An Empirical Analysis of Fruit and Vegetable Consumption and Its Relationship to Adult Obesity in the U.S.

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1. Introduction

Overweight and obesity (hereinafter overweight/obesity) have risen to an epidemic rate and are among the most important health challenges in the U.S. (Centers for Disease Control and Prevention, CDC, 2011, 2012b,c).[1] Figure 1 shows that adult overweight/obesity rates have increased markedly from 1995 to 2010. In 2009-2010, more than two-thirds of adults and more than one-third of children and adolescents are overweight or obese; and 35.7% (78 million) adults and 17% (12.5 million) of children and adolescents are obese (CDC, 2012c; Ogden et al., 2012). Figure 2 illustrates obesity prevalence over time and across states and regions. The obesity prevalence is higher than 20% in all states in 2010 compared to 22 states in 2000; and the prevalence is at least 25% in 36 states in 2010 compared to no state in 2000. No state had an obesity rate at or greater than 30% in 2004, and the number has increased to three states in 2005 and 12 states in 2010 (CDC, 2012c).

Overweight/obesity has serious health and economic consequences. Overweight/obesity is associated with increased risks of various health conditions, such as coronary heart disease, Type 2 diabetes, certain cancers, and hypertension, and premature death (National Institute of Health, NIH, 1998; U.S. Department of Health and Human Services, USHHS, 2001; CDC, 2012b). The medical costs attributed to overweight/obesity are estimated at staggering $147 billion in 2008 dollars (Finkelstein et al., 2009; CDC, 2012b).

[1] Overweight and obesity are both labels for ranges of weight that are greater than what is generally considered healthy for a given height. The body mass index (BMI) is used to determine the adult overweight and obesity ranges. An adult is considered overweight if BMI is between 25 and 29.9, or obese if BMI is at least 30 (CDC, 2012a).

The causes of overweight/obesity are myriad and complex, including genetic, behavioral, environmental, social, and economic factors. Nonetheless, obesity is on the whole a result of calorie imbalance involving excessive calorie consumption and/or inadequate physical activity. (USHHS, 2001; NIH, 2008; CDC, 2012b). Poor diet together with physical inactivity are recognized as the most important factors contributing to the epidemic of overweight/obesity in all segments of our society and are linked to major causes of illness and death (USDA and USHHS, 2011b). Poor diet is characterized by calorie and nutrient imbalance. The 2010 Dietary Guidelines for Americans (DGA) (USDA and USHHS, 2011b) and *2020 Healthy People* (USHHS, 2010) are expressly cognizant of the associations between diet and body weight and overall health. The keys to building a healthy diet are to increase nutrient-dense foods particularly fruits and vegetables, and reduce energy-dense foods, and thereby to balance calories. Healthy diets are not only solutions to health problems, but also central to sustainable health and wellness, life quality and satisfaction, and more productive and longer lives for the current and future generations.

The 2010 DGA and *2020 Healthy People* accentuate the chief importance and necessity of fruits and vegetables in building a healthy diet and recommend increasing fruit and vegetable intakes. The DGA suggests making half of the plate fruits and vegetables. The DGA recommendations and *2020 Healthy People* objectives are based on extensive scientific evidence on the benefits of fruits and vegetables (see literature review). Both recognize that a diet high in fruits and vegetables contributes to reducing risks of many health conditions as well as weight management. Figure 3 shows that fruit and vegetable intakes of the average American diet are 58% and 41% below the DGA recommended levels, respectively. As a result, nutrients like potassium, fiber, and vitamin D are low enough to be of public health concern. These nutrients can be found in fruits and vegetables. In contrast, the amounts of solid fats, added sugars, and refined grains have overly exceeded the DGA suggested limits (USDA and USHHS, 2011b). Promoting fruit and vegetable consumption in schools and communities is the priority of many agriculture and health policies, programs, and initiatives that aim to ameliorate overweight/obesity condition.[2] Effective policies and programs depend critically on our understanding of the link between overweight/obesity and fruit and vegetable consumption and the factors that influence overweight/obesity as well as fruit and vegetable consumption.

The first set of analysis estimates the effect of fruit and vegetable consumption on obesity prevalence while accounting for the effects of demographics and physical activity. The second set applies the similar model structure to estimate fruit and vegetable consumption as a function of demographic characteristics and health awareness indicators, such as being obese, aware of high blood cholesterol level or hypertension. The study will utilize a panel dataset from the CDC's Behavioral Risk Factor Surveillance System (BRFSS) from 1996 to 2009. The empirical models are estimated by fractional response econometric models. The paper, however, does not provide empirical implications for the overall benefits of fruit and vegetable consumption, which can be many and not limited to body weight management (see literature review).

2. Literature Review

Studies on Fruit and Vegetable Consumption and Body Weight

The DGA recommendations and *2020 Healthy People* objectives are based on extensive and systematic reviews of scientific evidence on the benefits of fruits and vegetables, which are

[2] These include 1) the DGA (www.dietaryguidelines.gov), 2) *2020 Healthy People* (www.healthypeople.gov/2020), 3) White House Task Force on Childhood Obesity (WHTFCO, 2010), 3) *Let's Move!* (www.letsmove.gov), 4) *MyPlate* (www.choosemyplate.gov), 5) *Fruits & Veggies—More Matters* (www.fruitsandveggiesmatter.gov), 6) CDC's State-Based Nutrition and Physical Activity Program to Prevent Obesity and Other Chronic Diseases (NPAO) (www.cdc.gov/obesity/stateprograms), and others.

documented in a report by the Dietary Guidelines Advisory Committee (DGAC) (USDA and USHSS, 2011a) and in Nutritional Evidence Library (NEL) (USDA, 2010). The main benefits of include: 1) most fruits and vegetables are major contributors of a number of under-consumed nutrients; 2) consumptions of fruits and vegetables are associated with reduced risk of many chronic diseases; and 3) most fruits and vegetables are relatively low in calories (USDA and USHHS, 2011b).

The DGAC reports, "the evidence for an association between increased fruit and vegetable intake and lower body weight is modest with a trend towards decreased weight gain over five or more years in middle adulthood. No conclusions can be drawn from the evidence on the efficacy of increased fruit and vegetable consumption in weight loss diets."[3] The DGAC's systematic review is based on 11 studies that were selected by a set of criteria and published between 2004-09. Five are studies on selected U.S. population. Goss and Grubbs (2005) utilize the 2002 BRFSS data for residents in seven counties in Florida, and find a negative association between mean BMI and fruit and vegetable consumption controlling for physical activity but not smoking. The methodologies include descriptive statistics and chi-square mean-comparison tests. The study is limited to associations between fruit and vegetable intake, physical activity, and/or smoking habit without other control variables, such as demographics.

The Economic Research Service (ERS) of USDA coordinated a congressionally mandated study on the public health effects of food deserts. The project yielded a workshop summary by Institute of Medicine and National (IOM) and National Research Council (NRC) (2009) and a report to the Congress by USDA (2009). Both publications include evidence

[3] Available online: www.nutritionevidencelibrary.com/conclusion.cfm?conclusion_statement_id=250343. "Part D. Section 5: Carbohydrates" and "Appendix E-1: Major Conclusions. Section 5: Carbohydrates" in the DGAC report (USDA and USHHS, 2011a).

reviews on the relationships of selected dietary factors (including fruits and vegetables) with obesity [primarily based on Mattes (2009)], and with diet-related diseases [mainly drawn from Hu (2009)]. The hypothesis is that fruits and vegetables have high fiber content, and thereby they induce satiety and substitution away from energy-dense food. This leads to stabilizing and/or reducing caloric intake and ultimately body weight (USDA, 2009). As discussed, low-caloric content is one of the benefits of fruits and vegetables highlighted in the DGA. Overall, Mattes (2009), IOM and NRC (2009), and USDA (2009), consistent with the DGAC, suggest that the evidence supporting or refuting this hypothesized relationship is weak and scant.

Research progress has been made in understanding the association between fruit and vegetable consumption and body weight or overweight/obesity. However, knowledge gaps and research needs exist in these areas: (1) the evidence is mixed and insufficient that increased consumption of fruits and vegetables leads to lower BMI or reduced risk of obesity; (2) studies that go beyond correlation and try to map out causal relationships are rare, and if they do, the studies hardly discern the effect of fruit and vegetable intake from the effects of confounding factors; and (3) most studies are cross-sectional. It is challenging to deal with confounding issue and identify causation in such a setting. It is also of value to study both the pattern in cross section and trend over time. Longitudinal/panel studies are in great need.

Economic Studies on Food Environment and Body Weight

The obesity epidemic is a complex issue, and has been studied by different disciplines and from different lenses (IOM and NRC, 2009). Recent empirical economic research on obesity has largely examined a reduced-form relationship between food environment, chiefly in terms of food accessibility and/or affordability, and body weight outcomes. These studies in general bypass the intermediate behavioral (food) choices, most likely due to the lack of data on food intake/demand. Nevertheless, this set of studies provides germane literatures on the conceptual model from decision-making and behavioral economics and on the empirical model and causal identification strategies. This section reviews empirical findings and research needs in economic research and the ensuing section presents the analytical model and associated literature.

Surveys of studies on the relationships between food access and dietary intake, and between food access and weight outcomes can be found in IOM and NRC (2009), Larson et al. (2009), USDA (2009), and WHTCO (2010). The studies, in general, find that better access to a supermarket (convenience store) is associated with lower (higher) risk of obesity. Some studies find fast food availability is associated with increased risk of obesity, and others do not. Recent economic studies have focused on food away from home especially from fast food restaurants, but not on food from grocery stores, such as Chou et al. (2004), Currie et al. (2009), Dunn (2010), Dunn et al. (2001b), and Anderson and Matsa (2011). Chen et al. (2009) and Powell and Han (2012) study the effects of grocery stores and restaurants on weight outcomes. Chen et al. (2009) find that the proximity of fast food restaurants (grocery stores) has positive (negative) effect on BMI, and both effects are small. Powell and Han (2012) examine the effects of price and availability and suggest that food price and availability measures have limited influence on weight outcomes. These studies are based on the premise that fast food likely represents unhealthy food choices, whereas food obtained from grocery stores may be closely associated with healthy food, such as fruits and vegetables. Because body weight is one among many potential outcomes of dietary choices, to the extent the link is found to be weak, the finding can be misleading in terms of understanding dietary choices and health outcomes.

There is a lack of empirical economic studies on the direct link between fruit and vegetable consumption and body weight outcomes. This literature also demonstrates research needs for longitudinal/panel studies and causality analysis. Many studies in this review employ disaggregate data that are advantageous in particular to causal identification. They are applied in specific locations and for variables.

3. The Analytical Framework

The analytical framework identifies factors that potentially contribute to overweight/obesity, and lays out an overall structure of associations as well as causal pathways between food choices, individual characteristics, and contextual/environmental factors. An economic model and a multi-disciplinary socio-ecological model provide the basis for the analytical framework.

The economic model is based on decision-making and behavioral economics. It has been developed by and/or applied in several studies on food choices and body weight outcomes, e.g., Lakdawalla et al. (2002, 2005), Chou et al. (2004), Chen et al. (2009), Currie et al. (2010), Anderson and Matsa (2011), Powell and Han (2011), and Gundersen et al. (2012). Obesity is a result of an individual's energy balance over time. In this framework, an individual maximizes her/his utility by making food choices that will lead to energy balance or imbalance subject to a set of constraints. Following a concise presentation by Chen et al. (2009), if health (H) is a function of food choices (F) and a composite good for other goods that affect weight (C), an individual chooses a consumption bundle that maximizes utility (U) as follows

$$\max_{\mathrm{F,C}} \mathrm{U}(\mathrm{H},\mathrm{C}) \text{ subject to } p\mathrm{F}+\mathrm{C}=\mathrm{I} \text{ and } \mathrm{H}=f(\mathrm{F},\mathrm{C}). \quad (1)$$

where p is the price of food, and I denotes disposable income. Assuming an interior solution, optimization results in reduced-form demand equations for food (both healthy and unhealthy food) and for composite good: $\mathrm{F}^* = g(\mathrm{I},\mathrm{p})$ and $\mathrm{C}^* = h(\mathrm{I},\mathrm{p})$. Demand for health is $H^* = f(F^*, C^*)$ or $\mathrm{H}^* = k(\mathrm{I},\mathrm{p})$ in a reduced form. Economic contextual factors are prices, income, and individual preferences. The empirical model can allow for heterogeneity across individuals, including individual characteristics, choices, and contextual factors. Individual choices and hence demand are influenced by individual characteristics and by different contextual factors that individuals face in cross section and over time.

These factors identified by the economic model are in concert with the alleged causes of overweight/obesity discussed in section 1. Figure 4 presents a social-ecological framework that illustrates how elements of the society combine to influence an individual's food choices, and eventually one's health outcomes. This framework has been developed and synthesized from an array of research in social, health, and various related disciplines. The model has been emphasized in the DGA by USDA and USHHS (2011a,b) as shown in figure 4, and by IMO and NRC (2009), USDA (2009), and CDC (2010). Whereas the economic model delineates determinants of food choices and health outcomes, the socio-ecological model depicts the overall structure of the casual pathways between food choices, individual characteristics, and contextual/environmental factors.

4. The Data

The data are obtained from the Behavioral Risk Factor Surveillance System (BRFSS) by CDC. BRFSS is the world largest telephone health survey organized by CDC and conducted by state health departments each year in the U.S. More than 35,000 adults of 18 years of age or older are interviewed each year. The survey asks individuals health-related questions including health conditions and health-related behaviors, and collects demographic information (CDC, 2006).

This paper utilizes the state-level annul prevalence data, which is derived from the BRFSS annual survey data. The BRFSS annul survey data is based on the results of the survey questionnaires by individual respondents and sampling weights assigned to individual respondents. Majority of the states had survey questions about fruit and vegetable consumption in 1996, 1998, 2000, 2002, 2003, 2005, 2007, and 2009, and some states had them in 2001 in addition. The study periods are, therefore, eight years. Forty-eight contiguous states and the District of Columbia (D.C.) are included in the study. Hawaii, Alaska, and three U.S. territories are excluded, because the distinct demographics in these areas, and two of these areas included survey questions about fruit and vegetable consumption for fewer years than other states. The BRFSS annual survey data in multiple years is repeated cross-section data, because individuals randomly selected for surveys are the cross-section units and majority of them differ from year to year. Whereas the BRFSS annul prevalence data has a panel data structure with a state as a cross-sectional unit and a year as a time period. The panel data extracted for this study contains 49 cross-sectional units and eight time periods.

All variables are categorical and measured either by percentages at the state level on the annual basis in the prevalence data. BRFSS employs a disproportionate random sampling scheme to select telephone numbers, uses a weighting design, and takes a series of measures and adjustment to ensure survey quality. This study considers the sampling design of BRFSS to be rigorous and assumes the validity of random sampling. Therefore, a percentage (prevalence/fraction/proportion) of obesity, for instance, corresponds to the probability that an individual randomly selected in a given state and a given year is obese. Table 1 presents the list of variables, their descriptions, and summary statistics. The variables include those on (1) overweight/obese status, (2) fruit and vegetable consumption, (3) other health-related behaviors, and (4) demographic and socioeconomic characteristics.

The BRFSS survey asks participants to report their heights and weights, and uses the information to calculate individuals' BMI. Subsequently, the number of respondents in each overweight/obese category is counted for each state and each year. The categories include being neither overweight nor obese (BMI≤24.9), being overweight (25≤BMI≤29.9), and being obese (BMI≥30). The annul prevalence of each category in each state is calculated as the percentage of respondents in each category out of the total number of respondents in each state-year. Respondents are asked about a list of questions regarding their fruit and vegetable consumption. Based on the answers and designed formula, CDC derives the information on whether an individual has consumed fruits and vegetables at least five times a day or not.

5. The Empirical Model

The empirical models are based on the analytical framework. Obesity is a result of individual's behavioral choices, including fruit and vegetable consumption, demographic and socioeconomic characteristics, and other cross-sectional and temporal contextual factors. The empirical model for obesity prevalence can be written as,

$$OB_{it} = \alpha + \beta_1 FV5_{it} + \beta_2 PA_{it} + \beta_3 DG_{it} + \alpha_i + \alpha_t + \varepsilon_{it} \quad (3)$$

where OB_{it} is the obesity prevalence in state *i* year *t* or the probability of a person being obese in state *i* year *t* based on random sampling. $FV5_{it}$ denotes the percentage of participants who consume five servings or more fruits and vegetables per day in state *i* year *t*. PA_{it} denotes physical activity. DG_{it} represents a set of variables for demographic and socioeconomic compositions of participants in state *i* year *t*. α_i denotes unobserved individual effects, which account for unobserved state-specific contextual factors that could influence weight outcome and do not vary over study period. α_t indicates time control variables either as time FE or as trend, which account for unobserved temporary variations in weight outcome common to individual states. ε_{it} represents the idiosyncratic and transitory errors. α, β_1, β_2, and β_3 are vectors of parameters to be estimated.

The empirical model for fruit and vegetable consumption is a function of demographic characteristic and potentially awareness of health outcomes/status, HA_{it}. Awareness of pre-existing health concerns, such as obesity, high blood pressure, and high blood cholesterol, may influence dietary choices. However, it could also be that poor dietary, e.g., lack of fruit and vegetable intake, has caused certain health condition, and that habitual dietary choices of people with these conditions may not lead to consuming more fruits and vegetables. Model (4) is estimated with and without HA_{it}.

$$FV5_{it} = \gamma + \vartheta_1 DG_{it} + \vartheta_2 HA_{it} + \gamma_i + \gamma_t + e_{it} \tag{4}$$

The dependent variable represents fractional response taking values between 0 and 1. Although models (3) and (4) are presented in linear format, they are estimated as both linear as and nonlinear econometric function. The empirical model is first estimated as linear probability model by fixed-effects (FE). Although the OLS estimator is generally not fitting to nonnegative responses, it still offers in some cases good estimates of the average partial effects (APE) on the conditional mean (Wooldridge, 2010). The OLS estimates will be obtained as a benchmark to compare the estimates from alternative estimators. Bernoulli Quasi-Maximum Likelihood Estimator (QMLE) fractional probit model is a potentially suitable econometric model.

6. The Results

The Results for Obesity Prevalence

Tables (2) and (3) report the estimation results for obesity prevalence (equation (3)). The model is estimated by seven linear and nonlinear fractional response models. APEs are calculated for nonlinear models and comparable to coefficient estimates for the linear model.

Fruit and vegetable consumption has negative effect on obesity prevalence, and the size of the effects is comparable across models. Linear FE model and WLS Logit FE model yield the estimate statistically significant at 5%; GLM logit FE estimates the effect significant at 10%; and Probit models by ML estimations do not yield statistically significant effect. Wooldridge (2011) suggests that the standard errors from LM estimations of these fractional response models are considerable large in general, and hence consideration and/or adjustment are needed. The estimated APE indicates that a 10% increase in percentage of people consuming more than five servings of fruits and vegetables would lead to a 0.64-0.69% reduction in obesity rates in the population. In sum, the results suggest a negative but modest effect of fruit and vegetable consumption on obesity rate, and the effect is statistically significant according to liear and logit model estimation results.

The estimated effects of all other variables are considerably coherent across all models, in particular between linear and logit regressions. Overall, the notable demographic characteristics that are associated with higher and significant obesity prevalence include being in middle-age group, being in the African-American ethnic group, being separated from a marriage, having three children in a household, unemployed less than a year, and be retied or unable to work.

Gender proportion has no significant or sizable effect on obesity rate. African-Americans have the highest obesity prevalence compared to all other ethnic groups, and the estimates are statistically significant at 5% across all estimation models except GEE PA logit estimation. The middle-age groups, age4554 and age5565, have the highest obesity prevalence compared with other age groups. Linear and logit estimations indicate the age group between 45 and 54 years has markedly higher obesity rates than other age groups; where probit estimations suggest the group of 55-64 years has somewhat higher obesity rates, following by the age group of 45-54 years and then the group at and older than 65 years.

People who are separated also have statistically significant and high propensity for being obese compared with other groups of various marital status. Martial status as being separated has the largest effect on the propensity of being obese compared with all other variables, although its effects are significant at 5% levels for all linear and logit estimations, and not statistically significant for probit ML estimations.

The discrepancy between linear and logit estimations and probit estimations lies in the estimates for education and income. Besides being in African-American and having three children in a household, education and income variables are the only other two groups the statistically significant effects on obesity rates in probit estimations. In particular, groups with some college and with college and higher degrees have significantly lower obesity rates compared with groups with high school education or less. However, according to linear and logit estimation results, compared with people without high school degree, people with high school degree have significantly lower obesity prevalence; people with some college have somewhat lower and less significant obesity rates; and college and higher education had little impact on obesity rates. There negligible and statistically insignificant difference in obesity rates among income groups from linear and logit estimations. However, the highest income group with annual household income at least $50,000 has significantly lower obesity rates from probit estimations.

The Results for Fruits and Vegetable Consumption

Tables (4) and (5) present the estimation results for fruit and vegetable consumption (equation (4)). The model is estimated by seven linear and nonlinear fractional response models. APEs are calculated for nonlinear models and comparable to coefficient estimates for the linear model. The proportion of survey participants consumed five or more servings of fruits and vegetables decrease over years. The year-FEs are all negative across all regressions, and some are statistically significantly negative in some regression results, so are the constant. This may indicate a trend in typical American dietary substituting away from fruits and vegetables with other foods that may not be healthy.

Female population is likely to consume more fruits and vegetables compared to their counterpart, although the difference is not statistically significant. The age group of 35-44 years have the lowest propensity for fruit and vegetable consumption, and the propensity tend to increase with age based on linear and logit regressions, suggesting older age groups may be more health conscious in their dietary choices. And dietary choice education may be more effectively target at younger age groups. The estimates on ethnic groups yield interesting results: linear and logit regression results suggest that Hispanic and other ethnic groups have significantly higher fruit and vegetable consumption rates compared with Caucasian- and African-Americans; the probit regression results, on the other hand, suggest that African-Americans have significantly lower rates of consuming fruits and vegetables more than five servings a day. This may suggest that the effects of fruits and vegetables on reducing obesity rates may be more apparent and/or effective for African-Americans.

People's martial status appears to have considerable effects on his/her dietary choices, as well as obesity outcomes as seen in the previous discussion. Widows/widowers are significantly more likely to consume more fruits and vegetables; in contrast, people who are separated have the lowest propensity to consumer fruits and vegetables, though the difference is large in magnitude but not statistically significant. People with college or higher education are most likely to consume five or more servings of fruits and vegetables across all models. People with less than college education do not appear to differ from people with no high school education in terms of fruit and vegetable consumption from probit results; whereas higher education attainments are associated with higher likelihood, but not statistically significant, of consuming more fruits and vegetables in linear and logit regression. People in the upper two income brackets overall tend to consume more fruits and vegetables, with the statistical significance varies between models. Income group with annual household income between $25,000 and $34,999 tend to consume less fruits and vegetables compared with all other income groups, and the difference is statistically significant in most regression results. This may be due to this income group is most likely to substitute expenditure on fruits and vegetables with other consumer goods.

7. Conclusions and Discussion

The study estimates the effect of fruit and vegetable consumption on obesity prevalence, and examines whether and how obesity rates differ among various demographic groups, and whether and how certain demographic and socio-economic factors have influence on obesity prevalence. In addition, I examine factors that influence the propensity of consuming five or more servings of fruits and vegetables in the population. This may provide valuable insights on promoting healthy dietary choice with more fruits and vegetables in designated groups.

The study found that increasing the rate of fruit and vegetable consumption with recommended levels will reduce obesity rates with a modest degree. Although the effect of fruit and vegetable consumption on obesity is negative and largely statistically significant across various estimation models and specifications, the estimated effect has very modest magnitude. Second, middle-age group has higher obesity prevalence, and relatively lower rates of fruits and vegetable consumption compared with other age groups. Third, African-American group has the highest obesity prevalence and significantly lower fruit and vegetable consumption rates. Martial status, in particular for those who are separated, appear to have substantial effect on people' dietary choice (fruit and vegetable consumption) and obesity outcomes. Education attainments, income levels, and employment status have either no significant effect or have expected effects on dietary choice and obesity outcomes, but generally have no counter-intuitive effects on either dietary choice or obesity outcome.

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List of Acronyms

BMI: Body Mass Index

CDC: Centers for Disease Control and Prevention

DGA: Dietary Guidelines for Americans

DGAC: Dietary Guidelines Advisory Committee

FE: Fixed Effects.

IOM: Institute of Medicine

NCHS: National Center for Health Statistics

NEL: Nutrition Evidence Library

NIH: National Institute of Health

NRC: National Research Council

OLS: Ordinary Least Squares Estimation

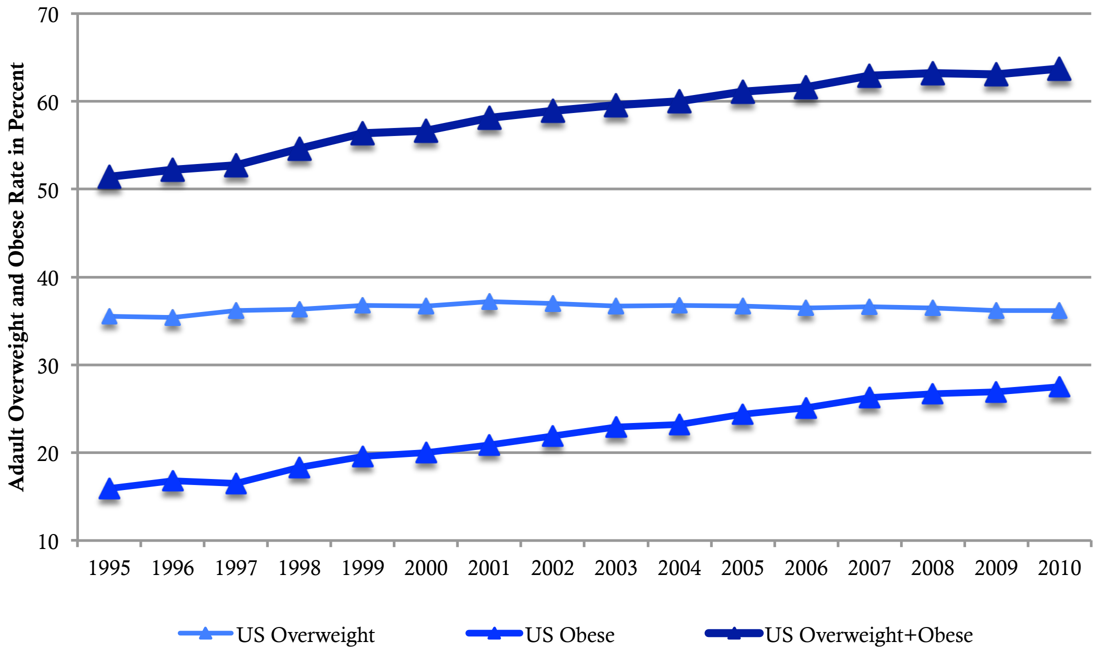
USDA: US Department of Agriculture

USDA, ERS: Economic Research Service of USDA

USHHS: US Department of Health and Human Services

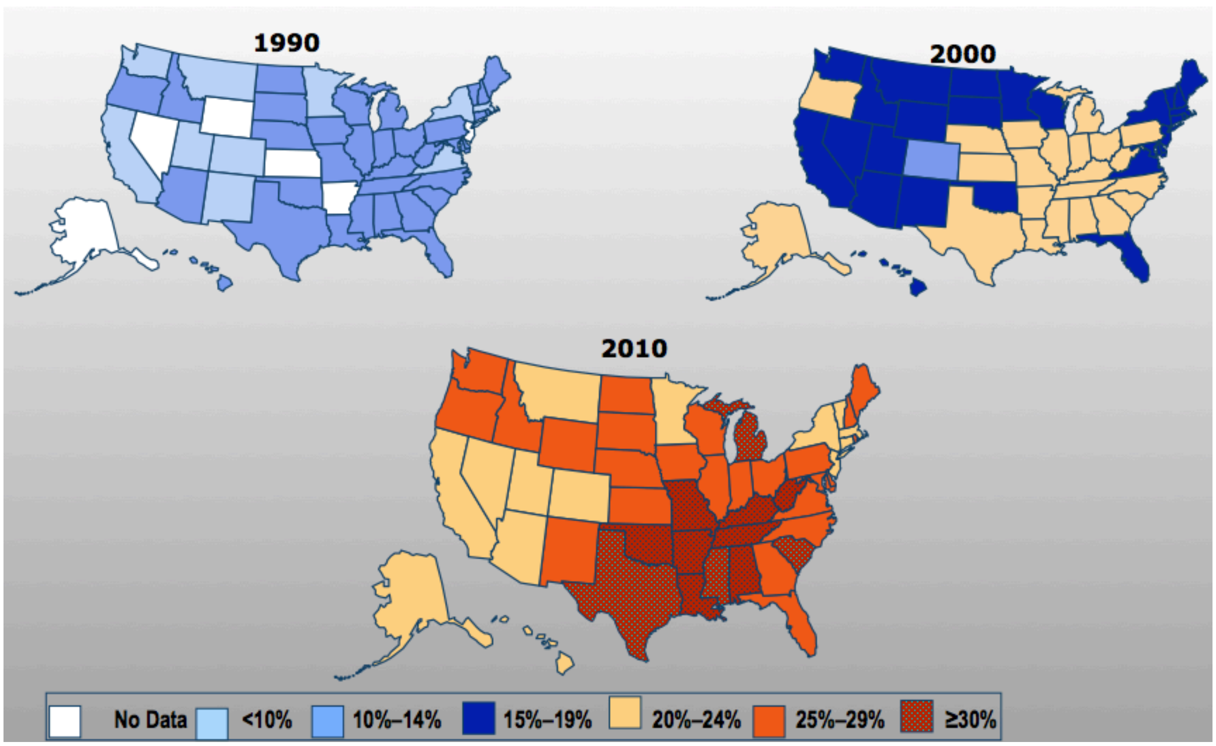
WHTFCO: White House Task Force on Childhood Obesity

Figure 1: Adult Overweight/Obesity Trends in the U.S., 1996-2010



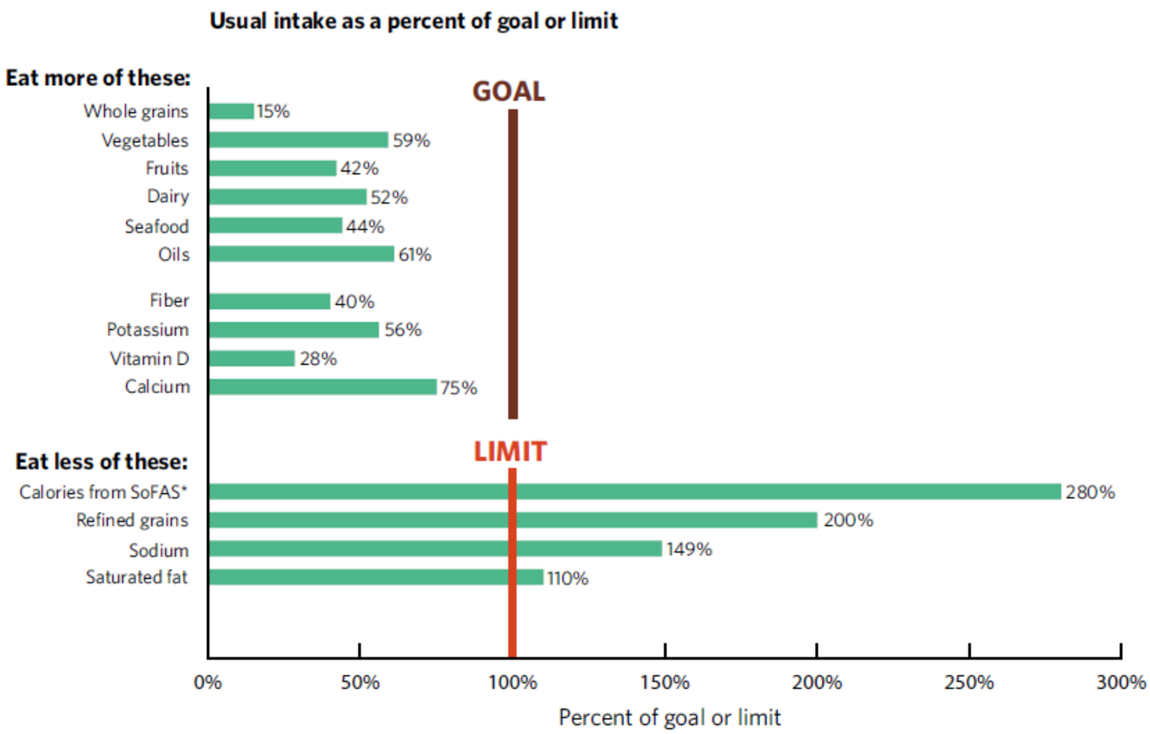
Source: *Behavioral Risk Factor Surveillance System Survey Data*, CDC, 1995-2010.

Figure 2: Adult Obesity Prevalence in the U.S. in 1990, 2000, and 2010



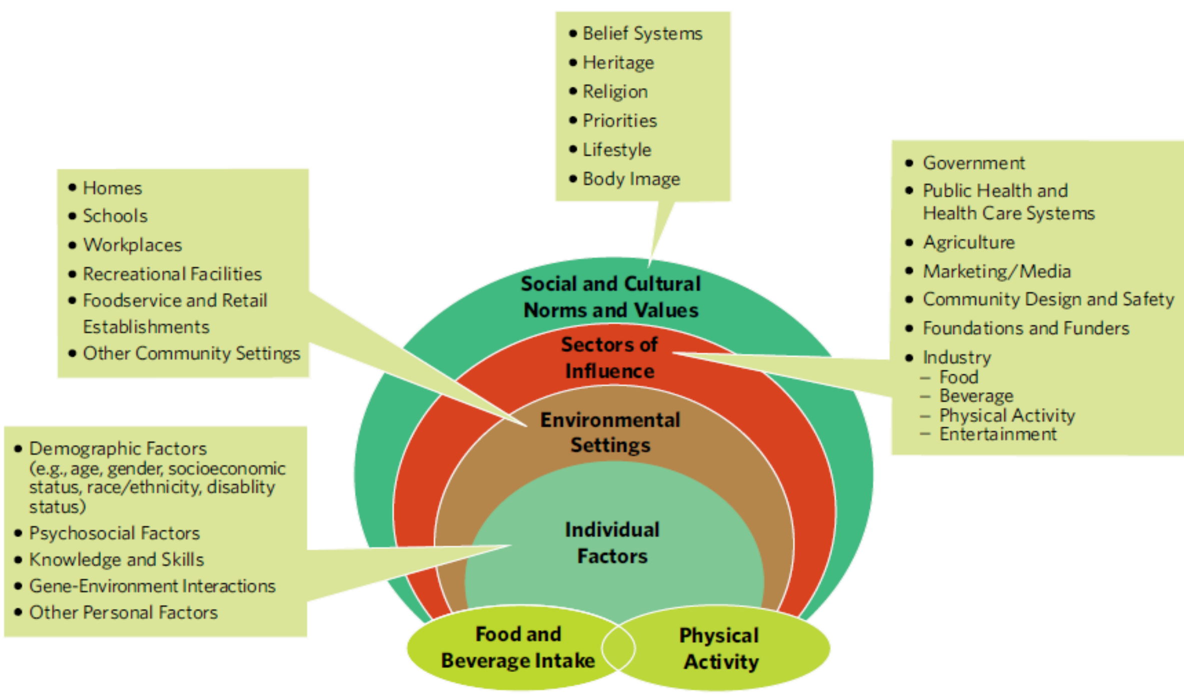
Source: Adult Obesity Facts, CDC: www.cdc.gov/obesity/data/adult.html.

Figure 3: Typical American Diets Compared to the 2010 DGA Recommended Levels or Limits



Source: The DGA, Figure 5-1 (USHHS and USDA, 2011).
Note: SoFAS refers to solid fats and added sugars.

Figure 4: Hypothesized Associations & Causal Pathways in a Socio-ecological Framework



Source: The DGA, Figure 6-1 (USHHS and USDA, 2011).

Table 1: List of Variables and Summary Statistics

Var. Name	Description	# of Obs	Mean	St. Dev.
OB	Obese (BMI≥30)	C=391	0.222	0.045
logOB	Logit (OB)	C	-1.276	0.269
FV5	Adults who have consumed fruits and vegetables five or more times a day.	C	0.235	0.040
logFV5	Logit (FV5)	C	-1.196	0.229
PAmv	Physical activity moderate or vigorous (*)	342	0.369	0.148
CHno	Cholesterol never checked.	196	0.211	0.041
CHh	Cholesterol checked, told high.	196	0.284	0.030
CHhno	Cholesterol checked, told not high.	196	0.507	0.031
HP	Told to have high blood pressure.	196	0.272	0.036
Female	Gender=Female	C	0.517	0.009
Age1824	Age 18-24	C	0.126	0.018
Age2534	Age 25-34	C	0.183	0.020
Age3544	Age 35-44	C	0.202	0.019
Age4554	Age 45-54	C	0.185	0.013
Age5564	Age 55-64	C	0.130	0.016
Age65	Age ≥ 65	C	0.174	0.020
Racew	White	C	0.789	0.138
Raceb	Black	C	0.090	0.105
Raceh	Hispanic	C	0.075	0.085
Raceo	Other	C	0.037	0.021
Mm	Married	C	0.604	0.055
Mp	Partnered	C	0.031	0.013
Md	Divorced	C	0.094	0.014
Mw	Widowed	C	0.069	0.011
Ms	Separated	C	0.019	0.008
Mn	Never married	C	0.183	0.041
Child0	No child.	C	0.597	0.038
Child1	Child=1	C	0.163	0.015
Child2	Children=2	C	0.150	0.015
Child3	Children=3	C	0.061	0.012
Child4	Children=4	C	0.020	0.008
Child5	Children≥5	C	0.009	0.005
EDhsno	Less than high school	C	0.112	0.037
EDhs	High school	C	0.317	0.045
EDcolsome	Some college	C	0.273	0.033
EDcol	College and higher	C	0.298	0.065
EPyes	Employed	390	0.539	0.040
EPself	Self-employed	390	0.087	0.020
EPnol	No work ≥ 1 year	390	0.017	0.008
EPnos	No work < 1 year	390	0.030	0.012
EPhm	Homemaker	390	0.073	0.019
EPst	Student	390	0.043	0.009
EPrt	Retired	390	0.167	0.021
EPdis	Unable to work	C	0.043	0.019
IN15	Income<$15,000	C	0.104	0.034
IN1524	Income $15,000-$24,999	C	0.182	0.041
IN2534	Income $25,000-$34,999	C	0.149	0.035
IN3449	Income $35,000-$49,999	C	0.183	0.028
IN50	Income$≥50,000	C	0.383	0.109

Note: (*) PAmv: Adults with 30 plus minutes of moderate physical activity five or more days per week, or vigorous physical activity for 20 plus minutes three or more days per week.

Table 2: Estimation Results for Obesity Prevalence

	(1) Linear FE		(2) Linear FE Logit(OB)		(3) WLS Logit FE				(4) GLM Logit FE			
	Coeff	St. Err.	Coeff	St. Err.	Coeff	St. Err.	APE	St. Err.	Coeff	St. Err.	APE	St. Err.
FV5	-0.069	0.031	**-0.393**	0.217	-0.386	0.164	-0.066	0.028	**-0.381**	0.202	**-0.065**	0.035
Female	-0.560	0.637	-4.195	3.591	-3.974	2.707	-0.678	0.462	-3.920	3.348	-0.669	0.571
Age2534	0.027	0.090	-0.356	0.488	-0.300	0.522	-0.051	0.089	-0.278	0.436	-0.048	0.074
Age3544	0.016	0.071	-0.469	0.395	-0.379	0.441	-0.065	0.075	-0.356	0.365	-0.061	0.062
Age4554	0.457	0.172	2.138	0.927	2.081	1.024	0.355	0.175	2.101	0.891	0.359	0.152
Age5565	0.096	0.176	0.970	1.012	1.039	0.974	0.177	0.166	1.058	0.914	0.180	0.156
Age65	-0.177	0.191	-1.419	1.149	-1.380	1.067	-0.235	0.182	-1.302	1.037	-0.222	0.177
Raceb	0.090	0.064	0.714	0.362	0.725	0.364	0.124	0.062	0.714	0.349	0.122	0.060
Raceh	0.005	0.088	0.138	0.531	0.157	0.363	0.027	0.062	0.171	0.489	0.029	0.084
Raceo	0.062	0.084	0.495	0.510	0.413	0.512	0.070	0.087	0.413	0.466	0.070	0.080
Mp	-0.171	0.144	-1.259	0.866	-1.130	0.725	-0.193	0.124	-1.107	0.801	-0.189	0.137
Mw	0.001	0.152	0.737	0.909	0.748	0.888	0.128	0.151	0.710	0.836	0.121	0.143
Ms	0.534	0.217	3.343	1.297	3.088	1.127	0.527	0.192	3.056	1.215	0.521	0.207
Mn	0.036	0.065	-0.268	0.412	-0.152	0.430	-0.026	0.073	-0.125	0.373	-0.021	0.064
Child1	-0.023	0.056	0.211	0.375	0.197	0.407	0.034	0.069	0.212	0.337	0.036	0.057
Child2	0.008	0.087	0.087	0.504	0.137	0.462	0.023	0.079	0.147	0.442	0.025	0.075
Child3	0.371	0.106	2.200	0.627	2.048	0.664	0.349	0.113	2.010	0.595	0.343	0.102
Child4	0.086	0.225	0.649	1.385	0.474	1.098	0.081	0.187	0.512	1.283	0.087	0.219
Child5	0.262	0.233	1.437	1.403	1.143	1.488	0.195	0.254	1.110	1.281	0.189	0.219
Edhs	-0.116	0.076	-0.914	0.451	-0.837	0.419	-0.143	0.071	-0.812	0.416	-0.139	0.071
Edhsp	-0.076	0.068	**-0.881**	0.466	-0.769	0.390	-0.131	0.067	**-0.745**	0.417	**-0.127**	0.071
Edcol	-0.063	0.064	-0.438	0.404	-0.364	0.418	-0.062	0.071	-0.362	0.378	-0.062	0.064
Epself	0.044	0.094	0.273	0.653	0.309	0.480	0.053	0.082	0.295	0.586	0.050	0.100
Epnolg	-0.161	0.142	-0.070	0.777	-0.288	0.853	-0.049	0.145	-0.302	0.718	-0.051	0.122
Epnost	0.255	0.103	1.735	0.629	1.665	0.666	0.284	0.113	1.659	0.587	0.283	0.100
Ephm	0.092	0.088	**0.981**	0.543	**0.899**	0.524	**0.153**	0.089	**0.868**	0.484	**0.148**	0.082
Epst	-0.036	0.091	-0.153	0.548	-0.190	0.544	-0.032	0.093	-0.188	0.505	-0.032	0.086
Eprt	0.284	0.108	1.935	0.710	1.753	0.541	0.299	0.092	1.729	0.665	0.295	0.113
Epdis	0.452	0.127	1.953	0.826	1.809	0.589	0.308	0.100	1.795	0.763	0.306	0.130
In1524	-0.001	0.087	0.074	0.553	-0.016	0.379	-0.003	0.065	-0.008	0.502	-0.001	0.086
In2534	-0.021	0.060	0.053	0.379	-0.019	0.391	-0.003	0.067	-0.011	0.343	-0.002	0.058
In3549	0.042	0.070	0.071	0.448	0.111	0.376	0.019	0.064	0.115	0.410	0.020	0.070
In50	-0.008	0.075	0.179	0.466	0.090	0.315	0.015	0.054	0.099	0.436	0.017	0.074

Note: The estimates shaded in grey are statistically significant at 5%; the estimates in bold are statistically significant at 10%. APE denotes average partial effect

Table 3: Estimation Results for Obesity Prevalence

	(5) GEE Logit Population-Averaged				(6) GLM Probit Pooled				(7) GLM Probit CRE			
	Coeff	**St. Err.**	**APE**	**St. Err.**	**Coeff**	**St. Err.**	**APE**	**St. Err.**	**Coeff**	**St. Err.**	**APE**	**St. Err.**
FV5	-0.495	3.897	-0.085	0.666	-0.196	0.134	-0.058	0.040	-0.188	0.198	-0.055	0.058
FV5bar									-0.020	0.305	-0.006	0.090
Female	-0.632	43.918	-0.108	7.501	0.081	1.171	0.024	0.345	0.081	1.173	0.024	0.345
Age2534	-0.309	12.224	-0.053	2.088	0.176	0.307	0.052	0.090	0.173	0.314	0.051	0.092
Age3544	-0.278	10.003	-0.048	1.708	0.344	0.214	0.101	0.063	0.347	0.214	0.102	0.063
Age4554	1.296	22.635	0.221	3.866	0.862	0.684	0.254	0.201	0.859	0.686	0.253	0.202
Age5565	0.710	22.091	0.121	3.773	**1.249**	0.663	**0.367**	0.195	**1.251**	0.664	**0.368**	0.195
Age65	-0.295	21.600	-0.050	3.689	0.653	0.566	0.192	0.167	0.651	0.570	0.192	0.168
Raceb	0.401	4.175	0.068	0.713	0.304	0.095	0.089	0.028	0.302	0.100	0.089	0.029
Raceh	-0.513	4.354	-0.088	0.743	-0.224	0.101	-0.066	0.030	-0.224	0.101	-0.066	0.030
Raceo	0.212	10.195	0.036	1.741	-0.058	0.274	-0.017	0.081	-0.061	0.284	-0.018	0.084
Mp	-1.641	15.864	-0.280	2.709	-0.770	0.481	-0.227	0.142	-0.769	0.485	-0.226	0.143
Mw	0.663	21.988	0.113	3.755	0.592	0.630	0.174	0.186	0.589	0.624	0.173	0.184
Ms	2.525	26.816	0.431	4.580	0.085	0.686	0.025	0.202	0.099	0.712	0.029	0.210
Mn	-0.397	8.512	-0.068	1.454	-0.062	0.197	-0.018	0.058	-0.059	0.207	-0.017	0.061
Child1	0.127	10.227	0.022	1.747	-0.082	0.254	-0.024	0.075	-0.083	0.250	-0.025	0.074
Child2	0.375	11.323	0.064	1.934	0.118	0.333	0.035	0.098	0.117	0.324	0.034	0.096
Child3	2.414	16.013	0.412	2.735	2.144	0.556	0.631	0.163	2.140	0.564	0.630	0.166
Child4	-0.197	26.791	-0.034	4.576	-1.304	1.002	-0.384	0.295	-1.307	0.990	-0.385	0.291
Child5	1.307	35.613	0.223	6.082	-0.216	0.842	-0.064	0.248	-0.220	0.869	-0.065	0.256
Edhs	-1.027	9.544	-0.175	1.630	-0.574	0.267	-0.169	0.079	-0.574	0.268	-0.169	0.079
Edhsp	-0.979	8.806	-0.167	1.504	**-0.421**	0.249	**-0.124**	0.073	**-0.422**	0.251	**-0.124**	0.074
Edcol	-1.151	8.875	-0.197	1.516	-1.004	0.249	-0.295	0.073	-1.002	0.257	-0.295	0.075
Epself	-0.290	10.989	-0.050	1.877	-0.955	0.366	-0.281	0.107	-0.950	0.375	-0.279	0.110
Epnolg	-0.875	21.069	-0.149	3.599	-0.603	0.469	-0.178	0.138	-0.588	0.484	-0.173	0.142
Epnost	1.194	16.181	0.204	2.764	0.495	0.387	0.146	0.114	0.496	0.388	0.146	0.114
Ephm	0.358	12.090	0.061	2.065	0.108	0.373	0.032	0.110	0.111	0.376	0.033	0.111
Epst	0.028	13.712	0.005	2.342	0.463	0.395	0.136	0.116	0.460	0.376	0.135	0.111
Eprt	0.897	12.539	0.153	2.142	-0.268	0.467	-0.079	0.138	-0.268	0.468	-0.079	0.138
Epdis	1.300	12.765	0.222	2.180	-0.083	0.424	-0.024	0.125	-0.082	0.426	-0.024	0.125
In1524	-0.083	9.227	-0.014	1.576	-0.417	0.273	-0.123	0.080	-0.417	0.268	-0.123	0.079
In2534	-0.181	9.672	-0.031	1.652	-0.131	0.187	-0.038	0.055	-0.130	0.186	-0.038	0.055
In3549	-0.014	9.379	-0.002	1.602	-0.076	0.306	-0.022	0.090	-0.075	0.309	-0.022	0.091
In50	-0.204	7.173	-0.035	1.225	-0.367	0.184	-0.108	0.054	**-0.365**	0.190	**-0.108**	0.056

Table 4: Estimation Results for Fruit and Vegetable Consumption

	(1) Linear FE		(2) Linear FE Logit (FV5)		(3) WLS Logit FE				(4) GLM Logit FE				
	Coeff	St. Err.	Coeff	St. Err.	Coeff	St. Err.	APE	St. Err.	Coeff	St. Err.	APE	St. Err.	P-Value
Female	1.134	0.909	6.327	5.032	6.186	5.382	1.101	0.958	6.287	4.924	1.121	0.878	0.202
Age25	0.109	0.220	0.326	1.342	0.533	1.108	0.095	0.197	0.609	1.219	0.109	0.217	0.617
Age35	-0.326	0.201	**-2.040**	1.212	-1.822	0.920	-0.324	0.164	-1.776	1.118	-0.317	0.199	0.112
Age45	0.176	0.403	0.331	2.122	0.838	2.124	0.149	0.378	1.167	2.121	0.208	0.378	0.582
Age55	0.131	0.420	0.406	2.373	0.497	1.984	0.088	0.353	0.757	2.235	0.135	0.399	0.735
Age65	0.187	0.619	0.643	3.567	1.034	2.176	0.184	0.387	1.030	3.290	0.184	0.587	0.754
Raceb	0.086	0.162	0.474	0.927	0.504	0.734	0.090	0.131	0.431	0.845	0.077	0.151	0.611
Raceh	0.315	0.128	1.626	0.722	1.666	0.728	0.296	0.130	1.724	0.670	0.307	0.119	0.010
Raceo	0.450	0.211	**2.359**	1.270	2.420	1.036	0.431	0.184	2.465	1.109	0.440	0.198	0.026
Mp	-0.388	0.284	-1.892	1.594	-1.919	1.458	-0.341	0.259	-2.122	1.492	-0.378	0.266	0.155
Mw	**0.728**	0.394	4.331	2.154	4.065	1.771	0.724	0.315	4.101	2.063	0.731	0.368	0.047
Ms	-0.907	0.675	-3.654	3.761	-4.596	2.268	-0.818	0.404	-4.748	3.455	-0.847	0.616	0.169
Mn	-0.237	0.204	-1.580	1.156	-1.351	0.880	-0.240	0.157	-1.228	1.049	-0.219	0.187	0.242
Child1	**-0.296**	0.170	-1.673	1.025	-1.615	0.827	-0.287	0.147	**-1.586**	0.921	**-0.283**	0.164	0.085
Child2	0.163	0.200	0.890	1.165	0.891	0.952	0.159	0.169	0.979	1.071	0.175	0.191	0.360
Child3	0.005	0.218	0.243	1.307	0.133	1.362	0.024	0.242	0.082	1.223	0.015	0.218	0.946
Child4	0.208	0.494	1.711	2.998	1.290	2.247	0.230	0.400	1.235	2.671	0.220	0.476	0.644
Child5	-0.007	0.527	0.763	2.833	0.357	3.067	0.063	0.546	-0.044	2.842	-0.008	0.507	0.988
EDhs	-0.123	0.151	-0.796	0.862	-0.723	0.847	-0.129	0.151	-0.663	0.780	-0.118	0.139	0.395
EDhsp	0.159	0.174	1.210	1.010	0.994	0.796	0.177	0.142	0.961	0.952	0.171	0.170	0.313
EDcol	0.258	0.197	1.860	1.187	**1.525**	0.848	**0.271**	0.151	1.502	1.058	0.268	0.189	0.156
EPself	0.048	0.208	0.025	1.232	0.298	0.960	0.053	0.171	0.263	1.107	0.047	0.197	0.812
EPnolg	0.001	0.398	0.374	2.238	0.110	1.774	0.020	0.316	0.045	2.032	0.008	0.362	0.982
EPnost	-0.045	0.196	-0.294	1.059	-0.173	1.371	-0.031	0.244	-0.277	0.988	-0.049	0.176	0.779
EPhm	0.027	0.233	-0.012	1.307	0.109	1.089	0.019	0.194	0.194	1.250	0.035	0.223	0.876
EPst	-0.113	0.191	-0.427	1.174	-0.580	1.109	-0.103	0.197	-0.647	1.007	-0.115	0.180	0.521
EPrt	0.198	0.334	1.122	1.912	1.060	1.093	0.189	0.195	1.158	1.798	0.207	0.321	0.519
EPdis	0.107	0.456	0.534	2.682	0.448	1.244	0.080	0.221	0.499	2.532	0.089	0.451	0.844
IN1524	0.186	0.176	1.167	1.077	1.061	0.772	0.189	0.137	1.097	0.992	0.196	0.177	0.269
IN2534	**-0.285**	0.168	-2.011	1.000	-1.896	0.809	-0.338	0.144	**-1.715**	0.916	**-0.306**	0.163	0.061
IN3549	0.338	0.213	1.858	1.331	1.853	0.762	0.330	0.136	1.862	1.184	0.332	0.211	0.116
IN50	0.039	0.161	0.170	1.000	0.183	0.650	0.033	0.116	0.188	0.901	0.034	0.161	0.834
yeari2	-0.005	0.010	-0.027	0.062	-0.026	0.039	-0.005	0.007	-0.029	0.056	-0.005	0.010	0.608
yeari3	-0.010	0.016	-0.060	0.103	-0.060	0.068	-0.011	0.012	-0.062	0.091	-0.011	0.016	0.501
yeari4	-0.006	0.025	-0.040	0.154	-0.039	0.092	-0.007	0.016	-0.041	0.139	-0.007	0.025	0.767
yeari5	-0.022	0.027	-0.137	0.168	-0.131	0.105	-0.023	0.019	-0.131	0.150	-0.023	0.027	0.383
yeari6	-0.019	0.032	-0.122	0.200	-0.114	0.124	-0.020	0.022	-0.116	0.178	-0.021	0.032	0.516
yeari7	-0.028	0.038	-0.176	0.243	-0.166	0.149	-0.030	0.027	-0.166	0.215	-0.030	0.038	0.440
yeari8	-0.040	0.040	-0.257	0.258	-0.238	0.172	-0.042	0.031	-0.234	0.226	-0.042	0.040	0.300
_cons	-0.565	0.557	**-5.431**	3.061	-5.594	2.740			**-5.838**	3.017			

Table 5: Estimation Results for Fruit and Vegetable Consumption

	(5) GEE Probit Population-Averaged				(6) GLM Probit Pooled			
	Coeff.	**St. Err.**	**APE**	**St. Err.**	**Coeff.**	**St. Err.**	**APE**	**St. Err.**
Female	3.333	25.892	1.020	7.919	2.123	1.856	0.648	0.568
Age25	0.356	8.235	0.109	2.519	0.153	0.660	0.047	0.202
Age35	-0.079	6.668	-0.024	2.040	0.766	0.684	0.234	0.209
Age45	1.694	14.825	0.518	4.535	0.610	0.841	0.186	0.257
Age55	0.690	14.271	0.211	4.365	**1.650**	0.972	**0.504**	0.296
Age65	-0.577	13.299	-0.176	4.068	-0.516	1.161	-0.158	0.355
Raceb	-0.049	2.376	-0.015	0.727	**-0.272**	0.162	**-0.083**	0.049
Raceh	0.148	2.425	0.045	0.742	-0.099	0.160	-0.030	0.049
Raceo	0.313	6.250	0.096	1.912	-0.435	0.666	-0.133	0.203
Mp	0.591	9.883	0.181	3.023	1.167	0.764	0.357	0.233
Mw	1.910	14.147	0.584	4.327	1.328	1.030	0.406	0.314
Ms	-1.501	17.076	-0.459	5.223	0.583	1.552	0.178	0.474
Mn	0.062	5.178	0.019	1.584	0.278	0.421	0.085	0.129
Child1	-0.964	6.627	-0.295	2.027	-0.940	0.699	-0.287	0.213
Child2	0.605	7.346	0.185	2.247	0.348	0.650	0.106	0.198
Child3	-0.486	10.444	-0.149	3.195	-1.090	0.809	-0.333	0.248
Child4	0.529	17.633	0.162	5.394	-0.564	1.527	-0.172	0.466
Child5	-0.187	23.112	-0.057	7.070	0.824	1.654	0.252	0.505
EDhs	-0.740	5.874	-0.226	1.797	-1.041	0.424	-0.318	0.130
EDhsp	-0.137	5.529	-0.042	1.691	-0.627	0.484	-0.192	0.148
EDcol	0.670	5.509	0.205	1.685	0.211	0.573	0.065	0.175
EPself	0.781	6.907	0.239	2.113	1.628	0.726	0.497	0.223
EPnolg	1.145	13.975	0.350	4.275	4.166	1.615	1.273	0.494
EPnost	0.369	10.724	0.113	3.280	0.390	0.870	0.119	0.266
EPhm	0.575	7.634	0.176	2.335	1.070	0.512	0.327	0.157
EPst	-0.361	9.000	-0.110	2.753	-0.578	0.661	-0.177	0.202
EPrt	0.753	7.881	0.230	2.411	0.260	0.617	0.079	0.188
EPdis	0.078	8.508	0.024	2.603	-0.431	0.781	-0.132	0.239
IN1524	0.711	5.807	0.218	1.776	0.366	0.710	0.112	0.217
IN2534	-0.986	6.120	-0.301	1.872	-0.892	0.758	-0.272	0.231
IN3549	1.308	5.882	0.400	1.799	1.382	0.692	0.422	0.212
IN50	0.334	4.417	0.102	1.351	0.407	0.397	0.124	0.121
yeari2	-0.026	0.268	-0.008	0.082	-0.010	0.027	-0.003	0.008
yeari3	-0.049	0.395	-0.015	0.121	-0.020	0.035	-0.006	0.011
yeari4	-0.086	0.510	-0.026	0.156	**-0.079**	0.045	**-0.024**	0.014
yeari5	-0.137	0.583	-0.042	0.178	-0.135	0.053	-0.041	0.016
yeari6	-0.125	0.687	-0.038	0.210	**-0.120**	0.065	**-0.037**	0.020
yeari7	-0.154	0.821	-0.047	0.251	-0.149	0.076	-0.045	0.023
yeari8	-0.202	0.970	-0.062	0.297	-0.210	0.086	-0.064	0.026
_cons	-3.300	15.064			**-2.331**	1.275		