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Economic Factors and Body Weight: An Empirical Analysis

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With this study, we investigate the effects of changes in economic factors on body weight by constructing a utility theoretic model. The model is empirically estimated by combining data on individuals' body weight, demographic and physical activity information, and state-level measures pertaining to the prices of food away from home, food at home, and wages. By combining these data sources, we aim to estimate directly the weight effects of price and income changes. The empirical analysis suggests that decreasing the price of food at home could decrease body weight, a finding which has important public policy implications.

Key Words: body mass index, body weight, obesity, subsidy, tax

JEL Classifications: D11, D12, I18, H20, R22

From 1985 to 2005, the number of obese adult Americans increased from 15% to 31% (CDC 2007; U.S. Department of Health and Human Services).[1] In addition to lost employee productivity and obesity-related medical expenses, market failures arise because of self-control problems, information asymmetry, and the lack of knowledge about health consequences associated with nutrition (Cawley; Cutler, Glaeser, and Shapiro; O'Donoghue and Rabin 1999, 2000). When such market failures exist, corrective measures such as taxes and subsidies might be warranted.

Several studies have identified the need for research to evaluate whether and to what extent price and income changes influence body weight (e.g., Jacobson and Brownell). A few studies have attempted to investigate the effect of price changes on food consumption or "lives saved" (e.g., Cash, Sunding, and Zilberman; Kuchler, Tegene, and Harris), but few have actually focused on body weight changes by formulating a solid utility-theoretic framework (e.g., Lakdawalla and Philipson; Philipson and Posner).

To our knowledge, only two studies have conducted an empirical analysis (Chou, Grossman, and Saffer; Sturm and Datar), which could be partially because of the difficulty of obtaining good survey data that contain information about body weight as well as economic information. Chou, Grossman, and Saffer merged micro-level data from the 1984–1999 Behavioral Risk Factor Surveillance System (BRFSS) with various state-level food prices from the American Chamber of Commerce Researchers Association (ACCRA) Cost of Living Index. Although Sturm and Datar used a similar approach, they found that changes in income and relative food prices, especially in the price of fast food, did not have a robust and significant effect on

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[1] Whether an individual is overweight or obese is determined by the Body Mass Index (BMI), which is determined by the formula: weight (kg)/height^2 (m). Among adults, overweight is classified by a BMI between 25.0 and 29.9, whereas a BMI greater than or equal to 30.0 defines obesity (CDC 2006).

BMI. Thus, these studies provide mixed evidence on the effect of economic factors on obesity. Furthermore, it is unclear how food taxes and subsidies might affect the health and welfare of various demographic subgroups of interest, such as low-income populations. Estimating price and income effects by demographic group will increase the usefulness of this health policy (e.g., Farrely et al.).

Several studies suggest a differential treatment of high- and low-calorie foods when considering body weight effects (Darmon, Ferguson, and Briend 2003; Drenowski and Specter; Sturm and Datar; WHO). Although it is intuitive that increasing the price of high-calorie foods will lead to decreased consumption of such goods; it is not necessarily the case that weight will also decline when ready substitutes are available. Thus, it is important to formulate a theoretical framework that distinguishes between weight effects resulting from price changes in high-calorie versus low-calorie foods. Schroeter, Lusk, and Tyner provide a general economic framework to determine the conditions under which high-calorie food taxes or low-calorie food subsidies would decrease body weight by drawing price and income elasticities from economic literature and using energy accounting. Given the limited alternatives considered, they found that a tax on caloric soft drinks would lead to a weight loss, while a tax on food away from home could actually lead to a body weight increases. Although this study is based on the utility-maximizing framework by Schroeter, Lusk, and Tyner, it uses a large-scale data set to directly estimate the effect of price and income changes on body weight.

Research Objectives

The objectives of this study are to (1) develop a utility-theoretic model linking body weight to food prices, exercise, and income and (2) determine empirically the relationship between food prices and income on body weight of various demographic subgroups. This study estimates the effect of price and income changes on body weight by considering three different interventions: (1) high-calorie food tax, (2) low-calorie food subsidy, and (3) income and wage changes.

The empirical analysis employs three different model specifications. First, as a robustness check, we estimate a quadratic model similar to that of Chou, Grossman, and Saffer, but we use an alternative and more recent dataset. We also go beyond their analysis by estimating standard errors of the price-weight elasticities, determining mean body weight changes. Second, we test alternative model specifications and compare them to the functional form chosen by Chou, Grossman, and Saffer. Our third model specification determines how the effect of relative price and income changes on body weight differs by demographic factors. Previous research has investigated price-weight relationships by gender, race, and ethnicity but has not considered important socioeconomic characteristics such as education or income level (e.g., Cutler, Glaeser, and Shapiro; Lakdawalla and Philipson). Overall, this study goes beyond previous research by providing a theoretical foundation to the empirical model, more thoroughly considering model specification, and by considering a wider array of socioeconomic characteristics.

A Model of Consumer Behavior Including Weight

Theoretical Model

This study follows the framework proposed by Philipson and Posner and further developed in Schroeter, Lusk, and Tyner. An individual's body weight is a function of the quantity of foods consumed and the level of exercise. The derivation will first be illustrated with a simple three-good model example and later will be extended to the N-good case. In the three-good example, the body weight W is affected by the quantity of high-calorie (F^{H}) foods consumed, the quantity of low-calorie (F^{L}) foods consumed, and the level of exercise (E); that is, $W = W(F^{H}, F^{L}, E)$. Weight W is strictly increasing in food intake F_f (f = H, L) and decreasing in exercise E (i.e., $\partial W/\partial F > 0$ and $\partial W/\partial E < 0$. Forming the utility function leads to

$$(1)\quad U\left[W\left(F^{H}, F^{L}, E\right), F^{H}, F^{L}, E, C\right].$$

where C represents all other consumption goods.

Utility Function (1) is maximized with respect to a budget constraint

$$(2)\quad p_{F^{H}}F^{H} + p_{F^{L}}F^{L} + p_{E}E + p_{C}C = I,$$

where p_{F^i} is the price of food type i (i = H, L), p_E is the price of exercise, p_C is the price of all other consumption goods, and I represents income. Given the traditional trade-off between an hour of labor for leisure-time activities, a price is associated with exercise. This set-up is similar to Philipson and Posner, who included an individual's weight in the utility function, but did not differ between multiple foods. As shown in subsequent analyses, this has important implications for the efficacy of a tax or subsidy.

Maximizing Utility Function (1) with respect to the budget constraint in Equation (2) results in Marshallian demand curves for high-calorie food, low-calorie food, and exercise. Solving the first-order condition creates an optimal weight equation W^*, which depends on prices of all goods and income

$$(3)\quad \begin{aligned} W^* = W^*\big[&F^{H*}(p_{F^{H}}, p_{F^{L}}, p_C, p_E, I),\\ &F^{L*}(p_{F^{H}}, p_{F^{L}}, p_C, p_E, I),\\ &E^*(p_{F^{H}}, p_{F^{L}}, p_C, p_E, I)\big], \end{aligned}$$

where the asterisk superscript indicates utility-maximizing levels.

To determine the effect of a high-calorie food tax, which would change the price of a high-calorie food, the optimal weight Equation (3) is differentiated with respect to the high-calorie food price $p_{F^{H}}$, which yields

$$(4)\quad \frac{\partial W^*}{\partial p_{F^{H}}} = \frac{\partial W^*}{\partial F^{H*}}\frac{\partial F^{H*}}{\partial p_{F^{H}}} + \frac{\partial W^*}{\partial F^{L*}}\frac{\partial F^{L*}}{\partial p_{F^{L}}} + \frac{\partial W^*}{\partial E^*}\frac{\partial E^*}{\partial p_{F^{L}}},$$

which can be converted to the first key elasticity equation as in Equation (5):

$$(5)\quad \varepsilon_{W^*p_{F^{H}}} = \varepsilon_{W^*F^{H*}}\varepsilon_{HH} + \varepsilon_{W^*F^{L*}}\varepsilon_{LH} + \varepsilon_{W^*E^*}\varepsilon_{EH}.$$

In this key elasticity equation, $\varepsilon_{W^*p_{F^{H}}}$ is the percent change in weight resulting from a 1% change in $p_{F^{H}}$. This weight change is influenced by the sum of three multiplicative terms of price and food-weight elasticities. The food-weight elasticities, $\varepsilon_{W^*F^{i*}}$, represent the percent change in weight resulting from a 1% change in food type i. The exercise-weight elasticity, $\varepsilon_{W^*E^*}$, is the percent change in weight resulting from a 1% change in exercise. The percent change in weight associated with a 1% change in high-calorie food price is also influenced by ε_{HH}, which is the own-price elasticity of demand for the high-calorie food, and ε_{LH} and ε_{EH}, which are cross-price elasticities associated with the percent change in consumption of low-calorie food and exercise, respectively, resulting from a 1% change in the price of high-calorie food. The elasticity equation resulting from a change in the price of the low-calorie food is equivalent to that in Equation (5) with the superscripts H and L reversed on the food types and prices. Income-weight changes can be determined by differentiating the optimal weight Equation (3) with respect to income I.

The policy objective is to reduce weight; thus, it is desirable that the price-weight elasticity $\varepsilon_{W^*p_{F^{H}}}$ is negative. This holds true when high- and low-calorie foods are complements, as Schroeter, Lusk, and Tyner demonstrate. In the case of the ability for substitutions, the weight outcome depends on the strength of the substitution between high- and low-calorie foods relative to the own-price effect. If the substitution is strong relative to the own-price effect, a tax on high-calorie food will actually *increase* weight (see Schroeter, Lusk, and Tyner for a derivation of these outcomes).

Empirical Model

In this study, we estimate price-weight and income-weight elasticities using three different functional forms. As a robustness check, the first model uses the same model specification as Chou, Grossman, and Saffer, who estimate the effect of the prices of meals in restaurants, food consumed at home, cigarettes, and alcohol on BMI. Second, this study expands

Chou, Grossman, and Saffer, by evaluating the specification of the functional form. Finally, we estimate the price-weight and income-weight elasticities for different demographic subgroups. The goal of this section is to derive the key equations used in the empirical estimations.

The functional form used by Chou, Grossman, and Saffer is

$$\text{(6)} \quad \begin{aligned} \text{BMI}^*_{jr} &= \alpha_{0r} + \beta_{1r}p_{1r} + \beta_{2r}p_{2r} + \dots \\ &\quad + \beta_{ir}p^*_{ir} + \delta_{jr}Z_{jr} + \gamma_{jr}I_{jr} \\ &\quad + \phi_{ir}p^2_{ir} + \varphi_{jr}I^2_{jr}, \end{aligned}$$

where BMI*_{jr} is the BMI of individual j living in region r, p_{ir} is the price of the ith good in region r, Z_{jr} is a demographic variable such as age of individual j in region r, and I_{jr} is the income of individual j in region r.

Price-BMI elasticities are specified by

$$\text{(7)} \quad \frac{\partial \text{BMI}^*_{jr}}{\partial p_{ir}}\left(\frac{p_{ir}}{\text{BMI}^*_{jr}}\right) = (\beta_{ir} + 2\gamma_{ir}p_{ir})\left(\frac{p_{ir}}{\text{BMI}^*_{jr}}\right).$$

The specification of the income-BMI elasticities is equivalent to that in Equation (7) when the subscript p_{ir} is substituted with I_{jr}.

The focus of this study is to determine how price and income changes directly affect individual *body weight*. Thus, after providing a robustness check of the results by Chou, Grossman, and Saffer, this study evaluates the functional form of the model specification by use of weight as the dependent variable instead of BMI. In the weight regressions, two alternative approaches are used: a log-linear and a translogarithmic transformation of Equation (3). The use of a combination of approaches helps to minimize the limitations associated with any single approach.

A log-linear model is used in Equation (8).[2]

$$\text{(8)} \quad \begin{aligned} \ln W^*_{jr} &= \alpha_{0r} + \beta_{1r}\ln p_{1r} \\ &\quad + \beta_{2r}\ln p_{2r} + \dots + \beta_{ir}\ln p_{ir} \\ &\quad + \delta_{jr}Z_{jr} + \gamma_{jr}\ln I_{jr} \end{aligned}$$

[2] It is important to note that Equation (8) is equivalent to the logarithmic transformation of Equation (6) if ln(height) is entered as independent variable and its coefficient equals 2.

This logarithmic transformation imposes a constant percent effect of the independent variables on body weight, which simplifies the calculation of elasticities. Transforming the variables into logarithmic form also has the advantage that measurement units can be ignored because the slope coefficients are invariant to rescaling. As long as the dependent variable is greater than zero, using its logarithmic transformation often satisfies the assumption of the classical linear regression model more closely than using a linear formulation. A strictly positive variable might have a conditional distribution that is heteroskedastic or skewed, which is reduced or even eliminated with the use of a logarithmic transformation. Overall, the range of the dependent or any independent variable is considerably narrowed compared with its linear form, which also has the advantage that estimates are less sensitive to outliers or extreme values (Wooldridge 2006).

Furthermore, a translog flexible functional form based on a Taylor series approximation is also investigated, which should provide an approximation to any true underlying functional form (Christensen, Jorgensen, and Lau). A general form of the equation to be estimated is

$$\text{(9)} \quad \begin{aligned} \ln W^*_{jr} &= \alpha_{0r} + \sum_{i=1}^{n}\beta_{ir}(\ln p_{ir}) + \beta_{jr}\ln I_{jr} \\ &\quad + 0.5\sum_{i=1}^{n}\sum_{l=1}^{n}\beta_{ilr}(\ln p_{ir})(\ln p_{lr}) \\ &\quad + 0.5\sum_{l=1}^{n}\sum_{k=1}^{n}\beta_{lkr}(\ln p_{ir})(\ln I_{jr}) \\ &\quad + \delta_{jr}Z_{jr}, \end{aligned}$$

where p_{ir} describes the price of good i across the geographic region r and p_{lr} describes the price of all other goods l across the geographic region r. Demographic characteristics (e.g., age) enter concomitant into the equation. The prices are normalized to display relative price changes in the goods. The translog model used in this study has interactions between all prices and income. The price-weight elasticities are determined by

$$(10) \quad \frac{\partial \ln W_{jr}^{*}}{\partial \ln p_{ir}} = \alpha_{ir} + \beta_{ir} \ln p_{ir} + 0.5 \sum_{l=1}^{n} \gamma_{lr} \ln p_{lr} + \gamma_{jr} \ln I_{jr}.$$

The third step in the empirical analysis is to provide additional insight into distributional effects of taxes and subsidies by estimating the subgroup specific results for Equations (8), (9), and (10). By estimating price-weight elasticities by demographic subgroup, this study extends the existing literature. Previous studies encourage deepening the empirical investigation of economic effects on body weight while controlling for demographic information (e.g., Marshall, Kennedy, and Offutt). Only in the context of these interactions can realistic estimates of distributional weight effects be obtained.

Data and Estimation Procedures

Following the approaches by previous studies, this research links health data to economic data (e.g., Chou, Grossman, and Saffer; Farrely et al.; Sturm and Datar). Data on individuals' body weight and demographic and physical activity information from the 2003 BRFSS are augmented with state-level measures from the U.S. Department of Labor Bureau of Labor Statistics (DOL/BLS) pertaining to the prices of food away from home, food at home, and wage information (CDC 2003; DOL; DOL/BLS 2003, 2005).

In this study, we employ Consumer Price Indices that are more encompassing than the ACCRA price indices used by others (Sturm and Datar; Chou, Grossman, and Saffer). The price of high-calorie foods can be approximated by the consumer price index (CPI) of food away from home.[3] The typical food away from home meal is less healthy than home-cooked food because it is more calorie dense and contains more total fat, more saturated fat, and fewer servings of fruit and vegetables. Several studies suggest a link between obesity and eating away from home (e.g., Jeffery and French; Lin and Frazão 1997, 1999). Regarding food at home consumption, previous studies show that consumers value the nutritional properties of food more when eating at home compared with when eating out. Therefore, this study uses the price of food at home as a proxy for low-calorie food (DOL/BLS 2007).

In addition to considering the weight effects of food price and income changes, the price-weight effects of changing the price of "exercise" are calculated. Given that a worker trades an hour of labor for leisure time activities, such as exercise, the *marginal* value of this time represents the opportunity cost of foregone wages from working. In this article, overtime wages, which are calculated as 1.5 times the average wage, are used as a proxy for the price of exercise. The actual overtime wage rates might be higher than 1.5, but BLS uses this rate (1.5) to compute 40-hour pay rates from reported wage payments that include overtime (DOL).

In total, we merge three different data sources to develop a final sample that consists of 202,323 adult men and women.[4] Summary

[3] The definitions for food away from home and food at home are based on the location where the foods are obtained and independent of where they are eaten. Foods purchased at retail stores, such as the grocery store or supermarket, are classified as food at home. Foods away from home are obtained from foodservice and entertainment establishments, which are "restaurants," or places with waiter service; "fast food" is from self-service and carry-out eating places and cafeterias; "schools" include daycare centers and summer camps; and "others" includes vending machines, community feeding programs, and someone else's home. Meals and snacks that consist of a mixture of both away-from-home and home foods are classified according to the component that contributes the most calories to that particular eating occasion (Lin and Frazão).

[4] Given that this study uses data with self-reported body weights and heights, extreme data outliers were first eliminated to prevent measurement errors. Weight and height cutoffs were determined on the basis of the upper and lower limiting heights and weights in the BMI tables in Whitney, Cataldo, and Rolfes. Also deleted were observations that were based on interviews with respondents during 2004, to guarantee a closer correspondence between the interviews and the prices and wages used in this study.

statistics and variable definitions are reported in Table 1.

Chou, Grossman, and Saffer determined the effect of an increase in the real price of food away from home and food at home on BMI. To display the effects of relative price changes, we use normalized prices in its further analysis. The use of normalized prices has the advantage that it relates the change in the price of one good to other consumer prices.

One of the consequences of using cross-sectional data is that it very likely includes unobserved effects that contain a strong regional component. Thus, to form an unbiased and consistent estimator, regional dummy variables are included to represent the unobserved components. The food prices are assigned to four U.S. regions—South, Midwest, West, and Northeast—on the basis of the original BLS geographical classification.

Results

Regressions

Table 2 shows the results of the BMI and weight regressions. The signs of the coefficients indicate the relationship between the effect on the mean sample BMI or mean sample weight and the independent variables.

The first model uses a quadratic functional form, as shown in Equation (5), following Chou, Grossman, and Saffer.[5] Overall, this study supports the findings of Chou, Grossman, and Saffer. One difference is that the current results show significant effects of the restaurant, fast food, food at home, and alcohol prices on BMI, whereas Chou, Grossman, and Saffer's estimates for fast food restaurant price and alcohol price are not significant for either the linear or the quadratic term.

Several limitations of the approach taken by Chou, Grossman, and Saffer require discussion. First, the use of the data set used by them could lead to measurement problems because the authors used a multiyear demographic data set, but cross-sectional prices. Second, preliminary regressions suggest that the model results are very sensitive—the elasticity estimates on food at home varied in sign and magnitude depending on the model specification, such as whether BMI or body weight was used as the dependent variables. After adding regional dummy variables, the models produced more robust estimates across all model specifications, in that we obtained lower AIC (Akaike Information Criterion)/SC (Schwarz Criterion) values in the BMI model with the regional dummy variables and a better model fit. However, the *t*-values declined sharply because of the variance inflation effect of collinearity, which is the trade-off that needs to be considered (Wooldridge 2002).

With regard to the second and third models, the study shows that increasing income decreases body weight. Higher income could signify a higher ability to purchase more healthful and typically higher priced foods, such as fruit and vegetables, and a better access to nutrition information compared with lower income households. Previous studies have shown that the poor tend to live in areas with more convenience stores and fewer supermarkets. The high prices and the limited product selection of convenience stores could encourage products with higher energy density (Darmon, Ferguson, and Briend 2002; Drenowski and Specter).

The variables *Employed* and *Overtime wage* reflect the technical change theory by Cutler, Glaeser, and Shapiro. Employed respondents are 1.6% heavier than unemployed respondents. This finding suggests the existence of a labor-leisure trade-off, which is consistent with Ruhm, who determined that unemployment is inversely related to obesity. Overtime wage had a negative effect on body weight. This seems reasonable, since an increase in wage rate also increases income, which would allow purchasing higher-priced, healthier food options.

Although the coefficient of the price of food away from home turned out to be negative, the coefficient of the price of food from home was positive, which differs from

[5] To facilitate the presentation, the tables show only the variables in common between this study and Chou, Grossman, and Saffer.

Table 1. Descriptive Statistics ($N = 202,323$)

Variable	Units	Mean	SD
Body mass index (BMI)	kg/m^2	26.951	5.470
Weight	kg	78.172	18.314
African American non-Hispanic	1 = yes 0 = no	0.074	0.262
Hispanic	1 = yes 0 = no	0.055	0.227
Asian	1 = yes 0 = no	0.017	0.128
Other ethnicity	1 = yes, if Native Hawaiian, other Pacific Islander, American Indian, Alaskan Native, multiracial, or from any other race, but not Hispanic, 0 = no	0.042	0.200
Other race	1 = yes, if Asian, Native Hawaiian, other Pacific Islander, American Indian, Alaskan Native, multiracial, or from any other race, but not Hispanic, 0 = no	0.058	0.234
Male	1 = male, 0 = female	0.416	0.493
Some high school	1 = yes, if $9 < x < 12$ years, 0 = no	0.064	0.244
High school graduate	1 = yes, if $x = 12$ years, 0 = no	0.299	0.458
Some college	1 = yes, if $13 \leq x < 16$ years, 0 = no	0.278	0.448
College graduate	1 = yes, 0 = no	0.330	0.470
Married	1 = yes, if married or a member of an unmarried couple, 0 = no	0.584	0.493
Divorced	1 = yes, if divorced or separated, 0 = no	0.171	0.377
Widowed	1 = yes, 0 = no	0.097	0.296
Household income	In $1,000s/household member: 4,999.5 if $x <$ $10,000; 12,499.5 if $x <$ $15,0000; 17,499.5 if $x <$ $20,000; 22,499.5 if $x <$ $25,000; 29,999.5 if $x <$ $35,000; 42,499.5 if $x <$ $50,000; 62,499.5 if $x <$ $75,000; 87.500.5 if $x \geq$ $75,000	26.778	17.346
Age	Years	48.508	16.582
Employed	1 = yes, 0 = no	0.624	0.484
Height	Meters	1.700	0.102
Moderate physical exercise	1 = yes, if performed moderate exercise (brisk walking, bicycling, vacuuming, gardening) for at least 10 minutes at a time in the past 30 days; 0 = no	0.313	0.464
Vigorous physical exercise	1 = yes, if performed vigorous exercise (running, aerobics, heavy yard work) for at least 10 minutes at a time in the past 30 days; 0 = no	0.411	0.492
5 Fruits and vegetables	1 = yes, if consumes at least 5 fruits and vegetables per day, 0 = no	0.765	0.424
Smoking	1 = yes, 0 = no	0.495	0.500
Alcohol price	In 1998 dollars	112.507	3.924
Normalized food at home price	Ratio of CPI of food at home and CPI of all items less food and energy	100.972	2.119
Normalized food away from home price	Ratio of CPI of food away from home and CPI of all items less food and energy	103.075	2.366
Overtime wage	Dollars, nominal average wage of respondent's state of residence × 1.5	25.523	3.314
South	1 = yes, 0 = no	0.311	0.463
Midwest	1 = yes, 0 = no	0.217	0.412
West	1 = yes, 0 = no	0.248	0.432

Table 2. Results of the BMI and Weight Regressions

	BMI				ln(Weight)			
	CGS (2004)		Current Data		Current Data			
	Quadratic				Log-Linear		Translog	
Variable	Estimate	*t*-value	Estimate	*t*-value	Estimate	*t*-value	Estimate	*t*-value
Constant	NA	NA	391.283**	10.82	3.076**	21.12	284.817**	6.12
African American	1.638**	57.58	2.020**	43.02	0.073**	44.05	0.074**	44.22
Hispanic	0.737**	26.09	0.341**	6.32	0.008**	3.92	0.007**	3.78
Asian					−0.103**	−31.04	−0.103**	−31.09
Other race	−0.406**	−7.14	−0.159**	−3.11				
Other ethnicity					0.028**	13.11	0.028**	13.32
Male	0.890**	54.41	0.882**	36.06	0.062**	50.35	0.062**	50.48
Some high school	−0.110**	−3.50	0.042	0.50	0.008**	2.84	0.008**	2.76
High school graduate	−0.503**	−17.21	−0.283**	−3.77	0.005	1.91	0.005	1.83
Some college	−0.572**	−19.17	−0.334**	−4.37	0.007*	2.49	0.007*	2.44
College graduate	−1.150**	−35.68	−1.200**	−15.44	−0.019**	−6.95	−0.019**	−6.74
Married	0.187**	11.99	−0.248**	−6.51	0.017**	13.30	0.016**	12.59
Divorced	−0.411**	−19.86	−0.304**	−6.67	0.016**	10.59	0.016**	10.36
Widowed	0.262**	10.00	0.024	0.42	−0.012**	−5.96	−0.013**	−6.21
Household income	−0.035**	−32.95	−0.047**	−22.15				
Household income^2	0.0002**	23.18	0.0003**	12.01				
ln(Household income)					−0.008**	−11.65	−0.377*	−2.14
Age	0.346**	165.73	0.339**	77.11	0.001**	22.58	1.776**	175.76
Age^2	−0.003**	−153.92	−0.003**	−73.67				
Fast food restaurant price	−1.216	−1.67	−2.455**	−7.33				
Full-service restaurant price	−0.687**	−4.28						
Fast food restaurant price^2	0.135	1.13	0.011**	7.37				
Full-service restaurant price^2	0.050**	3.97						
Food at home price	−6.462**	−3.37	−3.680**	−6.92				
Food at home price^2	2.244**	3.12	0.016**	6.90				
Alcohol price	1.140	1.29	−0.436**	−2.82				
Alcohol price^2	−0.734	−1.93	0.002**	2.70				
ln(Height)					1.776**	175.71	−0.017**	−14.89

Table 2. (Continued)

	BMI				ln(Weight)			
	CGS (2004)		Current Data		Current Data			
	Quadratic				Log-Linear		Translog	
Variable	Estimate	*t*-value	Estimate	*t*-value	Estimate	*t*-value	Estimate	*t*-value
Moderate physical exercise					−0.017**	−14.89	−0.050**	−44.83
Vigorous physical exercise					−0.050**	−44.95	0.012**	11.69
5 Fruits and vegetables					0.012**	11.75	−0.011**	−12.93
Smoking					−0.011**	−13.01	0.017**	16.59
Employed					0.016**	16.29	−44.717**	−2.75
ln(Food away from home price)					−0.044	−1.86	−66.644**	−7.36
ln(Food at home price)					0.114**	4.90	−14.592**	−7.73
ln(Overtime wage)					−0.016**	−3.65	−0.001	−0.53
South					0.0004	0.28	0.010**	5.27
Midwest					0.015**	9.88	0.002	1.6
West					0.004**	2.72	7.808**	3.52
ln(Normalized food away from home price^2)							11.873**	5.09
ln(Normalized food at home price^2)							−0.003	−0.06
ln(Overtime wage^2)							−0.004**	−3.52
ln(Household income^2)							0.001**	22.69
ln(Normalized food away from home price) × ln(normalized food at home price)							2.166	0.61
ln(Normalized food away from home price) × ln(overtime wage)							2.069**	3.66
ln(Normalized food at home price) × ln(overtime wage)							4.231**	8.52

Table 2. (Continued)

	BMI				ln(Weight)			
	CGS (2004)		Current Data		Current Data			
	Quadratic				Log-Linear		Translog	
Variable	Estimate	*t*-value	Estimate	*t*-value	Estimate	*t*-value	Estimate	*t*-value
ln(Household income) × ln(normalized food away from home price)							0.098	1.91
ln(Household income) × ln(normalized food at home price)							0.050	0.92
ln(Household income) × ln(overtime wage)							0.023*	2.36
$\bar{R}^2$	0.081		0.061		0.339		0.340	
RMSE			5.304		0.186		0.186	
AIC (SC)			3.337 (3.338)		−3.365 (−3.363)		−3.365 (−3.364)	
Sample size	1,111,074				202,323			

* Coefficient significant at the 5% level.
** Coefficient significant at the 1% level.

Table 3. Price-Weight Elasticities across Models for Dependent Variables BMI and Weight

	BMI				Ln(weight)			
	CGS (2004)		Current Data		Current Data			
	Quadratic				Log-linear		Translog	
Variable	BMI Elasticity	BMI change (Base BMI = 26.015)	BMI Elasticity (SE)	90% Confidence Interval BMI Change (Base BMI = 26.950)	Weight Elasticity (SE)	90% Confidence Interval Weight Change (Base Weight = 78.17)	Weight Elasticity (SE)	90% Confidence Interval Weight Change (Base Weight = 78.17 kg)
Fast food restaurant price	−0.048	−0.012	−0.044 (0.027)	−0.012 [−0.088, +0.0003]	−0.044 (0.024)	−0.034 [−0.083, −0.005]	−0.036 (0.030)	−0.028 [−0.086, +0.014]
Full-service restaurant price	−0.021	−0.005						
Food at home price	−0.039	−0.010	−0.027 (0.029)	−0.007 [−0.075, +0.002]	0.114 (0.023)	+0.089 [+0.076, +0.152]	0.084 (0.032)	−0.066 [−0.136, −0.032]
Alcohol price	−0.017	−0.004	−0.080 (0.016)	−0.022 [−0.096, −0.064]				
Income	−0.030	NA	−0.030 (0.001)	−0.008 [−0.028, −0.032]	−0.007 (0.001)	−0.006 [−0.009, −0.007]	−0.009 (0.001)	−0.007 [−0.010, −0.008]
Overtime wage					−0.016 (0.004)	−0.012 [−0.023, −0.009]	−0.011 (0.005)	−0.009 [−0.020, −0.003]

Table 4. Effects of Alternative Policies by Demographic Subgroup

Subgroup Category	Variable	10% Tax on Food Away from Home		10% Subsidy Food at Home		10% Change in Overtime Wage		10% Change in Income	
		Log-Linear	Translog	Log-Linear	Translog	Log-Linear	Translog	Log-Linear	Translog
Gender	Male	−1.003 (0.314)	−0.767 (0.403)	−1.107 (0.307)	−0.920 (0.042)	−0.243 (0.057)	−0.196 (0.067)	0.098 (0.009)	−0.102 (0.010)
	Female	0.061 (0.332)	−0.055 (0.433)	−1.114 (0.330)	−0.850 (0.455)	−0.100 (0.062)	−0.050 (0.074)	−0.171 (0.010)	−0.208 (0.011)
Race/ethnicity	African American	0.070 (0.850)	0.701 (1.364)	−1.074 (1.030)	−1.242 (1.413)	−0.316 (0.150)	−0.232 (0.296)	−0.014 (0.024)	−0.040 (0.033)
	Asian	−3.291 (1.902)	−1.790 (2.580)	−3.597 (1.682)	−5.389 (2.396)	−0.054 (0.333)	−0.149 (0.507)	−0.015 (0.035)	0.018 (0.048)
	Hispanic	−1.332 (1.351)	−2.688 (1.815)	2.694 (1.076)	3.010 (1.599)	−0.177 (0.238)	−0.057 (0.334)	−0.041 (0.025)	0.024 (0.035)
	Other ethnicity	2.310 (1.388)	1.405 (1.790)	−1.586 (1.287)	−2.058 (1.612)	−0.294 (0.222)	−0.388 (0.252)	−0.100 (0.031)	−0.081 (0.040)
	White	−0.415 (0.261)	−0.325 (0.330)	−1.388 (0.255)	−0.817 (0.351)	−0.100 (0.050)	−0.070 (0.056)	−0.086 (0.010)	−0.095 (0.008)
Education level	No schooling	−1.599 (1.433)	−2.010 (2.278)	−0.239 (1.520)	−0.668 (2.627)	−0.807 (0.301)	−0.781 (0.414)	0.004 (0.037)	0.042 (0.070)
	Some high school	−1.052 (1.007)	−1.750 (1.521)	−2.261 (1.038)	−1.056 (1.603)	0.035 (0.199)	0.232 (0.263)	−0.041 (0.026)	0.048 (0.044)
	High school graduate	−0.088 (0.441)	0.150 (0.579)	−0.413 (0.442)	−0.602 (0.614)	0.009 (0.086)	0.107 (0.100)	−0.074 (0.012)	−0.125 (0.014)
	Some college	−0.490 (0.458)	−0.217 (0.585)	−1.575 (0.456)	−1.154 (0.618)	0.224 (0.087)	0.180 (0.100))	−0.091 (0.012)	−0.082 (0.015)
	College graduate	−0.243 (0.383)	0.126 (0.539)	−1.095 (0.366)	−0.091 (0.553)	−0.525 (0.065)	−0.470 (0.100)	−0.085 (0.112)	−0.096 (0.012)
Marital status	Single	0.141 (0.643)	0.816 (0.851)	−1.432 (0.625)	−1.364 (0.897)	−0.373 (0.109)	−0.351 (0.148)	0.001 (0.010)	0.010 (0.019)
	Married	−0.612 (0.295)	−0.878 (0.379)	−0.756 (0.293)	−0.149 (0.400)	−0.182 (0.056)	−0.157 (0.064)	−0.105 (0.010)	−0.126 (0.010)
	Widowed	−0.720 (0.753)	−1.254 (1.005)	−0.790 (0.764)	−1.214 (1.076)	0.030 (0.144)	0.116 (0.166)	−0.125 (0.020)	−0.148 (0.024)
	Divorced	−0.085 (0.608)	0.969 (0.801)	−2.431 (0.594)	−2.282 (0.804)	0.047 (0.111)	0.010 (0.132)	−0.100 (0.015)	−0.100 (0.170)
Age	<30 years	0.708 (0.638)	1.466 (0.834)	−0.583 (0.623)	−0.140 (0.876)	−0.354 (0.116)	−0.181 (0.146)	−0.010 (0.016)	−0.066 (0.022)
	Between 30 and 49 years	−1.281 (0.393)	−0.195 (0.444)	−1.476 (0.383)	−1.262 (0.465)	−0.258 (0.073)	0.056 (0.073)	−0.186 (0.012)	−0.098 (0.010)
	Between 49 and 65 years	0.125 (0.453)	−0.136 (0.593)	−1.136 (0.452)	−0.975 (0.615)	−0.013 (0.084)	0.009 (0.099)	−0.096 (0.013)	−0.103 (0.014)
	>65 years	0.011 (0.519)	0.300 (0.692)	−1.166 (0.524)	−1.690 (0.742)	0.045 (0.098)	0.121 (0.114)	−0.096 (0.015)	−0.120 (0.018)
Employment status	Employed	−0.491 (0.291)	−0.508 (0.377)	−1.040 (0.286)	−0.400 (0.399)	−0.256 (0.053)	−0.243 (0.064)	−0.017 (0.009)	−0.034 (0.009)
	Unemployed	−0.384 (0.395)	−0.380 (0.538)	−1.457 (0.394)	−1.570 (0.557)	0.006 (0.076)	0.100 (0.100)	−0.150 (0.010)	−0.205 (0.014)
Exercise level	Vigorous or moderate exercise	−0.428 (0.249)	−0.394 (0.318)	−1.204 (0.245)	−0.821 (0.334)	−0.178 (0.046)	−0.130 (0.054)	−0.103 (0.007)	−0.118 (0.008)
	No exercise	0.064 (0.730)	1.119 (1.035)	−0.462 (0.743)	−2.006 (1.089)	−0.269 (0.143)	−0.110 (0.172)	−0.070 (0.019)	−0.067 (0.025)

Table 4. (Continued)

Subgroup Category	Variable	10% Tax on Food Away from Home		10% Subsidy Food at Home		10% Change in Overtime Wage		10% Change in Income	
		Log-Linear	Translog	Log-Linear	Translog	Log-Linear	Translog	Log-Linear	Translog
5 Fruits and vegetables a day	Consumes 5 a day	−0.428 (0.268)	−0.486 (0.347)	−1.147 (0.268)	−0.705 (0.367)	−0.140 (0.051)	−0.114 (0.059)	−0.062 (0.008)	−0.069 (0.009)
	Does not consume 5 a day	−0.518 (0.493)	−0.028 (0.638)	−1.139 (0.471)	−1.345 (0.649)	−0.236 (0.086)	−0.132 (0.107)	−0.125 (0.014)	−0.146 (0.015)
Region	Northeast	−1.400 (0.867)		−2.286 (0.737)		−0.230 (0.112)		−0.080 (0.013)	
	South	−0.539 (0.472)		−1.017 (0.455)		−0.548 (0.078)		−0.100 (0.120)	
	Midwest	−0.534 (0.600)		−0.954 (0.787)		−0.127 (0.183)		−0.095 (0.015)	
	West	8.952 (1.018)		0.285 (0.569)		0.915 (0.102)		−0.028 (0.013)	

the BMI regression result. These findings are consistent with the findings of previous studies. Sturm and Datar show that children who live in communities in which fruit and vegetables are expensive are more likely to be obese than children who live in areas with lower produce cost.

Furthermore, this study compared and evaluated the functional form of the model specification of the quadratic BMI model and the log-linear and translog weight regressions. The translog and log-linear weight regressions show higher adjusted R^2 values and lower root mean square error (RMSE) and AIC values than the BMI regression, which indicates a better model specification than the BMI regression used by Chou, Grossman, and Saffer.

Elasticities

Table 3 shows the effects of 1% changes in the prices of food away from home, food at home, and alcohol, and income changes on BMI and the effect of a 1% overtime wage change on body weight were estimated as well. Standard errors were calculated by the delta method.

A 1% increase in the price of either one of the food types decreases BMI by 0.036% on average. The income-BMI elasticity was identical between this study and Chou, Grossman, and Saffer. The 95% confidence intervals that reflect the likely variations in the individuals' weight responses are shown in brackets. The confidence intervals confirm the robustness, in that the effects on BMI were comparable between the two studies. Given that the confidence intervals for the fast food price-BMI elasticity and the food at home price-BMI elasticity in either the log-linear or the translog model include zero, these price changes could lead to a weight increase.

Regarding the price-weight changes, an increase in the price of food away from home by 1% decreases body weight by 0.04% on average, which is consistent with the previous estimates in the BMI regression. This effect can be explained with a substitution effect toward food at home after the change in the price of food away from home. Typically, food consumed at home tends to be lower in calories, and portion sizes consumed are smaller than food away from home. Lin, Guthrie, and Frazão determined that over the past two decades, Americans have made remarkable progress in reducing the densities of fat, saturated fat, and cholesterol in foods consumed at home. The researchers calculate that if food away from home had the same nutritional densities as food at home in 1995, Americans would have consumed 197 calories fewer per day.

Interestingly, the largest weight response results from changes in the price of food at home. A 1% increase in the price of food at home would increase body weight by 0.1% on average. This result is consistent with previous research that suggests a substitution effect encouraging the consumption high-calorie fast foods (*Seattle Times*). Thus, it might seem an efficient strategy to decrease body weight. In this case, these respondents might be encouraged to substitute more food at home for food away from home and achieve weight loss. Considering the case of subsidizing food at home, the sign of the food at home price-weight elasticity switches and turns negative to reflect the price decrease.

The 1% increase in income is associated with an average decrease in body weight of 0.08%, which might be because with increased income, healthier food choices are made. Increasing the overtime wage by 1% leads to decreasing body weight of 0.014% on average, which could be because an increase in wage increases income, which is associated with lower body weight because of a higher availability of healthier food.

Weight Elasticities by Subgroups

The results of the regression analyses showed that price and income changes influence body weight; however, a more differentiated analysis is important to determine the individual effects of price- and income-weight elasticities by subgroup, which allows the development of appropriate public policies.[6]

[6] Because the administrative cost of implementing a 1% tax would probably outweigh its benefits, this study focuses on policy changes of 10%, and all price-weight elasticities are scaled by a factor of 10.

Table 4 provides the subgroup elasticities by gender, race/ethnicity, education level, marital status, age, employment status, exercise level, fruit and vegetable consumption, and region. Overall, the effects of price and income changes on body weight varied greatly by demographic subgroup.

Only a few demographic subgroups showed a significant weight response after changing the price of food away from home, which is consistent with the nonsignificant price-weight elasticities of food away from home in the previous weight regressions.

However, most demographic subgroups showed a significant response after the 10% subsidy of food at home, and the main effect of the subsidy was a weight loss. Hispanics and respondents in the West were the only two demographic groups that showed weight gains.

Discussion and Conclusions

This study determined that decreasing the price of food at home is a relatively efficient method of significantly decreasing body weight. This option targets several high-risk population groups, such as low-income consumers, African Americans, whites, unemployed respondents, and consumers who do not consume enough fruit and vegetables. This finding is consistent with the finding by Cash, Sunding, and Zilberman, and Sturm and Datar, who determine a positive health and distributional effect of a small retail price subsidy on fruit and vegetables.

Furthermore, the analysis showed that the least efficient alternative is to tax food away from home, as it leads to significant weight increases across various demographic subgroups. This finding confirms the results by previous studies that argue that a high-calorie tax is regressive, because it would hurt lower income households who rely on fast food for cheap meals. Taxing the higher caloric food away from home might increase body weight because the reduction in the intake of the high-calorie foods could lead to a reduction in some other necessary nutrients. Thus, compensatory purchases of other foods might well result in an increase in total calorie intake, and thus, a weight increase (e.g., Darmon, Ferguson, and Briend 2002; Schroeter, Lusk, and Tyner; Smith and Tasnádi). Eating away from home has been associated with poor diet quality, perhaps because of fewer food choices or less information about the nutrient content of the foods consumed. Another reason could be that consumers regard eating away from home as a "splurge," independent of its frequency, and use it as an opportunity to enjoy foods other than their usual diet, such as desserts. In this case, behavioral strategies need to change consumer attitudes regarding eating out or modify the environmental setting of fast food and full-service restaurants. Increased information on the nutrient content of foods should be provided or institutional meal plans should be adjusted toward more healthful food choices to reduce the intake of high-calorie foods (Guthrie, Derby, and Levy).

Several limitations should be noted regarding this study. While aiming at incorporating several potential factors, the analysis explained, at most, a third of the variance in the obesity epidemic. Another limitation is the nonexistence of price data. Merging price data with demographic information serves only as a rough approximation of the prices that consumers would face in real life, in that it assumes that consumers within each region face the same food prices. Clearly, food prices vary because of the low search cost of some consumers and the ability to shop in many different stores. However, the major advantage of the CPI data is that has a more comprehensive regional coverage than other similar price data sets. This makes the inclusion of a large number of observations possible, which allows for a detailed stratified analysis by population subgroups.

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