displayed in Table 9. Separate Marshallian price elasticity matrices for disaggregated income groups are provided in Miao, Beghin, and Jensen (2010, Appendix F). The absolute values of the own-price elasticities for each food category are monotonically decreasing from the lowest 20% quintile to the highest 20% quintile income group, which indicates that poor consumers are more sensitive to the price variations than rich consumers. The parameters are used in the calculation of the demand for the final products, the sweeteners and the welfare evaluation.

Simulation and welfare evaluation

To compare the efficiency and regressive nature of the two tax instruments, the two taxes are designed to reduce the quantity of all sweeteners (sugar equivalent)[1] that all households consume by 10% (around 13.13 grams per capita daily sugar equivalent added sweeteners consumption which contain 52.54 calories) and to minimize the associated market welfare loss to all households. The reduction of sweetener quantity is the basis of equivalence to compare the scenarios. The parameter values from the LinQuad calculation allow simulation of sweeteners consumption changes caused by policy (tax) changes, and estimation of the corresponding changes on food demand, sweeteners consumption, and EV. We simulate four types of policy shocks: a tax on the price of final products; a tax on the price of caloric sweeteners; a tax on the price of all sweeteners, and tax on the price of individual sweeteners.

<u>Tax on final products</u>

First, we consider the case when an ad valorem consumption tax is imposed on the nine categories of sweetener-intensive final products as discussed in Table 3. To reach the goal 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 rate is estimated to be 39.30% on the final product group "Sweetener Products" and at rates that are much smaller or negligible on the other eight final products. 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. Table 10 shows the initial per capita food demand, real expenditure, sweeteners consumption, the percentage change for each measure and the estimated market welfare change on nine foods for all households with the simulated tax imposed on the price of final products.

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[1] The quantity of total sweeteners is converted into sugar equivalent based on the sweeteners' calories content. Cane sugar and Beet sugars are relatively pure sucrose. They have approximately 4 kcal per gram. HFCS are the primary Corn Sweeteners in the United States. It has approximately 3 kcal per gram. As a representative of Other Sweeteners, honey has approximately 3 kcal per gram. Aspartame is the most popular Artificial Sweeteners currently used in the U.S. food industry. It has approximately 4 kcal per gram.

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” before tax is imposed. 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). Demand decreases the most (-19.82%) in the group of “Sweetener products” with the simulated tax rate imposed on the price of final products. The demand for “Condiments / Spices” also decreases by a small amount. Demands for all other foods increase slightly through substitution effects.

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. 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. 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 rates as the final products consumed do.

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%. 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 the final product group “Sweetener products” and this food group has the highest rank in the distribution of Sugars and Artificial Sweeteners. Per capita real expenditure on all nine foods increases by 1.86% from the baseline condition of $726.13 per capita in 2002. The per capita welfare loss caused by the tax is $31.00, which represents 0.17% of the income.

The corresponding changes to the above-simulated tax on the price of final products were also computed for the five quintile income groups. All five income groups have large decreases in the demand for food category “Sweetener products”, small decreases in the food category “Condiments / Spices”, and increases in the other seven food categories. The absolute value of the rates of change in most food categories follows a monotonically decreasing trend from the lowest 20% quintile to the highest 20% quintile because low income consumers respond more strongly to price variations than do consumers with high income. The decrease for all households in the food category of “Sweetener products” is 19.820%. It is the average of the individual groups’ decreases from 29.277% for the highest income group to 14.032% for the lowest income group. But for other food categories, the differences of demand rates of change across income groups are relatively small. For example, the rates of change in demand for “Soft drink” remain almost flat throughout the income groups.

Since the initial consumptions of final products are not monotonically increasing or decreasing across the five income groups, the initial consumption 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 the rate of -13.10%) to the highest quintile income group (with the 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 sweeteners, the drop of the sweeteners quantity decreases monotonically from lowest quintile income group to highest quintile income group. Table 11 displays the sweeteners consumption quantity changes for all households and then disaggregated income groups under different tax policy situations.

Table 12 compares the real expenditure change and market welfare loss for all households and quintile income groups with the various tax scenarios. 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 lowest quintile income group to 2.70% for highest quintile income group monotonically as shown in Table 12. Although the per-capita real expenditure increases the most for the highest income group and the per capita EV is highest with the highest income group, the welfare loss represents 0.60% of income for the lowest quintile income group while only 0.10% of income for the highest quintile income group. The proportion of the market welfare loss in income for lowest income group is six times that for highest income group, which indicates that this consumption tax is regressive but its overall impact is small.

Finally, we also compare this tax with a tax on soft drinks which is often considered in policy debates. To reduce the sweetener consumption by 10%, the consumption tax on soft drinks is 63.19%. The associated per capita EV is $52.92, which takes 0.28% of the income. Hence it is clearly less efficient but of the same order of magnitude.

Tax on Caloric Sweetener inputs combined

Next, we simulate a tax imposed on caloric sweeteners inputs. Under the assumptions that the processor's markup is constant and consumer demand is not perfectly elastic, the tax on sweeteners' price is fully passed on to consumers of sweetener-intensive foods through higher output prices. The changes for all households in food demand, real expenditure, sweeteners consumption and welfare are shown in Table 13. 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 very small rate on Other Sweeteners. This simulated tax will 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 adjustment in their production process via scale and substitution effects. Scale effects result from the consumers' demand adjusting to higher unit cost hence higher consumer prices. Further, the variation of sweetener input prices lead food processors to substitute away 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. There is some decrease in the usage of Artificial Sweeteners in the "Sweetener product" group. The quantity of Sugars declines the most in the "Sweetener products" and the quantity of Corn Sweeteners declines the most for the "Soft drinks".

The contribution of "Soft drinks" in aggregate-sweetener use falls the most. "Processed fruits and vegetables", "Juice", and "Sweetener products" see their contribution fall by more than 10%. Accounting for the sweeteners change in all nine foods together, the Corn Sweeteners quantity decreases the most (by 12.41%), and the Sugars quantity second (by 8.95%). The quantities of Other Sweeteners and Artificial Sweeteners increase as they are substitutes to the taxed sweeteners. In sum, the sugar equivalent sweetener quantity is reduced by 10% again by design.

The use of Sugars and Corn Sweeteners decreases due to the increase in their prices. However, the cost of all four types of sweeteners goes up as the increase in prices exceeds the drop in quantities because the inputs are price-inelastic. This tax on Caloric Sweeteners causes the per capita real expenditure to increase 0.27%, at a rate smaller than occurs when tax is on the price of final products. The per capita EV is $5.98 (or 0.032% of the per capita income), which is also smaller than the one caused by the consumption tax on the price of final products.

Detailed simulation results on the five-quintile income groups with the tax on Caloric Sweeteners (results not presented here) 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 other food categories. The comparison across the five income groups shows that for most food categories, demand drops less as the income goes up as a consequence of difference in the price elasticities for the different income groups. The sugar equivalent quantity of added sweeteners consumed by all households is reduced by 10%, with an average of decrease 10.45% for the lowest quintile income group; 10.19% for the second quintile; 10.04% for the third quintile; 9.90% for the fourth quintile; and 9.73% for the highest quintile. The quantities of Sugars and Corn Sweeteners used in all nine foods decrease while the quantities of Other Sweeteners and Artificial Sweeteners increase. 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 changes 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.

The changes on the real expenditure and market welfare with tax on Caloric Sweeteners are also provided in Table 12. The per capita real expenditure changes move at ascending rates from 0.007% for lowest income group to 0.43% for the highest 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 for lowest income group and 0.02% of the income for the highest income group. The proportion of the market welfare loss in income for the lowest income group is six times that for 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 greater burden on poor consumers. However, the welfare loss is much smaller in the case of the input tax than for the case of the consumer tax. Hence, the tax burden on the poor is reduced with the input tax.

Tax on Individual Sweetener input

Finally, we consider the case when the tax is sequentially imposed on individual sweeteners. We are motivated to investigate the scenarios of taxing Sugar and Corn Sweeteners. The health literature often discusses whether the intake of sugar and HFCS causes obesity, hence a focus on these two major sweeteners Table 14 shows per capita food demand, real expenditure, sweeteners consumption, and the market welfare changes of nine foods for all households with a tax imposed on Sugars or Corn Sweeteners to reduce the sugar equivalent quantity of all sweeteners by 10% and minimize the associated market welfare loss. It turns out that a tax of 61.25% tax on the price of Sugars or a tax of 156.85% on the price of Corn sweeteners is needed to reach the 10% reduction target.

With the application of the tax on Sugars, manufacturers substitute from Sugars to other types of sweeteners. 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. These claims may not be confirmed, but it is still interesting to look at the consequences of singling out a caloric sweetener with a tax rather than another one. "Sweeteners products" consumption exhibits the highest decrease (-2.63%) because it uses Sugars the most. Considering all the Sugar in nine food categories together, the consumption quantity of Sugars decreases 22.09% while the associated expenditure increases. Other types of sweeteners exhibit increases both in their quantities and values. The per capita real expenditure on all nine foods increases by 0.46%. The per capita EV is about $6.65 and it takes 0.035% of the income.

With the application of the tax on Corn Sweeteners, manufacturers switch away from Corn Sweeteners to other types of sweeteners. "Soft drink" has the highest (3.02%) decrease in its food demand because it uses Corn Sweeteners the most. Counting all the Sugars in nine food categories together, the consumption quantity of Corn Sweeteners decreases (37.64%) while its consumption value increases. Other types of sweeteners increase both in their quantity and value. The per capita real expenditure of all nine foods increases by 0.09%. The per capita EV is about $6.90 and it takes 0.037% of the income.

In the case of an individual tax on the price of the Sugars input, results for the disaggregated income groups show differences across the income groups. The absolute value of the change on food demand goes down as income goes up. For the sweeteners, the absolute values of the rates of change in quantities of Sugars decrease monotonically from low income to high-income groups, while the absolute values of the proportional changes in quantities of Corn Sweeteners and Other Sweeteners increase in ascending order from low to high-income groups. The rates of change in quantities of Artificial Sweeteners increase from the negative values for lowest income group to positive values for highest income group. The values of all four types of sweeteners consumed rise. When a tax was applied to the price of Corn Sweeteners instead of sugar, the changes are similar to those for changes in the price of sugar except that the rates of change in quantities of Sugars are not monotonic. The values of all four types of sweeteners consumed rise.

The real expenditure and market welfare changes are shown in Table 12 along with the outcomes for other cases. With the tax on Sugars, the real expenditure increases monotonically from 0.25% for lowest income group to 0.60% for highest income groups. With the tax on Corn Sweeteners, the real expenditures decrease for the lowest 20% and second 20% quintile income groups but increase for the other three quintile income groups. For the market welfare evaluation, the absolute values of the per capita EV under both situations have a U-shaped trend across the income groups, but the fraction of EV in income decrease from the lowest income group to the highest income group. The tax on individual sweeteners is regressive too but the welfare loss to the poor is much lower than in the case of the consumer tax.

Sensitivity analysis

Doubling the sweetener reduction

All the above simulations are designed to reduce the sugar equivalent quantity of all sweeteners by 10%. In order to test whether the results are linear when the policy target changes, we simulate a 20% reduction (around 26.27. grams per capita daily sugar equivalent added sweeteners consumption which contain 105.07 calories) and minimize the associated market welfare loss**.**

For the case of a 20% reduction, the tax on the price of the final products would need to be 78.60% for the “Sweetener products” food group, and smaller numbers for other food categories. This causes a 39.64% decrease in “Sweetener products” consumption, 0.03% decrease in “Condiments / Spices” consumption, and some increase in other foods. We find that the simulated tax and the food demand changes are around twice those that occur when the sugar equivalent quantity of all sweeteners is reduced by 10%. The quantities of all four types of sweeteners fall. Sugars and Artificial Sweeteners fall more than do Corn Sweeteners and Other Sweeteners. The proportional decreases are about double those of the rates when sugar equivalent quantity of all sweeteners is reduced by 10%. But the relative change of the real expenditure does not vary much (from 1.86% to 1.85%) when the target goes from a 10% to a 20% reduction. The per capita EV is about $55.18 and is less than twice of the per capita EV $31.00 when the goal is a 10% decrease. It is about 0.29% of the income.

Doubling the targeted reduction in sugar equivalent quantity of all sweeteners requires a tax of 80.59% on Sugars, 117.12% on Corn Sweeteners, and small rate on Other Sweeteners. These values are almost three times those of the tax rates with the initial target of a 10% reduction of sweetener consumption. The combined results of changes in the tax rates are more than twice those of the rates when sugar equivalent quantity of all sweeteners is reduced by 10% except for Corn Sweeteners, whose proportional decrease is less than doubled. The non-linearity in results exists because sweetener input taxes are weighted by sweetener cost shares in imposing the effects on the price of final products, and further effects on the demand of foods and sweeteners consumption. The relative change of the real expenditure, EV, and fraction of EV in income are all more than twice those that occur under the 10% reduction target. Per capita EV is about $13.95 and it is about 0.074% of the income.

Parameter assumptions

For the simulation results on sweetener consumption, change comes from two sources: one is the substitution among final products chosen by consumers; the other is the substitution among sweeteners in production process managed by the manufacturers. The real values of the substitutability among sweeteners are unknown so all our above simulations are based on the values we assumed for the input price elasticities. To test how the results depend on the input elasticities, we decreased all the cross-price elasticities between sweeteners by one half in the upper-triangles of 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 quantify 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 (Table 13). The results are similar for other configurations of the taxes (taxing all sweeteners, Sugars or Corn sweeteners). From these simulations, we determine that if the substitutability among sweeteners is decreased by half, the tax required to reach the desired goal is reduced, but only a little. The input price elasticities play a less important role than do the demand price elasticities for the final products. The simulation results do not depend much on the parameter values assumed.

Summary and Discussion

This paper has analyzed the use of 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 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 and decrease in the demand of “Sweetener products” and all four types of sweeteners decrease in quantity. Taxing Caloric Sweeteners as inputs causes relatively large decreases in final consumption of final goods among “Sweetener products” and “Soft drink” 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. Imposing a tax on Sugars and on Corn Sweeteners causes the demand in “Sweetener products” and “Soft drink” to fall the most. And these results 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.

The consumer welfare impacts of various taxes were measured and compared. We showed that increasing the price of the sweetener-intensive foods, whether by taxing the final products or by taxing sweeteners components, 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 Caloric Sweeteners input tax. From an overall perspective, 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. Based on these findings, we conclude that both the tax on the price of sweetener-intensive final products and the tax on the sweeteners are regressive.

All the existing studies to date including this paper over-estimate the problem of regressiveness because the reduction in the sweeteners consumption is relatively more significant for low-income group than for high-income group. So the poor benefit more than the rich if health status is incorporated into the welfare evaluation. A possible way to correct the regressiveness would be to impose decreasing weights on the EV from low-income group to high-income group when designing the policy target. With higher weight on the EV of poor households, the aversion to regressive schemes is better addressed.

Overall, the tax on sweeteners has a smaller impact on the consumers’ real expenditures and market welfare than does the tax on final products. The tax on Caloric Sweeteners causes the smaller loss to the consumers on a per capita base ($5.98) compared to taxing all sweeteners. A tax on Sugars or Corn Sweeteners has a higher effect, but not much ($6.65 and $6.90 respectively). Tax on the price of final products poses a welfare loss burden about five times as great on all households and for each income group compared with the tax on Caloric Sweeteners. So taxing Caloric Sweeteners is the most efficient way to achieve the policy target.

It should be noted that 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 and expenditure. In reality, there exists a markup or gross margin between the wholesale and retail value of consumption. The gross margin for the food and beverage stores is estimated to be 28.3% of sales in 2001 by Bureau of Labor Statistics and Annual Benchmark report for Retail Trade and Food Services in Census Bureau (Nakamura, 2008). In aggregate, the wholesale values would need to be rescaled by 1.39 to get the retail value of consumption. The rescaled values of food consumption, real expenditure, sweeteners consumption and EV will reflect the real impacts on consumers.

Limitations and Extensions

There are obvious limitations in our analysis. First, we only account for the consumption effect of the policy instruments. Long-run health benefits derived from reduced sweetener consumption (e.g., reduced obesity) are not incorporated in the welfare measurement among the policy effects. So we overstate the loss in welfare and the regressive nature of the tax. The poor group with the largest initial added sweeteners consumption would have the greatest reduction in consumption thus would be likely to experience greater health benefits. Second, food items included in the investigation are relatively limited. Some caloric-intensive foods are not included (such as food with fat). Smed, Jensen and Denver (2007) found the reduction in sweetened products was accompanied by increased demand for higher fat foods. Future extension of our research should take into account the substitution between the added sugar and fat component or go to the sub food sectors to capture sector-specific effects.

Third, the composition of food at home and food away from home may be quite different. Food at home might be much healthier than food away from home (Schroeter and Lusk, 2007) which is often highly caloric. By more carefully accounting for expenditure differences in the distribution of different food at home to expenditures on food away from home, our results may change. Data are relatively limited in this regard. Fourth, and finally, this analysis enables evaluation of the effects for different demographic groups but we only include income as the demographic variable in this paper. Other demographic variables 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. 1998. "Examining Quantity and Quality Effects of Restricting Nitrogen Applications to Feedgrains." *American Journal of Agricultural Economics* 80: 369-381.

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

Beghin, J.C. and H.H. Jensen. 2008. "Farm Policies and Added Sugars in US Diets." *Food Policy* 33: 480-488.

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 EAAE (European Association of Agricultural Economists), Copenhagen, Denmark, 24-27 August.

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

Cash, S.B., D.L. Sunding, and D. Zilberman. 2005. "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: 167-174

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

—. 2010. "Milk Marketing Order Winners and Losers." *Applied Economic Perspectives and Policy* 32(1):59-76.

Farah, H. and J. Buzby. 2005. "U.S. Food Consumption Up 16 Percent since 1970". Amber Waves, United States Department of Agriculture, Economic Research Service. http://www.ers.usda.gov/AmberWaves/November05/Findings/USFoodConsumption.htm (accessed January. 2009)

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

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

Gustavsen, G. 2005. "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.

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

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

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

Miao, Z., J. Beghin, and H.H. Jensen. 2010. "Taxing Sweets: Sweetener Input Tax or Final Consumption Tax?" CARD Working Paper, Iowa State University.

Mullen, J.D., M.K. Wohlgenant, and D.E. Farris. 1988. “Input Substitution and the Distribution of Surplus Grains from Lower U.S. Beef-Processing Costs.” *American Journal of Agricultural Economics* 70: 245-254.

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

National Center for Health Statistics. 2006. “Prevalence of Overweight and Obesity Among Adults : United States, 2003-2004.” Health E-Stats. http://www.cdc.gov/nchs/products/pubs/pubd/hestats/overweight/overwght_adult_03.htm#Table%201 (accessed December. 2008)

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

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

Santarossa, J.M. and D.D. Mainland. 2003. “Employing an environmental taxation mechanism to reduce fat intake.” In Chern, W and Rickertsen, K, ed. *Health, Nutrition and Food Demand*. Oxford : CABI Publishing, pp. 223-245.

Schmidhuber, J. 2004. “The Growing Global Obesity Problem: Some Policy Options to Address It.” *Journal of Agricultural and Development Economics* 1(2): 272-290.

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.

Schroeter, C. and J. Lusk. 2007. “The impact of Economic Factors on Consumer Health”. Selected paper presented at the WAEA (Western Agricultural Economic Association) Annual Meeting, Portland, Oregon, 29 July-1 August.

Smed, S., J.D. Jensen and S. Denver. 2005. “Socio-economic Characteristics and the Effect of Taxation as a Health Policy Instrument.” *Food Policy* 32: 5-6..

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

U.S. Census of Bureau. 2004. Economic Census, Manufacturing Reports, Industry Series, 2002. U.S. Department of Commerce, Census Bureau.
www.census.gov/econ/census02/guide/INDRPT31.HTM (accessed April, 2008).

U.S. Department of Agriculture, Economic Research Service (USDA/ERS). 1992. “Weights, Measures, and Conversion Factors for Agricultural Commodities and Their Products”. Agricultural Handbook No. 697.

——. 2008a. “Commodity and Food Elasticities” http://www.ers.usda.gov/Data/Elasticities/ (accessed August. 2008)

——. 2008b. “Food Availability Data System”. http://www.ers.usda.gov/Data/FoodConsumption/FoodAvailIndex.htm (accessed September. 2008)

Table 1. Categories of the Sweeteners in the U.S. Food Manufacturing Industry

Sweeteners Group	Material code[a]	Materials consumed[a]
Sugars (Sugars from cane or beet)	31131001	Sugar, cane and beet (sugar solids)
	31131005	Sugar, cane and beet (sugar solids), excluding brown
	31131009	Brown sugar, cane and beet (sugar solids)
	31131100	Raw cane sugar (converted to 96 percent basis)
	11193000	Sugar cane
	11199100	Sugar beets
Corn sweeteners	31122101	Corn syrup
	31122103	High fructose corn syrup (HFCS) (solids)
	31122105	Fructose corn syrup (50 percent or less) (solids)
	31122107	Fructose corn syrup (50 percent or more) (solids)
	31122111	Glucose syrup (corn syrup), conventional and regular (solids)
	31122117	Crystalline fructose (dry fructose)
	31122119	Dextrose and corn syrup, including corn syrup solids (dry weight)
Other sweeteners	31100003	Other natural sweeteners (including dextrose, honey, molasses, and blends of corn sweeteners and sugar) (solids)
Artificial sweeteners	32510053	Sugar substitutes (mannitol, sorbitol, etc.)
	32510057	Artificial sweeteners (solids)

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

Table 2. Categories of Sweetener-Intensive Intermediate Materials in the U.S. Food Manufacturing Industry

Selected intermediate products	Representative industry NAICS code	Representative industry NAICS definition
Fluid milk	311511	Fluid milk mfg
Cheese	311513	Cheese mfg
Dry, condensed and evaporated milk	311514	Dry, condensed, and evaporated dairy product mfg
Ice cream and yogurt mixes	311520	Ice cream and frozen dessert mfg
Prepared mixes	311822	Flour mixes and dough mfg from purchased flour
Flour	311211	Flour milling
Liquid beverage base	311930	Flavoring syrup and concentrate mfg
Chocolate	311320	Chocolate and confectionery mfg from cacao beans

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

Table 3. Nine Target Sweetener-Intensive Foods in the U.S. Food Manufacturing Industry

Sweetener Intensive Foods	NAICS Code	NAICS Definition	Proportion of Products going to Direct Consumption (%)	Consumption Adjustment Ratio[a]
Milk (Fluid milk / Dry, condensed, and evaporated dairy product)	311511	Fluid milk mfg	91.06	1.00
	311514	Dry, condensed, and evaporated dairy product mfg	86.30	0.75
Cheese	311513	Cheese mfg	81.08	1.03
Ice cream / yogurt	311520	Ice cream and 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, and other pastries mfg	100	0.75
	311821	Cookie and cracker mfg	100	0.75
	311822	Flour mixes and dough mfg from purchased flour	91.94	0.75
Soft drink	312111	Soft drink mfg	100	1.00
	311930	Flavoring syrup and concentrate mfg	16.42	1.00
Juice	311411[b]	Frozen fruit, juice and vegetable mfg	100	1.78
	311421[c]	Fruit and vegetable canning	100	1.52
Sweetener products (Refined sugar / Confectionery / Honey, Molasses, Syrup and Gelatin pudding mix / Jam and jelly)	311312 / 311313	Cane sugar refining / Beet sugar manufacturing	58.02	1.02
	311320	Chocolate and 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
	311421[e]	Fruit and vegetable canning	100	1.52
Processed fruits and vegetables	311423[f]	Dried and dehydrated food mfg	100	0.63

(Dried fruits and vegetables / Tomato sauce/Catsup)	311421[g]	Fruit and vegetable canning	100	1.52
Condiments / Spices (Mayonnaise, dressing, and other prepared sauce+ Spice and extract)	311941	Mayonnaise, dressing, and other prepared sauce mfg	100	1.00
	311942	Spice and extract mfg	100	4.28

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

a- Consumption adjustment ratios (the ratio of food disappearance to food production) are based on USDA/ERS Food Availability Data System.

b- "Juice" was matched to segment of "Frozen juices, aides, drink, and cocktail" of food manufacturing industry 311411.

c- "Juice" was matched to segment of "Canned fruit juices, nectars, and concentrates + Fresh fruit juices and nectars" of food manufacturing industry 311421.

d- "Sweetener products" was matched to segment of "Desserts (ready-to-mix) + Sweetening syrup and molasses" of food manufacturing industry 311999.

e- "Sweetener products" was matched to segment of "Canned jams, jellies and preserves" of food manufacturing industry 311421.

f- "Processed fruits and vegetables" was matched to segment of "Dried and dehydrated fruits and vegetables, including freeze-dried" of food manufacturing industry 311423.

g- "Processed fruits and vegetables" was matched to segment of "Canned catsup and other tomato based sauce" of food manufacturing industry 311421.

Table 4. Values and Shares of Sweeteners in Nine Target Sweetener-Intensive U.S. Food Manufacturing Industry

Sweetener Intensive Food	Values of Sweeteners (million dollars) and Industry Value Shares				
	Sugars	Corn Sweeteners	Other Sweeteners	Artificial Sweeteners	All Sweeteners
Milk	145566.23 (3.76%)	204832.69 (10.00%)	0.00 (0.00%)	111.54 (0.07%)	350510.45 (5.52%)
Cheese	7005.03 (0.18%)	14767.97 (0.72%)	0.00 (0.00%)	0.00 (0.00%)	21773.00 (0.34%)
Ice cream / yogurt	88003.26 (2.28%)	78183.66 (3.82%)	0.00 (0.00%)	162.28 (0.10%)	166349.20 (2.62%)
Breakfast cereal / Bakery	792602.14 (20.49%)	171137.66 (8.35%)	118477.75 (44.93%)	13367.47 (7.88%)	1095585.03 (17.25%)
Soft drink	58065.00 (1.50%)	1113977.00 (54.36%)	42982.00 (16.30%)	33746.00 (19.89%)	1248770.00 (19.67%)
Juice	26169.29 (0.68%)	86191.00 (4.21%)	0.00 (0.00%)	0.00 (0.00%)	112360.30 (1.77%)
Sweetener products	2649603.07 (68.51%)	255077.12 (12.45%)	19092.95 (7.24%)	112985.72 (66.61%)	3036758.86 (47.82%)
Processed fruits and vegetables	18492.67 (0.48%)	65166.89 (3.18%)	0.00 (0.00%)	0.00 (0.00%)	83659.56 (1.32%)
Condiments / Spices	81829.56 (2.12%)	59831.74 (2.92%)	83132.41 (31.53%)	9255.16 (5.46%)	234048.88 (3.69%)
Sum of Nine Target Sweetener -Intensive Foods	17350095.40 (100.00%)	15361062.51 (100.00%)	800258.30 (100.00%)	151399.65 (100.00%)	29622485.68 (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 5. Cost Shares of Sweeteners in Nine Target Sweetener-Intensive U.S. Food Manufacturing Industry

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 6. Own-Price and Income / Total Expenditure Elasticities of Nine Target Sweetener-Intensive Foods

Food	Elasticities							
	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 Elasticity. 2008; Chouinard, et al.. 2010.

Table 7. Cross-Price 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		-0.0267		-0.0281	-0.0709	0.0171	0.0055	-0.0137	
Cheese			-0.0485	-0.0386		-0.0155	0.0364	0.0172	
Ice cream / yogurt				-0.0349		-0.0047			
Breakfast cereal / Bakery						0.0055	0.0203	0.0205	
Soft drink						-0.0030			
Juice							0.0482	0.0180	
Sweetener products								0.0050	
Processed fruits and vegetables									
Condiments / Spices									

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

Table 8. Per Capita Income and Food Expenditure Distribution among Nine Sweetener-Intensive Foods (Dollars)

		Quintiles of income				
	All households	Lowest 20%	Second 20%	Third 20%	Fourth 20%	Highest 20%
Population (billion)	0.28	0.04	0.05	0.06	0.06	0.07
Average annual income after taxes	18773.60	4857.46	9406.96	14214.37	20019.16	35049.03
Annual food expenditure (per capita)[a]	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
Sweeteners						
All Sweeteners (sugar equivalent) (pounds)	105.69	103.83	97.85	101.28	105.85	115.37
Sugars	61.90	61.21	56.96	59.54	61.73	67.67
Corn Sweeteners	54.81	53.41	51.24	52.26	55.22	59.63
Other Sweeteners	2.86	2.72	2.63	2.71	2.89	3.17
Artificial Sweeteners	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).

a- Industry level value of shipment in 2002 Economic Census Industry Series Reports (Manufacturing) are distributed to income groups by at-home food expenditure weight from CEX 2002. The weight for “Fluid milk / Dry, condensed, and evaporated dairy product” is from “Fresh milk and cream” in CEX; weights for “Cheese” and “Ice cream yogurt” are from “Other dairy products”; weight for “Breakfast cereal/Bakery” is from “Cereals and bakery products”; weight for “Soft drink” is from “Nonalcoholic beverages”; weight for “Juice” is from “Processed fruits”; weight for “Refined Sugar + Confectionery + Honey, Molasses, Syrup and Gelatin pudding mix + Jam and jelly” is from “Sugars and other sweets”; weight for “Dried fruit and vegetables + Tomato Sauce/Catsup” is from “Processed fruits and processed vegetables”; weight for “Mayonnaise, dressing, and other prepared sauce + Spice and extract” is from “Miscellaneous foods”.

Table 9. All Households 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	-0.72467	-0.02670	-0.00005	-0.02812	-0.07089	0.01710	0.00544	-0.01371	-0.00014
Cheese	-0.04194	-1.06820	-0.04846	-0.03849	-0.00144	-0.01555	0.03630	0.01715	-0.00109
Ice cream / yogurt	0.00090	-0.11461	-0.83342	-0.03491	0.00112	-0.00469	0.00077	0.00015	0.00085
Breakfast cereal / Bakery	-0.01991	-0.01686	-0.00696	-0.47447	-0.00147	0.00544	0.02015	0.02040	-0.00111
Soft drink	-0.05981	0.00009	0.00005	0.00020	-0.92680	-0.00300	0.00014	0.00003	0.00016
Juice	0.03811	-0.02427	-0.00380	0.01773	-0.01085	-0.85255	0.04798	0.01792	-0.00187
Sweetener products	0.00613	0.02778	-0.00008	0.03589	-0.00031	0.02430	-0.50441	0.00499	-0.00024
Processed fruits and vegetables	-0.04929	0.03734	-0.00082	0.10191	-0.00315	0.02595	0.01283	-1.97171	-0.00239
Condiments / Spices	-0.00063	-0.00033	-0.00021	-0.00076	-0.00079	-0.00018	-0.00054	-0.00010	-1.03918

Note: Elasticities for final products used for the calculation are from USDA/ERS and Chouinard, et al., 2010. (See Table 6 and 7).

Table 10. Changes for All Households with Tax on the Price of Final Products for Nine Sweetener-Intensive Foods

Food	Initial per capita food demand (dollars)[a]	Tax rate (%)	Price with tax	Food demand change (%)
Milk	100.44	0.000	1.000	0.214
Cheese	65.55	0.000	1.000	1.431
Ice cream / yogurt	27.39	0.000	1.000	0.027
Breakfast cereal / Bakery	149.78	0.000	1.000	0.796
Soft drink	118.41	0.000	1.000	0.005
Juice	42.96	0.000	1.000	1.893
Sweetener products	87.56	39.295	1.393	-19.820
Processed fruits and vegetables	29.39	0.007	1.000	0.498
Condiments / Spices	104.65	0.000	1.000	-0.019
Sweeteners	Initial per capita sweeteners consumption (lbs)		Sweeteners consumption quantity change (%)	
All Sweeteners (sugar equivalent)[b]	105.69		-10.000	
Sugars	61.90		-13.390	
Corn Sweeteners	54.81		-2.270	
Other Sweeteners	2.86		-1.083	
Artificial Sweeteners	0.54		-13.139	
Real expenditure on nine foods	Initial per capita real expenditure (dollars)		Real expenditure change (%)	
	726.13		1.86376	
Welfare	Market welfare change			
EV (million dollars)	-8688.339			
Per capita EV (dollars)	-31.000			
EV/Income (%)	0.165			

Note: Elasticities for final products are from USDA/ERS and Chouinard, et al., 2010. (See Table 6 and 7).

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

b- See footnote 1.

Table 11. Sweeteners Consumption Quantity Changes on All Households and Disaggregated Income Groups for Nine Sweetener-Intensive Foods

	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]	-10.000	-13.102	-10.734	-9.128	-7.794	-6.256
Sugars	-13.390	-19.775	-16.408	-13.816	-11.892	-9.488
Corn Sweeteners	-2.270	-3.400	-2.737	-2.363	-1.996	-1.618
Other Sweeteners	-1.083	-1.652	-1.321	-1.132	-0.950	-0.761
Artificial Sweeteners	-13.139	-19.621	-16.232	-13.507	-11.615	-9.274
Tax on the price of Caloric Sweeteners	Sweetener consumption quantity change (%)					
All Sweeteners (sugar equivalent)[a]	-10.000	-10.451	-10.193	-10.039	-9.899	-9.727
Sugars	-8.954	-9.460	-9.141	-9.006	-8.829	-8.668
Corn Sweeteners	-12.412	-12.798	-12.580	-12.443	-12.331	-12.174
Other Sweeteners	3.221	3.066	3.122	3.210	3.257	3.326
Artificial Sweeteners	1.322	0.682	1.057	1.241	1.482	1.703
Tax on the price of Sugars	Sweetener consumption quantity change (%)					
All Sweeteners (sugar equivalent)[a]	-10.000	-10.613	-10.132	-10.098	-9.821	-9.707
Sugars	-22.089	-22.804	-22.426	-22.139	-21.921	-21.652
Corn Sweeteners	7.405	7.207	7.302	7.389	7.418	7.559
Other Sweeteners	2.809	2.709	2.719	2.798	2.816	2.906
Artificial Sweeteners	0.203	-0.676	-0.193	0.109	0.407	0.745
Tax on the price of Corn Sweeteners	Sweetener consumption quantity change (%)					
All Sweeteners (sugar equivalent)[a]	-10.000	-10.273	-10.250	-9.979	-9.993	-9.744
Sugars	7.727	7.428	7.767	7.645	7.821	7.830
Corn Sweeteners	-37.636	-38.236	-37.884	-37.686	-37.491	-37.290
Other Sweeteners	4.729	4.394	4.564	4.710	4.829	4.909
Artificial Sweeteners	3.117	2.554	2.923	3.028	3.280	3.426

Note: Elasticities for final products are from USDA/ERS and Chouinard, et al. 2010 (See Table 6 and 7).

a- See footnote 1.

Table 12. Real Expenditure Changes and Welfare Loss on All Households and Disaggregated Income Groups for Nine Sweetener-Intensive Foods

	All households	Households by quintiles				
		Lowest 20%	Second 20%	Third 20%	Fourth 20%	Highest 20%
Tax on the price of Final Products						
Real expenditure change (%)	1.864	0.512	1.139	1.846	2.156	2.701
Market welfare change						
EV (million dollars)	-8688.339	-1114.503	-1361.776	-1700.009	-1978.280	-2533.770
Per capita EV (dollars)	-31.000	-29.044	-27.396	-30.096	-31.248	-34.999
EV/Income (%)	0.165	0.598	0.291	0.212	0.156	0.100
Tax on the price of Caloric Sweeteners						
Real expenditure change (%)	0.275	0.007	0.154	0.257	0.337	0.434
Market welfare change						
EV (million dollars)	-1676.896	-225.009	-275.217	-323.774	-379.645	-473.252
Per capita EV (dollars)	-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
Tax on the price of Sugars						
Real expenditure change (%)	0.461	0.246	0.351	0.451	0.507	0.596
Market welfare change						
EV (million dollars)	-1864.867	-251.309	-303.591	-361.428	-420.462	-528.077
Per capita EV (dollars)	-6.654	-6.549	-6.108	-6.399	-6.641	-7.294
EV/Income (%)	0.035	0.135	0.065	0.045	0.033	0.021
Tax on the price of Corn Sweeteners						
Real expenditure change (%)	0.094	-0.339	-0.084	0.058	0.198	0.341
Market welfare change						
EV (million dollars)	-1934.313	-256.827	-320.043	-371.551	-440.768	-545.124
Per capita EV (dollars)	-6.902	-6.693	-6.439	-6.578	-6.962	-7.530
EV/Income (%)	0.037	0.138	0.068	0.046	0.035	0.021

Note: Elasticities for final products are from USDA/ERS and Chouinard, et al. 2010 (See Table 6 and 7).

Table 13. Changes for All Households with Tax on the price of Caloric Sweeteners for Nine Sweetener-Intensive Foods

Food	Initial per capita food demand (dollars)[a]	Price with tax	Food demand change (%)	Tax rate				
				Sugars	Corn Sweeteners	Other Sweeteners		
				27.469%	42.946%	0.00001%		
				Sweeteners consumption quantity change (%)				
				Sugars	Corn Sweeteners	Other Sweeteners	Artificial Sweeteners	All Sweeteners (sugar equivalent)[b]
Milk	100.44	1.004	-0.369	-1.267	-11.592	1.980	14.198	-7.439
Cheese	65.55	1.000	-0.002	-0.928	-12.802	1.062	0.310	-8.971
Ice cream / yogurt	27.39	1.006	-0.560	-1.481	-9.077	2.461	12.288	-5.264
Breakfast cereal / Bakery	149.78	1.006	-0.232	-7.921	-5.904	1.984	9.754	-6.653
Soft drink	118.41	1.013	-1.182	-2.097	-16.439	8.762	5.041	-14.197
Juice	42.96	1.003	-0.103	-1.089	-14.018	5.626	1.505	-10.740
Sweetener products	87.56	1.030	-1.498	-11.164	-8.317	10.427	-0.963	-10.147
Processed fruits and vegetables	29.39	1.003	-0.580	-1.593	-14.580	3.603	0.566	-11.354
Condiments / Spices	104.65	1.001	-0.150	-1.317	-7.307	0.101	1.850	-3.125

Sweeteners	Initial per capita sweeteners consumption (lbs)	Sweeteners consumption quantity change (%)	Initial per capita sweeteners consumption (dollars)	Sweeteners consumption value change (%)
All Sweeteners (sugar equivalent)[b]	105.69	-10.000	22.66	20.133
Sugars	61.90	-8.954	13.80	17.498
Corn Sweeteners	54.81	-12.412	7.31	28.823
Other Sweeteners	2.86	3.221	0.94	3.346
Artificial Sweeteners	0.54	1.322	0.61	1.322

Real expenditure on	Initial per capita real expenditure (dollars)	Real expenditure change (%)

nine foods		
	726.13	0.27487
Welfare	Market welfare change	
EV (million dollars)		-1676.89600
Per capita EV (dollars)		-5.98315
EV/Income (%)		0.03187

Note: Elasticities for final products are from USDA/ERS and Chouinard, et al., 2010 (See Table 6 and 7).

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

b- See footnote 1.

Table 14. Changes for All Households with Tax on the price of Individual Sweetener for Nine Sweetener-Intensive Foods

Food	Initial per capita food demand (dollars)[a]	Tax on the price of Sugars		Tax on the price of Corn Sweeteners	
		Tax rate			
		61.245%		156.849%	
		Price with tax	Food demand change (%)	Price with tax	Food demand change (%)
Milk	100.44	1.002	-0.182	1.007	-0.733
Cheese	65.55	1.000	0.101	1.001	-0.138
Ice cream / yogurt	27.39	1.005	-0.488	1.010	-0.825
Breakfast cereal / Bakery	149.78	1.009	-0.330	1.004	-0.171
Soft drink	118.41	1.001	-0.092	1.032	-3.025
Juice	42.96	1.001	0.189	1.007	-0.525
Sweetener products	87.56	1.053	-2.633	1.010	-0.458
Processed fruits and vegetables	29.39	1.001	-0.061	1.007	-1.450
Condiments / Spices	104.65	1.001	-0.142	1.002	-0.204
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	-22.089		7.727	
Corn Sweeteners	54.81	7.405		-37.636	
Other Sweeteners	2.86	2.809		4.729	
Artificial Sweeteners	0.54	0.203		3.117	
Sweeteners	Initial per capita sweeteners consumption (dollars)	Sweeteners consumption value change (%)			
All Sweeteners	22.66	20.312		31.635	
Sugars	13.80	29.226		7.727	
Corn Sweeteners	7.31	7.405		82.578	
Other Sweeteners	0.94	2.809		4.729	
Artificial Sweeteners	0.61	0.203		3.117	
Real expenditure on nine foods	Initial per capita real expenditure (dollars)	Real expenditure change (%)			
	726.13	0.461		0.094	
Welfare		Market welfare change			
EV (million dollars)		-1864.867		-1934.313	
Per capita EV (dollars)		-6.654		-6.902	
EV/Income (%)		0.035		0.037	

Note: Elasticities for final products are from USDA/ERS and Chouinard, et al., 2010 (See Table 6 and 7).

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

b- See footnote 1.