DETERMINING THE IMPACT OF FOOD PRICE AND INCOME CHANGES ON OBESITY

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Determining the Impact of Food Price and Income Changes on Weight

Abstract

Despite the significant rise in obesity in the U.S., economic research on obesity is still in its infancy. This paper employs a microeconomic approach to investigate the effects of price and income changes on weight in an effort to determine how a high-calorie food tax, a low-calorie food subsidy, and/or income changes affect body weight. Although raising the price of high-calorie food will likely lead to decreased demand for such goods; it is not clear that such an outcome will actually reduce weight. The model developed in this paper identifies conditions under which price and income changes are mostly likely to actually result in a weight loss. The model is easily implemented using data on own- and cross-price elasticities that are often readily available from the extant literature. This is important because survey data that contain both economic information, such as food prices, and weight are extremely rare. Information on relationship between price and weight is critical in developing appropriate public policy and in determining when and where fat taxes, thin subsidies or income re-distribution will achieve the desired objective of reducing obesity.

Introduction

American eating habits have contributed to high obesity rates – the highest in the world. It has been suggested that agricultural policies combined with the switch from individual to mass food preparation, have reduced the price of food energy consumed (Critsler, 2004; Drenowski, 2003; Pollan, 2003). Others have argued that technological change decreased real food prices while shifting the work environment from manual to sedentary labor, the latter of which increased the price of burning calories (Lakdawalla and Philipson, 2002; Philipson and Posner, 1999). Although the number of calories consumed has increased, calories expended have not changed since the 1980's (Cutler, Glaeser, and Shapiro, 2003). The result has been an energy imbalance that manifests itself in higher weight.

The growing obesity epidemic, and the economic externalities it spawns, represents a public health problem that necessitates an exploration of public policy measures that can impact food consumption, physical activity, and consequently, body weight. Market interventions such as taxes and subsidies may be necessary to correct the market failures related to obesity. Externalities arise because of the increase in obesity-related cost, which society bears through higher taxes in order to fund Medicare and Medicaid and through higher insurance rates. Market interventions may also be necessary due to self-control problems or time-inconsistent preferences that exist from individuals deriving immediate gratification from food consumption not recognizing future health costs related to overconsumption (O'Donoghue and Rabin, 1999 and 2000; Cutler, Glaeser, and Shapiro, 2003). In addition to these issues, information asymmetry, which may result from a lack of knowledge about the health consequences associated with certain diets (e.g., Cawley, 2003), may be another motivation for market intervention.

The role of the public sector in managing obesity has so far been limited to information distribution (Kuchler, Tegene, and Harris, 2005). However several recent bills have been passed to discourage the consumption of unhealthy foods by increasing the effective price to consumers. Several states plan to impose or broaden sales taxes on soft drinks or syrups and to adjust taxes on other food items (Uhlman, 2003). Small taxes could also be placed on junk food, often called 'fat tax' or 'Twinkie tax'. Some 18 states are using different forms of the fat tax. The fat tax is not only a domestic issue; other countries are addressing increased obesity levels by taxes. For example, in addition to standardizing labeling of fat and sugar contents in processed foods, the UK is considering the introduction of a fat tax with different value added taxes (VAT) for foods with poor nutritional standards (British Broadcasting Corporation (BBC) News, 2004). The UK tax proposal suggests the taxation of unhealthy food items particularly considered culpable of raising serum cholesterol levels (Agence France-Presse (AFP), 2004; BBC News, 2004; Kuchler, Tegene, and Harris, 2005). Cash, Sunding, and Zilberman (2004) suggest that the fat tax is regressive because the income redistribution would be experienced most by low-income families, who spend a larger portion of their income on food. In contrast to the fat tax, Cash, Sunding, and Zilberman argue that a more progressive public policy measures would include 'thin subsidies' or 'income subsidies' to encourage the consumption of healthier foods. An income subsidy might be an efficient idea, given that previous research shows that lower income households consume lower quality diets, consisting mainly of high-calorie foods (Townsend *et al*., 2001, The Economist, 2002). Although previous research shows that income has a major impact on obesity (e.g. Deaton, 2003; Drenowski, 2003; Townsend *et al*., 2001; Dietz, 1995), recent findings suggest the prevalence of obesity has nearly tripled among higher income households,

which has diminished the difference in obesity rates between income groups (Hellmich, 2005; Microsoft/National Broadcasting Corporation, 2005).

Despite the significant increase in U.S. obesity, economic research on obesity has just recently begun. Few economic studies have focused on obesity and body weight; the most notable exceptions are Philipson and Posner (1999); Chou, Grossman, and Saffer (2002); Cutler, Glaeser, and Shapiro (2003); Cash, Sunding, and Zilberman (2004); and Lakdawalla and Philipson (2002), and Kuchler, Tegene, and Harris (2005). Although a number of state and federal proposals have been put forth to curb the rise in obesity, there remains an inadequate conceptual foundation for determining when and how market interventions will reach their desired objectives. Indeed, the need for research that evaluates whether food taxes or subsidies influence actual body weights has been identified by a number of previous studies (e.g. Jacobson and Brownell, 2000).

In contrast to previous studies that have focused on the role of public policy measures on calorie-consumption (Drenowski, 2003; Jacobson and Brownell, 2000), the primary goal of this study is to develop a model consistent with economic theory to identify the relationship between food prices and income on body weight. The framework used in this study expands on the work of Philipson and Posner (1999) and Lakdawalla and Philipson (2002) who propose entering body weight into the utility function. A few other studies have attempted to investigate the effect of price changes on food consumption or “lives saved” (e.g. Kuchler, Tegene, and Harris, 2005; Cash, Sunding, and Zilberman, 2004) but few have actually focused on weight changes. For example, Kuchler, Tegene, and Harris (2005) utilized price elasticities to forecast the impact of a tax on snack foods on consumption, but their study did not take individual body weight impacts into consideration. Demand theory suggests that under most conditions, a price increase will

result in a reduction in the quantity of the good consumed; however, it is not necessarily the case that weight will also decline when ready substitutes are available.

This study identifies the conditions under which price and income changes will result in a weight reduction in a very general manner. The suggested model consists of price and income elasticities, as well as weight elasticities. Our approach is useful in the sense that it will allow policy makers to determine when a tax, subsidy, or income-redistribution will be most effective. We then show how our approach can be empirically applied using the cases of a tax on food away from home, a tax on regular soft drinks, a subsidy on fruits and vegetables, a subsidy on diet soft drinks, and an income subsidy. Given that it is rather difficult to obtain good survey data that contains information about body weight as well as economic information, this study presents a convenient way to overcome these data limitations. Price and income elasticities are readily available in economic literature. We further show how energy accounting can be used to calculate weight elasticities. Thus, the empirical framework presents a convenient way to determine the impact of price and income changes on weight.

A Model of Consumer Behavior Including Weight

This study works within a utility maximization framework, where utility is a function of body which, which in turn is a function of the quantity of foods consumed and the level of exercise. To illustrate the mechanics of the model, we begin by starting with simple three-good example (a high-calorie food, a low-calorie food, and exercise), but later we extend then the analysis to the *N*-good case. Assumed that an individual's weight, *W*, is affected by three factors: the consumption of high-calorie (F^1) food, low-calorie (F^2) food, and exercise (E) –

i.e., $W = W(F^1, F^2, E)$. Weight is strictly increasing in food intake and decreasing in exercise, i.e., $\partial W/\partial F>0$ and $\partial W/\partial E<0$.[1]

As in Philipson and Posner (1999), an individual's weight is included as an argument in the utility function. Overall, an individual derives utility from weight, the intake of food, exercise, and other consumption goods *(C)*. The utility function can be stated as

(1) $U(W(F^1, F^2, E), F^1, F^2, C)$.

The function has the usual properties of being increasing at a decreasing rate in F^1, F^2, and C. Utility is assumed to be increasing in weight up to some "ideal" weight level, W^I and is decreasing in weight levels greater than W^I. This ideal weight is an individual-specific, subjective measure. The utility function is maximized with respect to a budget constraint that limits the amount of money spent on food and other consumption goods

(2) $p_{F^1}F^1 + p_{F^2}F^2 + p_E E + p_C C = I$,

where p_{F^i} is the price of food type *i*, p_E is the price of exercise, p_C is the price of all other consumption goods, and *I* represents income. The set-up is similar to that used by Philipson and Posner (1999) and by Cawley (2003) who proposed stating an individual's utility as a function of weight and health, which both depend on the food consumed; our key departure from these studies is the inclusion of multiple foods, which as will be shown in subsequent analysis has important implications for the efficacy of a tax or subsidy.

Individuals maximize equation (1) subject to the budget constraint given in equation (2). The objective function and first order conditions for an interior solution can be written as:

[1] Whether an individual is overweight or obese is determined by the Body Mass Index (BMI), which is determined by the formula: weight (in kilograms)/height^2 (in meters squared). Among adults, overweight is classified by a BMI between 25.0 and 29.9, while a BMI greater than or equal to 30.0 defines obesity (USDHHS-NCHS, 2002).

(3) $$\underset{F^1,F^2,E,C,\lambda}{L} = U(W(F^1,F^3,E),F^1,F^2,E,C) - \lambda(p_{F^1}F^1 + p_{F^2}F^2 + p_C C + p_E E - I)$$

FOC's:

(4) $$\frac{\partial L}{\partial F^1} = \frac{\partial U}{\partial W}\frac{\partial W}{\partial F^1} + \frac{\partial U}{\partial F^1} - \lambda p_{F^1} = 0$$

(5) $$\frac{\partial L}{\partial F^2} = \frac{\partial U}{\partial W}\frac{\partial W}{\partial F^2} + \frac{\partial U}{\partial F^2} - \lambda p_{F^2} = 0$$

(6) $$\frac{\partial L}{\partial E} = \frac{\partial U}{\partial W}\frac{\partial W}{\partial E} + \frac{\partial U}{\partial E} - \lambda p_E = 0$$

(7) $$\frac{\partial L}{\partial C} = \frac{\partial U}{\partial C} - \lambda p_C = 0$$

and

(8) $$\frac{\partial L}{\partial \lambda} = -p_{F^1}F^1 - p_{F^2}F^2 - p_C C - p_E E + I = 0$$

Solving equations (4) through (8) yields optimal levels of food and other consumption.

(9) $F^{1*} = F^{1*}(p_{F^1}, p_{F^2}, p_C, p_E, I)$

(10) $F^{2*} = F^{2*}(p_{F^1}, p_{F^2}, p_C, p_E, I)$

(11) $E^* = E^*(p_{F^1}, p_{F^2}, p_C, p_E, I)$

(12) $C^* = C^*(p_{F^1}, p_{F^2}, p_C, p_E, I)$

(13) $W^* = W^*(F^{1*}(p_{F^1}, p_{F^2}, p_C, p_E, I), F^{2*}(p_{F^1}, p_{F^2}, p_C, p_E, I), E^*(p_{F^1}, p_{F^2}, p_C, p_E, I))$,

where the * superscript indicates utility maximizing levels. W^* is the optimal weight, which is dependent on the prices of both food types, exercise, other consumption goods and income. At this point, is important to recognize that economically optimal weight, W^*, that results from the utility maximization decision does not necessarily coincide with the "ideal" weight W^I or even

weight that is optimal for the health of the individual. For example, low food prices may lead individuals to gain weight beyond W^I because the utility of lower-priced food consumption outweighs the disutility of being overweight relative to an individuals' ideal.

Now, to determine the impact of a change in the price of a high-calorie food, such as that that would occur through the imposition of an ad valorem high-calorie food tax, differentiate (13) with respect to the high-calorie food price p_{F^1}, which yields[2]:

$$(14)\ \frac{\partial W^*}{\partial p_{F^1}} = \frac{\partial W^*}{\partial F^1}\frac{\partial F^1}{\partial p_{F^1}} + \frac{\partial W^*}{\partial F^2}\frac{\partial F^2}{\partial p_{F^1}} + \frac{\partial W^*}{\partial E}\frac{\partial E}{\partial p_{F^1}}.$$

After a bit of algebra, equation (14) can be converted to our first key elasticity equation as shown below:

$$(15)\ \varepsilon_{W^* p_{F^1}} = \varepsilon_{W^* F^1}\varepsilon_{11} + \varepsilon_{W^* F^2}\varepsilon_{21} + \varepsilon_{W^* E}\varepsilon_{E1},$$

where $\varepsilon_{W^* p_{F^1}}$ is the percentage change in weight resulting from a 1% change in p_{F^1}. This weight change is influenced by ε_{11}, which is the own price elasticity of demand for the high-calorie food and ε_{21} and ε_{E1}, which are cross-price elasticities associated with the percentage change in consumption in low-calorie food and exercise resulting from a 1% change in high-calorie food, respectively. The percentage change in weight associated with a 1% change in high-calorie food is also influence by $\varepsilon_{W^* F^i}$, the percentage change in weight resulting from a 1% change in food type *i* and $\varepsilon_{W^* E}$, the percentage change in weight resulting from a 1% change in exercise.

[2] The discussion can be generalized to multiple-price changes by totally differentiating (13) w.r.t. the prices of the goods in consideration. An example of such will be shown later in the text.

The sign of $\varepsilon_{W^* p_{F^1}}$ depends on whether F^2 and E are substitutes or complements for F^1 and the degree to which changes in food consumption and exercise change weight. The signs of the equation will be discussed in detail later.

In a similar fashion to that shown above, one can derive the weight change resulting from a change in the low-calorie food (e.g., a low-calorie subsidy) or income. The elasticity equation resulting from a change in the price of the low-calorie food is equivalent to that in equation (15) with the superscripts 1 and 2 reversed on the food types and prices. Regarding income changes, the optimal weight equation (13) can be differentiated with respect to. income to generate

$$(16)\ \frac{\partial W^*}{\partial I} = \frac{\partial W^*}{\partial F^1}\frac{\partial F^1}{\partial I} + \frac{\partial W^*}{\partial F^2}\frac{\partial F^2}{\partial I} + \frac{\partial W^*}{\partial E}\frac{\partial E}{\partial I}.$$

Converting this equation to elasticity form yields the second key elasticity equation,

$$(17)\ \varepsilon_{W^* I} = \varepsilon_{W^* F^1}\varepsilon_{1I} + \varepsilon_{W^* F^2}\varepsilon_{2I} + \varepsilon_{W^* E}\varepsilon_{EI},$$

where $\varepsilon_{W^* I}$ is the percentage change in weight resulting from a 1% change in income, ε_{1I} ε_{2I} and ε_{EI} are income elasticities of high-calorie food, low-calorie food and exercise, respectively. $\varepsilon_{W^* F^i}$ is the percentage change in weight resulting from a 1% change in food type *i* and $\varepsilon_{W^* E}$ is the percentage change in weight resulting from a 1% change in exercise.

Now that the basic model has been outlined, it should be clear that the elasticity equations can be easily extended to any N-good case. If an individual consumes N food types, equation (15) generalizes to

$$(18)\ \varepsilon_{W^* p_{F^1}} = \varepsilon_{W^* F^1}\varepsilon_{11} + \sum_{i=2}^{N}\varepsilon_{W^* F^i}\varepsilon_{i1} + \varepsilon_{W^* E}\varepsilon_{E1}$$

and equation (12) generalizes to

$$(19)\ \varepsilon_{W^*I} = \sum_{i=1}^{N} \varepsilon_{W^*F^i}\varepsilon_{1i} + \varepsilon_{W^*E}\varepsilon_{EI}\ .$$

Efficacy of a Tax on High-Calorie Foods

The elasticity equation (18) is used to determine the signs and magnitudes of the elasticities necessary to cause a decline in body weight. The policy objective is to reduce weight; so it is desirable that the price-weight elasticity $\varepsilon_{Wp_{F^1}}$ is negative (note: in subsequent discussion the superscript * has been dropped for notational convenience). In order for an increase in high-calorie food price to generate a weight reduction, the following relationship needs hold

$$(20)\ 0 > \varepsilon_{WF^1}\varepsilon_{11} + \sum_{i=2}^{N} \varepsilon_{WF^i}\varepsilon_{i1}\ ,$$

where the cross-price elasticity between exercise and high-calorie food is assumed to be zero. Rearranging (20) yields

$$(21)\ -\left(\frac{\sum_{i=2}^{N} \varepsilon_{WF^i}\varepsilon_{i1}}{\varepsilon_{WF^1}}\right) > \varepsilon_{11}\ .$$

It is known that $\varepsilon_{WF^1} > \varepsilon_{WF^2}$ because the percentage change in weight resulting from a 1% change in high-calorie food is always greater than the percentage change in weight resulting from a 1% change in lower-calorie food. We also know that ε_{WF^1}, ε_{WF^2}, and $\sum_{i=2}^{N} \varepsilon_{WF^i} > 0$.

However, in the multiple good case, it is not known whether the numerator or the denominator of the left hand side of (21) is larger and thus, whether the magnitude of this ratio would be less than or greater than 1. In order to obtain more specific ideas regarding the signs of the

parameters, equation (21) could be simplified to the case of only two goods, high- and low-calorie, in which case, it becomes

$$(22) -\left(\frac{\varepsilon_{WF^2}}{\varepsilon_{WF^1}}\varepsilon_{21}\right) > \varepsilon_{11}.$$

With the negative own-price elasticity on the right hand side, and a negative sign on the LHS the inequality sign is switched, so that the following is obtained

$$(23) \left(\frac{\varepsilon_{WF^2}}{\varepsilon_{WF^1}}\varepsilon_{21}\right) < \left|\varepsilon_{11}\right|.$$

Given that $\varepsilon_{WF^1} > \varepsilon_{WF^2}$, we know the ratio $\left(\frac{\varepsilon_{WF^2}}{\varepsilon_{WF^1}}\right)$ is less than one. In order to determine under what conditions the inequality in (23) holds, it is necessary to differentiate between whether high- and low-calorie foods are substitutes or complements.

When high- and low-calorie foods are complements in the 2-good case, $\varepsilon_{21} < 0$, and the left hand side of (23) will be negative – i.e., weight is ensured to decline when a tax is placed on a high-calorie good with a close compliment. An example for this case would be taxing high-calorie salad dressing, which would decrease the consumption of both dressing and salad. Thus, with both the left hand side being negative and the right hand side being positive, the inequality in (23) will always hold.

The case of substitutability between high- and low-calorie foods , $\varepsilon_{21} > 0$, is slightly more complicated. For values of $\left(\frac{\varepsilon_{WF^2}}{\varepsilon_{WF^1}}\right)$ close to zero, which would result from a very small magnitude of ε_{WF^2} or a large magnitude of ε_{WF^1}, weight is almost certain to decline for any

value of ε_{21}. On the other hand, if $\left(\frac{\varepsilon_{WF^2}}{\varepsilon_{WF^1}}\right)$ is close to one and the substitution between high- and low-calorie foods is strong relative to the own-price effect (e.g., $\varepsilon_{21} > |\varepsilon_{11}|$), a tax on high-calorie food will actually *increase* weight. The extent to which there are strong substitutes available, $\varepsilon_{21} \approx |\varepsilon_{11}|$, which are of similar caloric composition to the high-calorie food, the less effective a "fat tax." Consider a couple of examples. First, consider a tax would be placed on all regular soft drinks. Because soft drinks have a readily available substitute, diet soft drinks, one might be tempted to conclude this tax will not reduce weight; however, recognizing that diet soft drinks contribute no calories, i.e., ε_{WF^2} =0, it should be clear that weight will decline (at least in this two-good example) as the left hand side of equation (23) would be zero. As a counter example, consider a tax that targeted donuts, but not cinnamon rolls. In this case, $\left(\frac{\varepsilon_{WF^2}}{\varepsilon_{WF^1}}\right)$ would be close to one and the large degree of substitutability would imply little or no reduction in weight.

Relative Effectiveness of a Tax on High-Calorie Food versus a Subsidy on Low-Calorie Food

Rather than taxing high-calorie foods, one might be interested in subsiding low-calorie foods; however, it is at present unclear which strategy might be more effective at reducing weight. For the case of a subsidizing low-calorie food, the optimal weight equation W^* in (13) is differentiated with respect to the price of low-calorie food p_2, which leads to the elasticity equation

(24) $\varepsilon_{Wp_{F^2}} = \varepsilon_{WF^1}\varepsilon_{12} + \varepsilon_{WF^2}\varepsilon_{22}$

in the two-good case and

(25) $\varepsilon_{Wp_{F^2}} = \sum_{i=1}^{N} \varepsilon_{WF^i} \varepsilon_{1i} + \varepsilon_{WF^2} \varepsilon_{22}$.

in the N-good case. In order for a thin subsidy to reduce weight (e.g., a negative price-weight elasticity), the following inequality must hold

(26) $\left[-\frac{\sum_{i=1}^{N} \varepsilon_{WF^i} \varepsilon_{1i}}{\varepsilon_{WF^2}} \right] < \left| \varepsilon_{22} \right|$.

Given that is not known what the magnitudes of the numerator and denominator would be in this equation, (26) can be reformulated to the more specific case of just two goods as in (22), where it is assumed that the cross-price elasticity between F^2 and exercise is zero.

(27) $\frac{\varepsilon_{WF^1}}{\varepsilon_{WF^2}} \varepsilon_{12} < \left| \varepsilon_{22} \right|$.

In order to determine the conditions under which a fat tax of equal percentage value would have a greater impact on body weight than a thin subsidy, one should determine when $\varepsilon_{Wp_{F^1}} > \varepsilon_{Wp_{F^2}}$.

Substituting from above, this inequality implies that the following inequality must hold for a fat tax to reduce weight by more than a thin subsidy

(28) $\varepsilon_{WF^1} (\varepsilon_{12} - \varepsilon_{11}) - \varepsilon_{WF^2} (\varepsilon_{21} + \varepsilon_{22}) > 0$.

It is known that $\varepsilon_{WF^1} > \varepsilon_{WF^2}$, $\varepsilon_{WF^1}, \varepsilon_{WF^2} > 0$, and $\varepsilon_{11}, \varepsilon_{22} < 0$. In order for the fat tax to have a greater impact than the thin subsidy, the first part of the LHS needs to be a larger positive value than the second part of the LHS, such that the total sum of the LHS is greater than the value on the RHS. This can be achieved by high- and low-calorie foods being weak complements, $\varepsilon_{21}, \varepsilon_{12} < 0$ such that $\varepsilon_{12} > \varepsilon_{11}$.

For the case of substitutability between high- and low-calorie foods, condition (28) can be met by $\varepsilon_{12} > \varepsilon_{21}$ and $\varepsilon_{11} < \varepsilon_{12}$.

Effect of Income Changes on Weight

In order to evaluate the conditions for the efficiency of an income subsidy, equation (19) can be reformulated to the more general case of multiple goods,

(29) $\varepsilon_{WI} = \sum_{i=1}^{N} \varepsilon_{WF^i} \varepsilon_{iI} + \varepsilon_{WE} \varepsilon_{EI}$.

Here, it is important to consider the impact of exercise on body weight, because while the cross-price elasticity between food and exercise can be assumed to be low or close to zero, the income elasticity of exercise may be substantial. In order to obtain a negative price-weight elasticity ε_{WI} , the following relationship need hold

(30) $0 > \sum_{i=1}^{N} \varepsilon_{WF^i} \varepsilon_{iI} + \varepsilon_{WE} \varepsilon_{EI}$.

In the simple case of two food groups, high- and low-calorie foods, and exercise, this equation becomes

(31) $0 > \varepsilon_{WF^1} \varepsilon_{1I} + \varepsilon_{WF^2} \varepsilon_{2I} + \varepsilon_{WE} \varepsilon_{EI}$.

Note that homogeneity property implies

(32) $\varepsilon_{1I} + \varepsilon_{2I} + \varepsilon_{EI} = 0$ or $\varepsilon_{EI} = -\varepsilon_{1I} - \varepsilon_{2I}$

Now, plugging (32)into (31) and rearranging leads to

(33) $0 > \varepsilon_{1I} (\varepsilon_{WF^1} - \varepsilon_{WE}) + \varepsilon_{2I} (\varepsilon_{WF^2} - \varepsilon_{WE})$

This equation shows that the effect of the income subsidy depends on the relative effect of food consumption and exercise on weight and the signs of the income elasticities of the two foods.

Because both $\varepsilon_{WF^1}, \varepsilon_{WF^2} > 0$ and $\varepsilon_{WE} < 0$, the only way for the above inequality to hold is if one of the foods is an inferior good. Thus, the income subsidy does not lead to any weight reduction for normal goods.

Empirical Analysis of the Weight Impacts by Taxes and Subsidies

The main difficulty with any new field of research is obtaining good data. Even though surveys on U.S. BMI's exist, these surveys are typically not linked to any economic factors such as food prices, wages, income, type of employment, food consumption, prevalence of fast food restaurants, etc., that might help to determine the increase in BMI (Tabarrok, 2004). Fortunately, the framework of this study provides a convenient manner to empirically determine the effect of price and income changes on weight. As shown in the above equations, the primary statistics needed to parameterize the model are price and income elasticities, statistics which are routinely estimated by economists. The other statistics that need to be determined are the weight elasticites, which we show can be calculated using energy accounting. Because these later statistics are likely less familiar to economists, we following sub-section delves into this issue more deeply.

Energy Accounting and Food-Weight Elasticities

Energy accounting refers to the calculation of an individual's daily energy expenditure in terms of kilocalories (kcals). In steady state, energy consumed equals the energy expended and no weight gain or loss occurs. Weight gain is associated with increased calorie consumption, holding all other factors constant. On average, in order to gain (lose) one pound, a person needs to consume (burn) 3,500 calories in addition to the typical caloric intake (expenditure). Overall,

a deficit of 500 kcal a day brings about a loss of body fat at the rate of one pound per week and at a deficit of 1,000 kcal a loss of two pounds per week (Whitney, Cataldo, and Rolfes, 2002). On the other hand, a 10-12 pound increase in weight results from overeating 100-150 kcal per day. These figures imply, for example, that consuming one can of regular soft drinks can be offset by walking one and a half miles.

The energy utilization of the body is a result of three inter-related factors: the Basal Metabolic Rate (*BMR*), the Thermic Effect of Food (*TEF*), and physical activity (*Energy*). *BMR* represents about 60% of energy utilization for most people. It is the energy cost needed to keep the body alive and at rest. The energy cost is weight-dependent. The higher a person's weight, the more energy is necessary to sustain basic bodily functions. *BMR* can be determined by

(34) $BMR = \alpha + \beta * W(kg)$,

where W is body weight in kilogram (kg). In order to predict *BMR* from body weight, previous studies estimated α to be 879 (829) and β to be 11.6 (8.7) for men (women) of the age group from 30 to 60 (Food and Agriculture Organization of the United Nations (FAO), 1985, Schofield, Schofield, and James, 1985).

Energy is also utilized via *TEF*, which is required in order to process food. It takes about 10% of the total daily energy expenditure.

(35) $TEF = 0.1 * K$

where K is the total daily kcal in the food consumed.

Finally, physical activity forms the third way of burning calories, which can be expressed by

(36) $Energy = \sum_{\alpha} \eta_a * W * Time_a$,

where η_a can be denoted as the activity factor, which has the unit calories/minute/kg and varies with the activity a that is performed. The activity factor translates between the individual's

weight, the duration and the total caloric expenditure associated with the activity. Typically, the activity factor ranges from light activity, such as walking, to moderate activity, such as swimming, and heavy activity, such as running. An exercise index *E* is formed

(37) $E = \sum_{\alpha} \eta_a * Time_a$

which sums across activities and reflects total physical activity in a period of time (Cutler, Glaeser, and Shapiro, 2003). The amount of energy expended varies by the type of activity and the time spent on the activity (Ainsworth *et al*., 1993). To calculate *E*, it is necessary to divide the day of an average U.S. adult into A_a activities, obtain the average number of minutes per day spent on each activity and the according amount of energy spent. Table 1 shows information on time usage and the total activity factor from 1965 to 2001. Since 1975, the time spent on paid work has increased, while less time is spent on personal needs and care, and other calorie-burning activities such as recreation. At the bottom of table 1, the activity factor is calculated for each year. Even though the activity factor has fluctuated, the estimated activity factor has decreased since 1965. The estimated activity factor is used to calculate the exercise index *E* in the subsequent calculations.

Summing up the three ways of energy expenditure leads to the total energy expenditure *(TEE)*

(38) $TEE = BMR + E + TEF$

In steady state, energy expended equals energy consumed. Setting *TEE* equal to the energy consumed (*K*) leads to

(39) $K = \alpha + (\beta + E) * W + 0.1 * K$.

which is the energy balance equation (Cutler, Glaeser, and Shapiro, 2003).

In order to utilize equation (15) and form the price-weight elasticities, it is necessary to collect weight, height and exercise information. Height and weight data is derived from the National Health Examination Survey (NHES) and the National Health and Nutrition Examination Surveys (NHANES). NHANES provides nationally representative information on the health and nutritional status of the U.S. population and it is administered by the U.S. Department of Health and Human Services (USDHHS). Overall, 40,000 people of 2 months of age and older have been selected from households across the U.S. to participate in this cross-sectional survey. Respondents have to answer a forty-minute personal household interview and undergo a three-hour examination (or less depending on age) in a mobile examination center (CDC, 2003; USDHHS-NCHS, 2002). This study uses data for an adult average man and an adult average woman on body weights, heights, and BMI from NHANES 2002 (table 2). Table 2 also shows that both men and women gained on average about 10-12 kg (22-27 lbs) since 1963.

The calorie balance equation (39) can serve to solve for the weight elasticities in equation (15)' by differentiating it w.r.t. weight *W*.

Solving (39) for weight *W* leads to

(40) $0.9K = \alpha + (\beta + E) * W = \dfrac{\alpha + (\beta + E) * W}{0.9}$

and

(41) $W = \dfrac{0.9K - \alpha}{(\beta + E)}$.

Taking the derivative w.r.t. calories *K* leads to

(42) $\dfrac{\partial W}{\partial K} = \dfrac{0.9}{\beta + E}$.

This expression may satisfy assumption (A). For the example of an average man in 1999-2002, using the numbers from table 2 (E =12.07), with β =11.6 for men, leads to

(43) $$\frac{\partial W}{\partial K} = \frac{0.9}{11.6 + 12.07} = \frac{0.9}{23.67} = 0.038 .$$

Given that *TEE* of an average man (woman) in 1999-2002 is about 3250 kcal (2560 kcal)and assuming that three main meals are consumed per day, the per-meal calorie consumption is 1,083 kcal (853 kcal). In order to calculate the high-calorie (low-calorie) food elasticities, it is assumed that one of those daily meals consists of the high-calorie (low-calorie) food, which increases (decreases) the total energy contribution. For all other foods, an average energy contribution is assumed. This procedure leads to three different amounts of K, which allows the calculation of a high- and a low-calorie food elasticity, as well as the food elasticities of all other goods. When consuming the high-calorie food, the elasticity $\frac{\partial W}{\partial F^1}\frac{F^1}{W}$ can be obtained by multiplying (43) by $\frac{K}{W}$, where it is assumed that the total calories K are the total amount of calories when consuming the high-calories meal instead of the regular meal. The low-calorie elasticity $\frac{\partial W}{\partial F^2}\frac{F^2}{W}$ can be obtained by multiplying (43) by $\frac{K}{W}$ where it is now assumed that K represents the total daily calories when consuming one meal of low-calorie food. The calculation of the calorie elasticities of all other foods F^n follows accordingly, with K being an average calorie amount.

Forming the exercise elasticity $\frac{\partial W}{\partial E}\frac{E}{W}$ by taking the derivative w.r.t. exercise E which leads to

(44) $$\frac{\partial W}{\partial E} = \frac{-0.9K - \alpha}{(\beta + E)^2} .$$

Then the appropriate numbers for K, α, β (11.6 for men) and E (=12.07) and K are plugged in where multiplying by $\frac{E}{W}$ leads then to the exercise elasticity.

Parallel to the derivation of the weight elasticities in the case of the income subsidy follows the calculation of the weight elasticities in the case of the income subsidy.

Empirical Example of the Weight Impact by a High-Calorie Food Tax

To illustrate how the elasticity equations can be used to determine price effects on weight, we consider the important question of whether discouraging food away from home consumption can lead to weigh reduction. Several studies suggest a link between obesity and eating out-of-house; the average American eats out four to five times per week, which means that they spend 45% of their food dollars away from home (Binkley, Eales, and Jekanowski, 2000; Jeffery and French, 1998). However, the typical away-from-home meal is less healthy than home-cooked food, since it is more calorie-dense and contains more total fat, more saturated fat, less calcium, fiber, iron and fewer servings of fruits and vegetables (Chou, Grossman, and Saffer, 2002; Lin, Guthrie, and Frazão, 1999). Furthermore, due to the 'super-sizing' trend which has swept the restaurant industry, when Americans eat out, they eat more (Young and Nestle, 2002). Larger portions are not only higher in calories but also encourage eating more (Booth, Fuller, and Lewis, 1981). Thus, a rising away-from-home consumption appears to establish a significant barrier to improve American dietary habits and health status (Lin, Guthrie, and Frazão, 1998). Interestingly, independent of income class, U.S. households allocate the same percentage of expenditures on eating away from home (Atkinson, 2005). This validates the idea to proxy food away from home with high-calorie food, because all income groups would experience the tax. Furthermore, taking into consideration that U.S. Americans spend half of

their food expenditures on food away from home, this taxation could be applied to the goods independent of point of purchase or stage of preparation.

In order to quantify the weight impact of a tax on food away from home consumption, the appropriate parameters are plugged into the weight elasticities as derived above. Energy accounting is used to calculate the price-weight elasticities for food away from home. It is assumed that one of the daily meals consists of food away from home with an energy contribution of 1,500[3] kcal. Given that the *TEE* of an average man is 3,250 kcal, the total energy consumed increases to 3,666 kcal when consuming the higher calorie meal of 1,500 kcal instead of the regular meal of 1,083 kcal.

Thus, using (43) to calculate the food away from home elasticity leads to

$$(45)\ 0.038 * \frac{K}{W} = 0.038 * \frac{3{,}666}{86.80} = \frac{139.31}{86.80} = 1.606 .$$

For the low-calorie food elasticity, it is assumed that one of the daily meals consists of fruits/vegetables and contributes only 500[4] kcal to the total energy consumed, which decreases to the total daily energy consumption to 2,666 kcal.

$$(46)\ 0.038 * \frac{K}{W} = 0.038 * \frac{2{,}666}{86.80} = \frac{101.31}{86.80} = 1.168 .$$

It is assumed that the energy amount of all other foods (cereal/bakery, meat, dairy, and other foods at home) is *K*=1000 kcal each, which is used in the calculations of the according elasticities.

[3] This amount represents the approximate calorie intake from consuming a hamburger, large fries and a large regular coke in a fast food restaurant (calorie-count.com, 2005)

[4] This amount represents the approximate calorie intake from consuming mixed vegetables with a fruit salad (calorie-count.com, 2005)

In order to form the exercise elasticity, plugging in numbers for *K (K*=3,666 for food away from home), α, β (11.6 for men) and *E* (=12.07) and assuming a tax on food away from home leads to

$$(47)\ \frac{\partial W}{\partial E} = \frac{-0.9K - \alpha}{(11.6 + E)^2} = \frac{-0.9K - 879}{(11.6 + 12.07)^2} = \frac{(-0.9 * 3{,}666) - 879}{560.27} = -7.458$$

where multiplying by $\frac{E}{W}$ leads to an exercise elasticity of

$$(48)\ -7.458 * \frac{E}{W} = -7.458 * \frac{12.07}{86.80} = \frac{-90.02}{86.80} = -1.037\,.$$

In addition to the weight-elasticities shown above, it is also necessary to collect price elasticities in order to determine the price-weight elasticity. We use the price elasticities reported in Reed, Levedahl, and Hallahan (2005) (see table 3). Plugging the statistics in the equation above leads to $\varepsilon_{Wp_{F^1}} = 1.489$. This means that increasing the price of food away from home by 1% increases body weight by 1.489%. For an average male, who weighs 86.80 kg (191.36 lbs), this is a 0.015*86.80=1.293 kg (2.851 lbs) weight gain. Calculating the appropriate elasticities for a woman of average weight in 1999-2000 and using the same elasticities from (Reed, Levedahl, and Hallahan, 2005), leads to $\varepsilon_{Wp_{F^1}} = 1.728$. Thus, a 1% increase in the price of food away from home increases the body weight of an average female by 1.728%. For a 74.70 kg (164.68 lbs) woman, this translates to a final weight of 75.991 kg (167.5lbs).

A high-calorie food tax could also be applied to beverages[5]. Several studies have shown the contribution of regular soft drinks to obesity (Apovian, 2004; Hitti, 2004; Ludwig, Peterson, and Gortmaker, 2001; Harnack, Stang, and Story, 1999). Between 1977 and 2001, calories consumed daily from soft drinks and fruit drinks nearly tripled. Sugar-sweetened soft drinks

[5] In the case of multiple-price changes we totally differentiate (13) w.r.t. the prices of the goods in consideration.

represent the largest single food source of calories in the U.S. diet and contribute 7% of the total energy intake (Block, 2004). Nielsen and Popkin (2004) point out that even though reducing the intake of high-calorie soft drinks might be one of the simpler ways to reduce obesity; however, little research has focused on the benefits of the proposal. One example of such a tax would be a tax on regular soft drinks, while diet soft drinks would remain untaxed.

The example chosen here is the consumption of a regular (nondiet) super-sized soft drink versus a diet super-sized soft drink[6]. The price elasticities for the soft drinks are drawn from Dhar, Chavas, and Cotterill (2003) (table 4). Table 5 shows that a tax on regular soft drinks leads to a weight loss of 2.220 kg (4.894 lbs) for an average man and 2.031 kg (4.478 lbs) for an average woman, respectively.

Empirical Example of the Weight Impact by a Low-Calorie Food Subsidy

Using energy accounting, as well as price elasticities from previous literature allows for a quantification of the weight impact of a low-calorie food subsidy. Considering the same scenario such as in the high-calorie food tax on eating away from home, where fruits and vegetables were the low-calorie food option, now a subsidy on fruits and vegetables is imposed, with eating away from home is the high-calorie food option. The exercise elasticity changes to reflect the interaction with low-calorie food. Again, in addition to food away from home, the impact of all other foods, represented by cereal/bakery, meat, dairy, and other foods at home, was determined as well.

In the case of the fruits/vegetables subsidy, the exercise elasticity for an average man can be calculated as

[6] It is assumed that a super-sized (33.8 fl oz.) regular (nondiet) soft drink contributes 410 kcal to the energy intake, which is the representative calorie amount of a regular Coca Cola, while consuming a diet soft drink does not contribute any calories (calorie-count.com, 2005).

(49) $\frac{\partial W}{\partial E} = \frac{-0.9K - \alpha}{(11.6 + E)^2} = \frac{-0.9K - 879}{(11.6 + 12.07)^2} = \frac{(-0.9 * 2{,}666) - 879}{560.27} = -5.851$

and

(50) $(-5.851) * \frac{E}{W} = (-5.851) * \frac{12.07}{86.80} = \frac{-70.63}{86.80} = -0.814$.

Calculating the price-weight elasticity leads to $\varepsilon_{Wp_{F^2}} = -0.808$, which means that a subsidy on fruits/vegetables would lead to a weight loss of 0.701 kg (1.545 lbs) for an average male. Calculating the appropriate elasticities for an average woman and using the same price elasticities from (Reed, Levedahl, and Hallahan, 2005), leads to $\varepsilon_{Wp_{F^2}} = -0.910$ and a weight loss of 0.680 kg (1.499 lbs) for an average female. Thus, a subsidy on fruits and vegetables proves to be efficient for both male and female (see table 5).

Applying a subsidy on diet soft drinks (see table 4) leads to even larger weight impacts. As table 5 shows, an average man would lose about 4.313 kg (9.509 lbs), while the weight loss of an average woman would be 3.894 kg (8.585 lbs).

Empirical Example: Weight Impact by an Income Subsidy

Using energy accounting and income elasticities from Reed, Levedahl, and Hallahan (2005) (see table 3), the income-weight impact by an income subsidy can be calculated. As table 5 shows, the income subsidy leads to weight gain. This finding is consistent with the theoretical derivation in the earlier section of this paper, where it has been shown that an income subsidy on normal goods does not lead to any weight reduction. The income subsidy could lead to a weight decrease if the foods subsidized are inferior goods. Also, the theoretical and empirical models show that a weight decrease would occur if an income reduction would take place.

Impact on Society: Obesity, consumer welfare and self-control

A question that naturally arises in the context of the utility model outlined above is how a market intervention can lead to a welfare improvement. That is, if an individual takes prices as given and maximizes utility with respect to a budget constraint, the resulting weight, W^*, is economically optimal for that individual; they cannot be made better off because of a tax or subsidy. The key to resolving this apparent contradiction is to understand that while equation (1) represents the utility function maximized by the individual; their *realized* level of utility is given by

(51) $U(W^*, F^{1*}, F^{2*}, C^*) - Z$,

where Z is a cost that an individual ignores and thus, not fully internalizes, when maximizing utility. Z could represent the cost of being overweight resulting from an unhealthy diet that is not considered at the immediate time of consumption or it could represent the cost an individual imposes on society through increased medical costs. Food consumption does not involve any immediate cost other than the price paid; most costs of consuming high-calorie foods are delayed effects due to overweight and obesity. However, food consumption leads to immediate rewards, because the benefits of consuming high-calorie food are obtained immediately. Food consumption is not always rational: people overeat, despite evidence that they want to lose weight. Using the terminology in O'Donoghue and Rabin (1999 and 2000), people with self-control problems are called naive, while sophisticated people overcome self-control problems. Sophisticated people foresee that they will have a self-control problem in the future. Naive people do not foresee these self-control problems and believe that future preferences will be identical to current preferences, not realizing that as she gets closer to the executing decisions,

the tastes will change. O'Donoghue and Rabin (2000) determined that intertemporal preferences of naive people are time-inconsistent because of self-control problems, which is called the present-bias effect. It leads to the situation that people procrastinate if actions involve immediate costs. Naive people are influenced solely by the present-bias effect. When costs are immediate, e.g. the time and monetary cost of starting a weigh-loss program, sophistication weakens the tendency to procrastinate- in fact the sophistication effect can outweigh the present-bias effect so that a sophisticated person may perform an onerous activity *before* she would otherwise if she had no self-control problem. Hence, when costs are immediate, a person is always better off with sophisticated beliefs than with naive beliefs. Naivety can lead to you to repeatedly procrastinate an unpleasant activity under the incorrect belief that you will do it tomorrow, while the sophistication means that you know exactly how costly delay would be. Even with an arbitrarily small bias for the present, naive people can experience severe welfare losses, while the welfare loss from a small present bias is small if you are sophisticated (O'Donoghue and Rabin, 1999).

If (51) describes behavior, a tax can serve to improve societal welfare by bringing weights levels closer to what would be observed if individuals actually took Z into account when maximizing utility. As an example, suppose a naive person becomes fat from eating large quantities of French fries. She may consume so many French fries because of a self-control problem, which means she buys too much fries at the prevailing price. A naive person will overindulge today because consuming now yields to immediate pleasure while health cost is delayed. However, regarding her individually maximized utility of French fry consumption, she buys the right amount of fries because she enjoys eating it more than the cost of being fat (Smith, 2003; O'Donoghue and Rabin, 1999). Thus, if a naive individual maximizes utility of food consumption, she does not take any kind of market failures into consideration such as

externalities, self-control problems or information asymmetry. A tax on high-calorie food will increase the monetary cost of food consumption which will bring food consumption more inline with what might have been realized if the consumer actually took Z into consideration and maximized equation (51). That is, a tax might make naive people behave as if they were sophisticated.

Discussion and Conclusions

This study utilized a microeconomic framework to investigate the impact of three public policy approaches- a high-calorie food tax, a low-calorie subsidy and an income subsidy- on body weight. The weight impact depends on the substitutability or complementarity of high-and low-calorie foods and the effect of changes in high- and low-calorie food consumption on weight. In order to evaluate more general results, this study determined conditions under which the public policy measures would decrease body weight. When high- and low-calorie foods are complements, the high-calorie food tax always leads to a weight decrease, while the weight effect varies in the case of substitutability. When comparing the efficiency of the high-calorie food taxes versus a low-calorie food subsidy, substitutability and weak complementarity lead to a higher weight impact of the high-calorie food tax. An income subsidy would only be beneficial in the case of inferior goods.

Utilizing price data and energy accounting, the theoretical framework was applied to quantify the weight impact by a high-calorie food tax as well as a low-calorie food subsidy. This framework showed that the most efficient intervention is to apply a small subsidy on diet soft drinks, which is more beneficial than a tax on diet soft drinks. The fruits/vegetables subsidy leads to a weight loss, which is consistent with the finding by Cash, Sunding and Zilberman

(2004), who determined the positive health and distributional impact of small retail price subsidy on fruits and vegetables. Previous studies showed that due to the diminishing marginal health benefit of produce consumption, low-income consumers who typically eat fewer fruits and vegetables would be more responsive to small diet changes than consumers who consume more fruits and vegetables (Cash, Sunding, and Zilberman, 2004, Huang and Lin, 2000). Overall, the low-calorie food subsidy might have the greatest health benefit for low-income consumers (Cash, Sunding, and Zilberman, 2004). A tax on food away from home would be weight-increasing, thus, inefficient.

With regard to self-control problems, a market intervention would lead a naive person to behave as a sophisticated one, and thus, decreases internalizes social cost. In conclusion, a market intervention such a fat tax, or a thin subsidy would be able to increase the welfare of the society.

Overall, fat taxes have provoked many different opposing opinions among researchers, interest groups, the government and the general public. Supporters of the fat tax emphasize its signaling power to producers and consumers, which would show that nutritional content in food is important to health. Several U.S. state legislatures support the fat tax due to its capability to raise state revenue. Beside the idea that a one penny tax may lead consumers to switch from their junk food purchase to a more healthful alternative, the tax would also provide an important financial incentive to food manufacturers and fast-food restaurants to revise the nutritional content of their foods. Accompanying the tax would be an actual redistribution of income, which would make all consumers worse off (Cash, Sunding, and Zilberman, 2004). Most consumers spend between 10 and 15% of their disposable income on food, except very poor or very rich consumers. Interestingly, rich and poor allocate the same percentage of spending on

food away from home (Atkinson, 2005). Poverty groups suggest that a fat tax is a regressive tax, because it would hurt lower income households who rely on fast food for cheap meals (Canadian Broadcasting Corporation (CBC) News Online, 2004). The proposed bill for the VAT on fatty food in the UK includes a cash compensation for low-income families in the amount of the rise in their food bill (BBC News, 2004), which might be a possibility for any form of fat tax in the U.S. as well. The implementation of a low-calorie subsidy would benefit consumers by decreasing the cost for healthy food that will increase their longevity and health. A major advantage of the low-calorie food subsidy is that it would be progressive, because low-income households would obtain the highest benefits on a proportional basis. Lower income households in high-income countries consume lower quality diets, consisting of high-fat and high-sugar foods, than people in low-income countries (Drenowski, 2003). However, a legitimate concern of a low-calorie food subsidy is the financial feasibility. In order to offset decreases in profits, which would result from price reductions of the targeted foods, sales volumes would need to increase. One successfully tested strategy to offset this could be to raise the prices of high-calorie foods to generate revenues that could then be used to subsidize the price reductions of healthier foods (Hannan *et al*., 2002, French, 2003).

Disentangling the effects of high-calorie food taxes and thin subsidies on body weights certainly merits further investigation. Such information will help government and taxpayers lower public health expenses attributable to obesity.

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Table 1: Time Use in Minutes per day for Adults (Age 18-64) from 1965-2001

Activity	**1965**	**1975**	**1985**	**1995**	**2001**
Paid Work	290	258	259	267	310
Eating on the job	11	8	8	-	6
Breaks	8	4	3	1	1
Household Work	146	128	124	104	109
Food Preparation	44	41	39	27	30
Meal Cleanup	21	12	10	4	7
Child Care	35	30	29	17	40
Obtaining Goods and Services	51	45	53	49	53
Personal Needs and Care	622	644	634	632	618
Meals at Home	58	54	50	66[A]	62[A]
Meals Out	11	19	19	-	-
Sleeping/Napping	473	496	479	495	479
Education and Training	12	16	18	22	35
Organizational Activities	20	24	18	18	17
Entertainment/Social	78	65	65	70	68
Recreation	27	37	43	47	34
Active Sports	5	4	10	13	7
Outdoor	1	7	5	6	2
Walking/Hiking/Exercise	3	5	7	9	7
Communication	158	191	195	214	153
TV	89	129	129	151	110
Total minutes in 24 hours	1440	1440	1440	1440	1440
Activity Factor (kcal per time per kilogram)	1.695	1.572	1.623	1.531	1.558

[A] Sum of Meals at Home and Meals out

Source: Authors' calculations, based on Cutler, Glaeser, and Shapiro (2003) and Ainsworth *et al*. (1993). Time Use Data from Robinson and Godbey (1997), National Time Use Studies (WebUse, 2003)

Table 2: Trends in Body Weight, Height, BMI and Exercise Expenditure for U.S. Adults (Age 20-74 Years), 1963-1965 vs. 1999-2002

Gender		1963-1965	1999-2002
Male	Weight[A] (=*W*)	75.60 kg (166.67 lbs)	86.80 kg (191.36 lbs)
	Height[A]	1.73 m (68.30 inches)	1.76 m (69.40 inches)
	BMI[A] $\left[\frac{kg}{m^2}\right]$	25.26	28.02
	BMR[B] (kcal)	1748.40	1877.20
	Exercise Expenditure[C] (=*E*) based on the according weight and activity factor	16.07	12.07
	TEE (kcal)	3292.82	3249.64
Female	Weight[A] (=*W*)	63.70 kg (140.43 lbs)	74.70 kg (164.68 lbs)
	Height[A]	1.60 m (63.10 inches)	1.62 m (64.00 inches)
	BMI[A] $\left[\frac{kg}{m^2}\right]$	24.88	28.46
	BMR[B] (kcal)	1383.19	1478.89
	Exercise Expenditure[C](=*E*) based on the according weight and activity factor	16.14	11.05
	TEE (kcal)	2605.01	2560.12

[A] Source: Ogden, Fryar, Carroll, and Flegal (2004), based on data from NHES and NHANES
[B] Source: Author's calculations, based on Food and Agriculture Organization of the United Nations (FAO, 1985)
[C] Source: Authors' calculations, based on Cutler, Glaeser, and Shapiro (2003), Time Use Data from Robinson and Godbey (1997), National Time Use Studies (WebUse, 2003)

Table 3: Food Price Elasticities

Goods	Cereal and Bakery	Meats	Dairy	Fruits and Vegetables	Other Food (Home)	Food Away from Home	Nonfood	Income
Cereal and Bakery	-0.606	0.036	-0.396	0.399	-0.673	0.182	-0.293	1.351
Meats	0.014	-0.605	0.257	-0.072	0.180	-0.736	-0.849	1.810
Dairy	-0.547	0.589	-0.861	-0.143	-1.260	1.321	-1.346	2.246
Fruits and Vegetables	0.357	-0.108	-0.089	-0.979	-0.237	0.497	-1.042	1.601
Other Food (home)	-0.337	0.176	-0.461	-0.125	-0.741	0.656	-0.207	1.038
Food Away from Home	0.049	-0.337	-0.276	0.154	0.344	-0.692	1.173	1.379
Nonfood	0.001	-0.002	-0.002	-0.008	-0.003	-0.045	-0.864	0.924

Source: Reed, Levedahl, and Hallahan, 2005.

Table 4: Soft Drink Price Elasticities

Brands	BR1	BR2	BR3	BR4	BR5	BR6	BR7	BR8	BR9	BR10	BR11	BR12	BR13	BR14	BR15	BR16
Diet Pepsi	-3.20	0.62	0.13	0.23	0.14	0.10	-1.05	0.32	1.42	0.51	0.19	-1.63	0.34	0.60	0.13	0.09
Diet Coke	0.43	-2.88	0.04	0.12	0.11	-0.02	-1.44	0.24	0.31	0.16	-0.04	1.60	0.55	0.11	0.61	-0.67
Diet 7-Up	0.60	0.27	-1.13	-0.08	-0.11	-0.05	0.01	-0.17	0.73	-0.34	0.09	-0.04	-0.58	-0.01	-0.17	0.25
Diet Sprite	1.75	1.40	-0.13	-1.84	-0.20	-0.66	4.25	-0.62	-0.60	-0.58	-1.77	-0.18	-0.31	-1.45	0.22	-0.23
Diet Dr. Pepper	1.20	1.39	-0.21	-0.23	-1.46	0.10	0.77	-0.35	1.55	-1.41	-0.59	-0.34	-0.82	-0.49	-1.52	-0.91
Diet Private Label	1.04	-0.26	-0.11	-0.83	0.12	-2.29	2.50	-0.28	1.85	1.14	-1.39	-0.95	-0.34	-1.07	1.79	-1.39
Diet All-Other	-0.21	-0.47	0.00	0.12	0.02	0.05	-2.89	0.32	0.95	0.14	-0.12	0.78	-0.23	0.24	0.26	0.15
Regular 7-up	0.92	1.03	-0.11	-0.23	-0.11	-0.08	4.25	-1.95	-1.52	-0.70	0.82	-2.02	0.20	-0.30	-0.78	-0.20
Regular Coke	0.74	0.20	0.08	-0.04	0.10	0.10	2.27	-0.30	-5.60	0.31	0.58	0.45	0.13	-0.31	0.01	0.05
Reg. Dr. Pepper	1.68	0.82	-0.24	-0.24	-0.52	0.38	2.23	-0.78	1.99	-4.56	-1.13	0.36	0.76	-0.33	-1.56	0.81
Reg. Mt. Dew	0.76	-0.27	0.08	-0.95	-0.28	-0.60	-2.44	1.18	4.49	-1.46	-7.66	5.82	0.54	-2.01	1.74	-0.12
Reg. Pepsi	-0.95	1.35	-0.01	-0.02	-0.02	-0.06	2.03	-0.42	0.49	0.05	0.82	-4.32	0.14	0.24	-0.67	0.18
Reg. RC Cola	2.55	6.12	-0.95	-0.30	-0.71	-0.26	-7.95	0.54	1.93	1.75	0.99	1.88	-11.63	0.25	-0.53	5.61
Reg. Sprite	1.95	0.47	-0.02	-0.63	-0.19	-0.38	3.52	-0.38	-1.96	-0.36	-1.63	1.34	0.10	-2.59	-0.13	-0.69
Reg. Private Label	0.17	1.45	-0.08	0.04	-0.31	0.31	1.80	-0.50	-0.02	-0.87	0.72	-2.05	-0.13	-0.07	-2.90	0.62
Reg. All-Other	0.07	-0.60	0.03	-0.02	0.07	-0.09	0.43	-0.04	0.10	0.14	-0.01	0.21	0.44	-0.11	0.25	-1.72

Source: Dhar, T., Chavas, J.-P., and R.W. Cotterill (2003).

Table 5: Weight and BMI Impacts by a High-Calorie Food Tax, a Low-Calorie Food Subsidy and an Income Subsidy

	Intervention Type	Price-Weight Elasticity[A]	Change in Weight in kg[B]	Change in BMI after Intervention[C]
High-Calorie Food Tax				
Male	Tax: Food away from home	1.489	+1.293	+0.417
	Tax: Regular soft drinks Other goods: Diet drinks	-2.558	-2.220	-0.717
Female	Tax: Food away from home	1.728	+1.291	+0.492
	Tax: Regular soft drinks Other goods: Diet soft drinks	-2.719	-2.031	-0.774
Low-Calorie Food Subsidy				
Male	Subsidy: Fruits/vegetables	-0.808	-0.701	-0.226
	Subsidy: Diet soft drinks Other goods: Regular soft drinks	-4.969	-4.313	-1.392
Female	Subsidy: Fruits/vegetables	-0.910	-0.680	-0.259
	Subsidy: Diet soft drinks Other goods: Regular soft drinks	-5.213	-3.894	-1.484
Income Change				
Male	Income subsidy	10.653	+9.246	+2.985
Female	Income subsidy	11.960	+8.934	+3.404

[A] The price-weight elasticity measures the percentage change in body weight resulting from a 1% price (income) change.
[B] The average body weight of an adult U.S. male is 86.8 kg, the average body weight of an adult U.S. female is 74.7 kg (Source: Ogden, Fryar, Carroll, and Flegal (2004), based on data from NHES and NHANES)
[C] The average BMI of an adult U.S. male is 27.9, the average BMI of an adult U.S. female is 28.2 (Source: Ogden, Fryar, Carroll, and Flegal (2004), based on data from NHES and NHANES)