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STRUCTURAL ESTIMATION OF CALORIC INTAKE,  
EXERCISE, SMOKING, AND OBESITY

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**ABSTRACT**

The escalating rate of obesity in the US highlights the importance of understanding the causes for this rise. In this paper I employ the First, Second, and Third National Health and Nutrition Examination Surveys to estimate a structural model of the determinants of adult obesity. To control for the potential endogeneity of some explanatory variables, such as caloric intake (adjusted for activity level) and smoking, a set of reduced form equations for these outcomes is estimated simultaneously with the obesity equation. To identify each equation, I use an array of state-level characteristics as instrumental variables. Trends in these variables shed light on the sources of the rapid increase in obesity since 1980.

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## **I. Introduction**

According to the National Health and Nutrition Examination Survey, the percentage of individuals classified as obese in the United States increased by 67 percent between 1971 and 1994, my period of analysis, with most of this increase occurring during the 1980s. Obesity is the second most important cause of premature death (McGinnis and Foege, 1993; Allison et al., 1999), a statement still supported by the Centers for Disease Control despite their recent downward correction to the death toll attributed to obesity (Mokdad et al., 2005). While certain foods can influence hormones and genes, the increase in obesity probably does not reflect a change in the genetic make-up of the US, since the gene pool did not change significantly between 1990 and 1994 (Koplan and Dietz, 1999). The way our built environment looks is very different from the way it looked just over two decades ago, largely due to advancements in technology. This paper explores the idea that the recent rapid increase in obesity rates is due to economic changes that have in turn changed the amount that Americans eat, exercise, smoke, and do other things that affect their weight. These changes, while advantageous in numerous ways, have nevertheless had negative health consequences. In addition, since demographic characteristics and socioeconomic status influence overweight and obesity, I consider the effect of demographic changes on trends in obesity.

In order to study the determinants of a person's body mass index, which is most often used in measuring obesity, I employ pooled micro-level data from the First, Second, and Third National Health and Nutrition Examination Surveys. I augment these data using state-level data on the price of a restaurant meal, the cigarette tax, average January and July temperatures, and clean indoor air laws.

## II. Background

Obesity and sedentary lifestyles are second only to smoking as the leading cause of premature death (McGinnis and Foege, 1993; Allison et al., 1999). They have been linked to coronary heart disease, stroke, high blood pressure, cancers of the colon, breast and prostate, and diabetes (Must et al., 1999; Mokdad et al., 2003). Obesity has also been associated with high cholesterol, menstrual irregularities, pregnancy complications, and psychological disorders such as depression (NIDDKD, 1996). Type II diabetes, once termed adult-onset diabetes, is now not uncommon in children as a result of the obesity epidemic (Freedman et al., 1999). Recently obesity in adulthood has been shown to reduce life expectancy, especially among persons overweight in their youth (Peeters et al., 2003; Fontaine et al., 2003). Economic costs related to overweight and obesity were estimated to be \$99.2 billion as of 1995 (Wolf and Colditz, 1998), and more recently this estimate has risen to \$117 billion (USDHHS, 2001). This is especially a major concern for the public, as obesity-related illnesses have contributed to the overall growth in health care spending (Thorpe et al., 2004). Social costs of obesity being higher than private costs are grounds for possible government intervention.<sup>1</sup>

There has been much debate as to what constitutes a proper diet, and recently the USDA's Food Guide Pyramid was replaced with an alternative that stresses vitamin intake, the intake of whole wheat foods, and exercise, the so-called Healthy Eating Pyramid (McCullough et al., 2002; Willett, 2001). Excess carbohydrates in the body have been shown to be converted to fat. Measurements of the glycemic index in the body, which measures the rate of carbohydrate absorption after a meal, has shed light on

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<sup>1</sup> See Rashad and Grossman (2004) for a discussion of the role of the government and possible policy implications of obesity.

the importance of controlling the intake of carbohydrates as well as that of fat, a high glycemic index being what contributes to obesity (Ford and Liu, 2001; Ludwig, 2002). Since the carb-to-lipid ratio might not be so important, it seems to make more sense to focus on total caloric intake rather than, say, intake of calories from fat. However, there is still some potential concern about the origin of calories, that not all calories are the same.

Money spent on weight-loss drugs has largely contributed to increasing the costs of obesity, as drugs intended to reduce weight have become popular, with a rapid increase since 1990. Surgeries such as gastric bypass surgery are only recommended for the morbidly obese and have numerous surgical risks associated with them. In addition, patients undergoing surgery often do not achieve their desired weight and are put under lifelong medical surveillance (Livingston, 2002; Brolin, 2002). More is being studied about genes and hormones that play a role in regulating body weight. Ghrelin, a hormone primarily produced in the stomach, increases food intake and is strongly responsible for why dieters often gain weight that they have lost (Cummings et al., 2002). The body interprets dieting as starving, and increases its secretion of ghrelin, slowing down metabolism. Sure enough, severely elevated or lowered body weight is associated with offsetting metabolic processes that oppose the maintenance of an altered body weight (Leibel et al., 1995). Low levels of leptin are also associated with obesity (Heymsfield et al., 1999). Injecting obese subjects with leptin as a cure is being looked into.<sup>2</sup>

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<sup>2</sup> This has largely been ineffective as the severely overweight tend to be leptin-resistant. One recent study by Spiegel et al. (2004) has found that lack of sleep in young men tends to reduce leptin levels and increase ghrelin levels. Not only does one have more time to eat when one is not sleeping, but increased ghrelin levels trigger hunger.

In analyzing overweight and obesity, I use the body mass index (BMI), measured as weight in kilograms divided by height in meters squared. An obese person is defined as one having a BMI of  $30 \text{ kg/m}^2$  or greater. BMI is convenient as it is routinely measured in physical examinations. Yet BMI might overestimate body fat in athletes who have a muscular build and underestimate body fat in older people who have lost muscle mass (NIDDKD, 1996). While this is the case, it is the standard that the Centers for Disease Control use to track obesity over time and will be employed here.

Using the National Health Interview Survey (1976-1994) and the National Longitudinal Survey of Youth (1982-1998), Lakdawalla and Philipson (2002) show that an index of job strenuousness is inversely related to BMI. They suggest that changes in technology over time have been largely responsible for the increase in the obesity rate. As their data contain only self-reported measures of weight and height rather than actual measures, they somewhat correct for this using a method employed by Cawley (1999). This method uses NHANES data, which contain both self-reported and actual measures of weight and height, to obtain age-, gender-, and race-specific corrections. This is also the method used by Chou et al. (2004) in their study using the Behavioral Risk Factor Surveillance System. Yet some have argued that even this correction does not completely eliminate error and, while better than no correction, is not a perfect substitute for actual measures (see, for example, Plankey et al., 1997).

A number of other causes and consequences of obesity have been studied, such as the effect that the degree of urban sprawl has on weight outcomes (Ewing et al., 2003). Cutler et al. (2003) present evidence suggesting that reductions in the time costs of preparing meals at home for certain groups in the population contribute to an increase in

weight for those groups. Philipson (2001) points out that a shift in the American economy from agriculture to industry has been accompanied by innovations that economize on time spent in the household sector, such as convenience food for consumption. Cawley (1999) has presented evidence that caloric intake is addictive. This is in line with findings that high-density fast food might indeed be addictive (Naik and Moore, 1996; Schlosser, 2001). Fat consumption in the US has increased (Ippolito and Mathios, 1995; Frazee, 1999). Evidence has also been put forth suggested that obesity is associated with lower wages for women (Averett and Korenman, 1996; Cawley, 2004).

Due to the importance of the obesity epidemic, there is a pressing need for answers as to why its increase has been so rapid, as well as what can be done in order to rectify or reverse this trend.

### **III. Analytical Framework**

The model of this paper follows a similar reasoning and theoretical approach as that of Chou et al. (2004). I go further in this paper in that I estimate instrumental variables models and focus on analyzing demographic determinants of obesity. Differences across gender are focused on, as differences in coefficients across gender are significant at the one percent level when tested. I briefly summarize the framework below.

Energy balance at time  $t$  ( $E_t$ ) is defined as caloric intake ( $C_t$ ) minus energy expenditure or activity ( $A_t$ ):

$$E_t = C_t - A_t \quad (1)$$

The body mass index (*BMI*) is a function of the sum of energy balance in all periods, as well as a vector of variables ( $\mathcal{E}$ ) that are specific to an individual and reflect that individual's predisposition towards obesity:

$$BMI = f\left(\sum_t E_t, \mathcal{E}\right) \quad (2)$$

If caloric intake and physical activity offset each other in each period, one would expect the individual to have a constant body weight. The vector of variables ( $\mathcal{E}$ ) includes determinants such as education, age, state of residence, race, marital status, and income. These variables can influence either the process by which a person converts caloric intake into caloric expenditure (via activity) or behavior, and thus affect a person's body mass and predisposition towards obesity. Demographic variables such as education, income, marital status, and state of residence are included to see the effects they potentially have on BMI and because there might be mismeasurement in the self-reported values of caloric intake and activity level that might be correlated with these variables (although I attempt to somewhat correct for possible mismeasurement in caloric intake using degree of mismeasurement in BMI). In addition, these demographic variables might be related to calorie composition, as not all calories are the same.

While no one desires to be obese, some people gain more utility out of consuming food than others. People combine the obtaining of goods and services in the market with their own time to achieve objects that enter their utility functions – such as health, entertainment, and the enjoyment of eating palatable food. Energy expenditure is measured by physical activity. The importance of activity is highlighted in a large literature (see, for example, Hill, 1997; Public Health Service, 2001; USDHHS, 2000), and now the recommended regimen has been increased from half an hour of exercise



three times a week to a full hour (USDHHS, 2000). I expect smoking to be a negative function of BMI, as smoking has been used as a method of weight control (Philipson, 2001; Chou et al., 2004; Fehily et al., 1984; Tomeo et al., 1999). A combination of federal and state tax hikes, clean indoor air laws forbidding smoking in designated areas, and the anti-smoking campaign have caused people to smoke less over time; this may be part of the reason for the increase in BMI over time.

#### **IV. Empirical Implementation**

In order to account for the potential endogeneity of caloric intake, activity level, and smoking, I estimate structural equations where the body mass index is the outcome of interest in addition to models where these variables are treated as exogenous. Whole sample means for the variables I use in my regressions are shown in Table 1. Activity-adjusted caloric intake (caloric intake taking activity level and thus calorie needs into account) and smoking, to be defined later, are functions of a vector of instruments  $Z$ , as well as exogenous variables  $X$ . Included in  $Z$  are state-level variables pertaining to the price of a restaurant meal, the cigarette tax, average January and July temperatures, and clean indoor air laws. I translate equation (2) into an empirical one by estimating the following:

$$BMI = \alpha_0 + \alpha_1 AC + \alpha_2 S + \alpha_3 X + u_1 \quad (3)$$

Equation (3) represents the primary equation of interest, treating activity-adjusted caloric intake ( $AC$ ) – to be defined shortly – and smoking ( $S$ ) as exogenous right-hand side variables. Note that the empirical model focuses on *current* caloric intake, adjusted for physical activity, rather than accumulated energy balance over time. I also estimate structural equations, where  $AC$  and  $S$  are treated as endogenous variables and their

predicted values are obtained after regressing them on all the exogenous variables. Theoretically, since caloric intake, energy expenditure, and smoking are inputs in the production of body mass index, they should be treated as endogenous. The above equations are estimated independently by ordinary least squares (OLS) and by two-stage least squares (TSLS) for the whole sample as well as by gender. Results for BMI as the dependent variable for the whole sample, then separately for males and females, are shown in Table 2. Results by race are shown in Table 3.

The effectiveness of instrumental variables procedures crucially depends on the validity of the instruments. In order to test the validity of the exclusion restrictions (to ensure that the instruments significantly affect activity-adjusted caloric intake and smoking, but not BMI), I employ the overidentification test suggested by Davidson and MacKinnon (1993). In this test, the residual of the TSLS model is regressed on all exogenous variables. The value of r-squared that results, when multiplied by the number of observations, follows a chi-square distribution with degrees of freedom equal to the degree of overidentification. The null is that the instruments are valid. In all cases the null hypothesis could not be rejected at the one percent level, suggesting that the instruments were valid. (Chi-squared values for overidentification tests are given in Tables 2 and 3. The one percent chi-squared value for 10 degrees of freedom – twelve instruments minus two RHS endogenous variables – is 23.21. All chi-squared values are below this, indicating valid instruments.) I also check that the instruments are jointly significant in first-stage equations, and find that they are at the one percent level. (F-values and their corresponding significance levels are given in Table 4, which shows first-stage results. First-stage results are not reported by race, yet F-values for the

instruments by race are shown in Table 3.) Durbin-Wu-Hausman tests for the consistency of the OLS models relative to the TSLS models reveal that the OLS models are consistent at the one percent level. (Significance levels for Durbin-Wu-Hausman tests are reported in Tables 2 and 3.)

Micro-level data from confidential versions of the First, Second, and Third National Health and Nutrition Examination Surveys (NHANES I, II, and III, respectively) are used in this analysis. All three surveys are national samples of the population of the United States and were conducted by the National Center for Health Statistics; NHANES I between 1971 and 1975; NHANES II between 1976 and 1980; and NHANES III between 1988 and 1994. Most states of the United States are represented in each survey. I focus in this paper on all adults 17 years of age and older, who typically control their caloric intake.

Each subject in the surveys received a detailed physical examination including measurement of height and weight. Caloric intake was computed from detailed food consumption during the previous 24 hours reported by the respondent. Since this is a self-reported variable, and likely to have similar under- and over-reporting as BMI, I adjust caloric intake by multiplying it by the ratio of actual to self-reported BMI.<sup>3</sup> Caloric intake is further adjusted to take into account caloric needs based on reported physical activity. One of the survey questions I use to measure physical activity is, “In your usual day, aside from recreation, how active are you?” for NHANES I and NHANES II (answer choices are very active, moderately active, and quite inactive), and

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<sup>3</sup> While this is not a perfect adjustment, it somewhat repairs the error in self-reported caloric intake. While questions on weight and height are asked of individuals and not BMI per se, respondents tend to overreport height and underreport weight, yielding a downward-biased BMI (Rashad, 2004). That being said, the correlation between caloric intake and adjusted caloric intake is over 0.99.

“Compared with most (men/women) your age, would you say you are more active, less active, or about the same?” for NHANES III.<sup>4</sup>

NHANES I and II also ask similar questions on how active respondents are in recreation. NHANES III has more detailed physical activity variables than either NHANES I or NHANES II; indicators for a variety of activities are given as well as the number of times each activity was performed in the past month. The activities are walking a mile without stopping, jogging, riding a bicycle, swimming, aerobics, dancing, calisthenics, garden work, lifting weights, and other exercise. (Respondents are allowed to choose up to four more types of exercise from a detailed list.) These activities were assigned intensity ratings according to a coding scheme developed by Ainsworth et al., (1993); intensity is measured as the ratio of metabolic rate when engaged in the activity to resting metabolic rate. Table 5 shows how increased intensity is correlated with a lower BMI. For the recreation portion of physical activity measurement, I therefore use the question, “In your usual day, aside from recreation, how active are you?” for NHANES I and II (answer choices are, again, very active, moderately active, and quite inactive) and create an analogous variable to the recreation variable in NHANES I and NHANES II by using activity intensity in NHANES III.

I use activity-adjusted caloric intake as caloric intake and activity are likely to be strongly correlated, and proceed as follows. If activity intensity is less than 50, the respondent is inactive in recreation; if between 50 and 149.9, moderately active; and if 150 or greater very active. Thus an alternative way to run the regression, rather than

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<sup>4</sup> I recognize the possible shortcomings of using answers to a slightly differently-phrased question for the same variable, especially since the question in NHANES III is a relative one. NHANES III has much more detailed data on activity intensity, which I incorporate into the recreation portion of physical activity measurement.

including caloric intake and activity level on the right-hand side, is to make use of the Harris-Benedict (1919) multipliers in order to adjust caloric intake for activity level. I classify multipliers for activity according to the following guidelines:

- Sedentary: 1.2 (inactive in both recreation and work)
- Lightly Active: 1.375 (inactive in one, active in the other)
- Moderately Active: 1.55 (active in both, OR inactive in one, very active in the other)
- Very Active: 1.725 (very active in one, active in the other)
- Extra Active: 1.9 (very active in both).

I thus divide caloric intake by the above numbers according to activity category in both recreation and work.

Harris-Benedict equations have largely been used in the medical literature to predict basal metabolic rate (BMR) for a person based on his or her age, weight, height, and gender. While they may overestimate BMR in obese people and possibly female anorectics, they are still the most commonly used equations for clinical and research purposes (Frankenfield et al., 1998; Kien and Ugrasbul, 2004; Marra et al., 2002). The equations themselves are not used here but, rather, simply the activity multipliers are employed to obtain a measure of caloric intake that takes into account the individual's level of activity.

Caloric intake not only influences BMI but is also likely to be influenced by BMI, especially if caloric intake is habituating. For similar reasons as those for caloric intake, physical activity is also likely to be endogenous. I identify activity-adjusted caloric intake by using the state-level price of a restaurant meal, and average January and July temperatures. Frequency of fast food restaurant use has been shown to be associated with

higher fat intake and greater body weight (French et al., 2000; Rolls and Hammer, 1995; Public Health Service, 2001), as fast food restaurants serve especially large portions (Nielsen and Popkin 2003). According to the Census of Retail Trade, the per capita number of restaurants increased by 61 percent between 1972 and 1997. The ready availability of cheap, prepared food greatly reduces the time cost associated with eating, especially important now that more females have entered the labor force. Information on the average price of a meal at restaurants is collected from the Census of Retail Trade (Bureau of the Census, various years). The Census of Retail Trade is part of the Economic Census and is collected every five years. The data I use are from 1972, 1977, 1982, 1987, 1992, and 1997. Fast food restaurants correspond to the Census category *refreshment places* while full service restaurants correspond to the Census category *restaurants and lunchrooms*. In 1997 this classification system changed; refreshment places were analogous to *limited service restaurants*, and restaurants and lunchrooms were analogous to *full service restaurants*. Since these categories did not exactly overlap, I use a correction based on national data that the Census collected in 1997 for both categories. Data for years not covered are linearly interpolated and extrapolated. The restaurant price variable takes the average of the prices of the combination of fast food and full service restaurants, weighted by the number of restaurants in each category. Outside temperature is likely to influence an individual's level of activity. Temperatures used pertain to the mean 1976 temperature in the state of residence. Information on January and July temperatures is from the 1998 *Area Resource File*.

Smoking, which tends to increase metabolism and suppress appetite, thus having a negative effect on BMI, is measured using a dichotomous indicator for whether or not

the person is currently smoking. To account for the potential endogeneity of smoking, included among the instruments are cigarette taxes and clean indoor air laws. Higher cigarette taxes lead to lower cigarette consumption, while clean indoor air laws discourage smoking indoors (Tauras and Chaloupka, 1999; Ross et al., 2005; Chaloupka and Wechsler, 1997; Chaloupka and Saffer, 1992). The cigarette tax is taken from the Tax Burden on Tobacco (Orzechowski and Walker, 2002). Clean indoor air laws are taken from the Centers for Disease Control and Prevention website (<http://www.cdc.gov>). The four indoor air laws pertain to government workplaces, private workplaces, restaurants, and other places.

Since structural models are difficult to estimate, caution should be taken with interpretation. Instruments, while passing tests for validity, might nevertheless be slightly weak.<sup>5</sup> In addition, since non-random measurement error is likely to exist in the self-reported, potentially endogenous variables, instrumental variables methods will not necessarily eliminate this bias. I estimate ordinary least squares models, where I treat activity-adjusted caloric intake and smoking as exogenous, in addition to two-stage least squares models.

## **V. Results**

Table 1 shows definitions, means, and standard deviations of the variables. They are based on the sample of 28,696 that emerges when observations with missing values are deleted. NHANES sample weights are employed in all regressions, as well as state and year controls. To account for the aggregate nature of the instruments, standard errors allow for state clustering. Table 2 shows results for the whole sample and separately by

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<sup>5</sup> One indication of weak instruments is obtaining low F-values when testing for their joint significance in the first stage (Bound et al., 1995). As seen in Tables 3 and 4, not only are the instruments highly significant, but their F-values are very high as well.

gender for BMI as the dependent variable. I see a consistent pattern in terms of the strong positive effect of caloric intake and the strong negative effect of smoking on BMI in ordinary least squares models. Older people, blacks, Hispanic females, and married males are more likely to have a higher BMI, while those with a college education, and females with a higher household income, are more likely to have a lower BMI. Although tests reveal OLS models to be consistent, two-stage least squares models show how the strong effects of caloric intake and smoking seem to disappear after controlling for their potential endogeneity, with the exception of caloric intake for females. This is notable, as it was the female who most frequently prepared meals at home, whereas now there is less time and energy available for activities such as food preparation. Increases in hours worked and declines in real wage rates have increased the demand for inexpensive, prepared food, which has increased caloric intake. At the same time, work has become more sedentary. Note also that, although caloric intake is positive but insignificant for males in TSLS regressions, marital status is significant for males (but not for females). With 69 percent of males in the sample married, this could be strongly correlated with caloric intake. In addition, household income is associated with a higher BMI for males (but a lower BMI for females); if males earn most of the household income, this effect could be partially capturing the more sedentary nature of higher-income jobs, as there is likely to be mismeasurement in self-reported activity. I also ran regressions where I only instrument for smoking using the cigarette tax and clean indoor air laws, and smoking consistently loses its effect on BMI when controlling for its endogeneity. This could be because smoking is correlated with other unhealthy behaviors, or because, if people are smoking to lose weight, then they might already be overweight to begin with. Two-stage



least squares models reveal that behavior within the same period might not have a strong effect, as accumulation over time is not being accounted for.

Table 3 shows differences across race. Here smoking has a negative, significant impact on BMI for Hispanics in two-stage least squares models. Black males have significantly lower BMIs than black females in both ordinary least squares and two-stage least squares models. Household income appears to lower BMI for whites but not for blacks or Hispanics.

First-stage regression results for the whole sample as well as by gender are reported in Table 4. The instruments are jointly very significant with high F-values. Values of r-squared are not too high, ranging from 0.07 to 0.19, but are typical of individual-level regressions in the health economics literature. The effect of the price of a restaurant meal on smoking for females is  $(0.235 - 0.024 * 2 * 4.872) = 0.001$ , indicating a positive effect of price on smoking, as expected.<sup>6</sup> The cigarette tax has a consistently negative effect on smoking. A consistently negative and significant effect of indoor air laws in restaurants on caloric intake might be indicative of unhealthy behaviors being complementary, especially in social situations, while a positive and significant effect in private workplaces might suggest the substitutability of caloric intake for smoking.

## **VI. Discussion**

Obesity is an escalating problem in the United States. Caloric intake, which is habituating, and lack of physical activity, or a sedentary lifestyle, are prime contributors to this epidemic. An unforeseen contributor is possibly the decrease in the percentage of

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<sup>6</sup> The average price for a restaurant meal for females is 4.872.

people who smoke.<sup>7</sup> The ready availability of inexpensive restaurants has not only caused people to consume more, but has made them less active – less likely to prepare food at home or travel further distances to obtain a healthy meal. The decrease in food prices has allowed for the prevalence of restaurants and the availability of inexpensive junk food, thus facilitating increased caloric intake; man is conditioned to consume because, historically, this has been a means for survival.

Pooled data from NHANES, spanning the 1971-1994 time period, show caloric intake, activity level, and smoking to be important determinants of obesity. These determinants are not as important when using confidential versions of the data to merge state-level variables to account for the endogeneity of these determinants, indicating that accumulated behaviors over time and genetic factors might have a greater influence. Reduced-form models reveal that the price of a restaurant meal and the cigarette tax have significant effects in determining obesity. I find that increases in caloric intake increase female BMI, and that education and income in general lower it; married men and men with higher incomes also tend to have a higher BMI. Increases in the availability of restaurants and lowered food prices contribute to the epidemic.

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<sup>7</sup> Saying that a factor, such as smoking, contributes to escalating BMI rates is clearly not suggestive of picking up that behavior in order to reverse the trend of obesity, substituting one unhealthy behavior for another. Those who stop smoking, however, have been told to watch their weight.

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**Table 1**

Definitions, Means, and Standard Deviations of Variables for Whole Sample

Variable	Definition	Mean and Standard Deviation
Body mass index	Weight in kilograms divided by height in meters squared	25.689 (5.279)
Caloric intake	Activity-adjusted kilocalories consumed in one day, based on 24-hour recall	1,533.030 (779.427)
Smoking	Dichotomous variable that equals 1 if respondent smokes, and 0 otherwise	0.353 (0.478)
Black non-Hispanic	Dichotomous variable that equals 1 if respondent is black but not Hispanic	0.104 (0.306)
Hispanic	Dichotomous variable that equals 1 if respondent is Hispanic	0.066 (0.248)
Other race	Dichotomous variable if respondent's race is other than white, black, or Hispanic	0.025 (0.156)
Male	Dichotomous variable that equals 1 if respondent is male	0.496 (0.500)
Elementary	Dichotomous variable that equals 1 if respondent completed 8 years of formal schooling	0.055 (0.227)
Some high school	Dichotomous variable that equals 1 if respondent completed at least 9 years but fewer than 12 years of formal schooling	0.163 (0.369)
High school graduate	Dichotomous variable that equals 1 if respondent completed exactly 12 years of formal schooling	0.352 (0.477)
Some college	Dichotomous variable that equals 1 if respondent completed at least 13 years but fewer than 16 years of formal schooling	0.183 (0.387)
College graduate	Dichotomous variable that equals 1 if respondent graduated from college	0.170 (0.376)
Married	Dichotomous variable that equals 1 if respondent is married	0.643 (0.479)
Divorced	Dichotomous variable that equals 1 if respondent is divorced or separated	0.091 (0.288)
Widowed	Dichotomous variable that equals 1 if respondent is widowed	0.054 (0.226)
Household income	Real household income in tens of thousands of 1982-84 dollars	3.007 (2.431)
Age	Age of respondent	41.741 (16.390)



**Table 1 (continued)**

## Definitions, Means, and Standard Deviations of Variables

Variable	Definition	Mean and Standard Deviation
Restaurant price	Average real fast-food and full-service restaurant meal price in respondent's state of residence in 1982-84 dollars	4.880 (0.695)
Cigarette tax	Real state cigarette tax in 1982-84 cents	20.567 (8.938)
January temperature	Average January temperature in degrees Fahrenheit	33.168 (12.492)
July temperature	Average July temperature in degrees Fahrenheit	73.236 (11.531)
Private	Dichotomous variable that equals 1 if smoking is prohibited in private workplaces in respondent's state of residence	0.155 (0.362)
Government	Dichotomous variable that equals 1 if smoking is prohibited in state and local government workplaces in respondent's state of residence	0.215 (0.411)
Restaurant	Dichotomous variable that equals 1 if smoking is prohibited in restaurants in respondent's state of residence	0.314 (0.464)
Other	Dichotomous variable that equals 1 if smoking is prohibited in other public places such as elevators, public transportation, and theaters in respondent's state of residence	0.364 (0.481)

Standard deviation is reported in parentheses. Sample size is 28,696. NHANES sample weights are used in calculating the mean and standard deviation.

**Table 2**

Body Mass Index Regressions, Whole Sample and By Gender,  
Persons 17 Years of Age and Older

Independent Variables	Whole Sample		Males		Females	
	(1) OLS	(2) TSLS	(1) OLS	(2) TSLS	(1) OLS	(2) TSLS
Activity-adjusted caloric intake	0.0004*** (5.01)	0.002 (1.47)	0.0003*** (3.63)	0.001 (0.46)	0.001*** (2.98)	0.004* (1.68)
Smoking	-1.318*** (15.01)	-3.851 (0.96)	-1.267*** (8.96)	-4.827 (1.30)	-1.238*** (7.79)	-6.461 (1.67)
Black	1.478*** (9.80)	1.660*** (5.31)	0.369*** (3.57)	0.491 (1.46)	2.471*** (10.19)	2.361*** (5.84)
Hispanic	0.686*** (3.45)	0.411 (0.64)	0.253 (0.80)	-0.041 (0.07)	1.064*** (6.63)	0.107 (0.16)
Other race	-1.350*** (3.04)	-1.353*** (2.74)	-1.549*** (3.95)	-1.434*** (2.74)	-1.257** (2.08)	-1.873** (2.48)
Male	0.315** (2.25)	-0.684 (0.66)	-	-	-	-
Elementary	0.031 (0.16)	0.032 (0.10)	0.167 (0.64)	0.253 (1.03)	-0.175 (0.53)	-0.163 (0.36)
Some high school	0.136 (0.96)	0.153 (0.41)	0.192 (1.05)	0.258 (0.86)	-0.173 (0.63)	0.330 (0.83)
High school graduate	-0.036 (0.24)	-0.269 (0.87)	0.405* (1.98)	0.349 (1.00)	-0.740*** (3.00)	-0.932*** (3.15)
Some college	-0.531*** (3.06)	-0.970** (2.49)	0.219 (1.17)	-0.200 (0.46)	-1.493*** (4.32)	-2.044*** (4.54)
College graduate	-1.299*** (7.09)	-1.864** (2.69)	-0.597*** (2.79)	-1.303* (1.82)	-2.475*** (7.39)	-3.493*** (4.64)
Married	0.486** (2.30)	0.599*** (3.39)	0.897*** (4.90)	1.011*** (4.41)	0.159 (0.50)	0.420 (1.32)
Divorced	0.079 (0.38)	0.419 (0.93)	0.130 (0.53)	0.677 (1.12)	-0.207 (0.73)	0.483 (0.98)
Widowed	0.679** (2.25)	0.809** (2.09)	0.768** (2.13)	1.407* (1.96)	-0.100 (0.27)	0.443 (1.35)
Household income	-0.203*** (2.96)	-0.305* (1.91)	0.164* (1.90)	0.003 (0.01)	-0.491*** (5.28)	-0.640*** (3.86)
Household income squared	0.014** (1.96)	0.023* (1.71)	-0.017** (2.09)	-0.005 (0.27)	0.037*** (3.57)	0.051*** (3.24)
Age	0.351*** (19.91)	0.393*** (6.56)	0.306*** (14.54)	0.374*** (5.10)	0.379*** (14.58)	0.443*** (8.94)
Age squared	-0.003*** (18.10)	-0.004*** (4.07)	-0.003*** (13.58)	-0.004*** (3.74)	-0.003*** (12.39)	-0.004*** (5.83)

**Table 2 (continued)**

Body Mass Index Regressions, Whole Sample and By Gender,  
Persons 17 Years of Age and Older

Independent Variables	Whole Sample		Males		Females	
	(1) OLS	(2) TSLS	(1) OLS	(2) TSLS	(1) OLS	(2) TSLS
Intercept	16.485*** (29.57)	14.664*** (4.90)	17.970*** (24.58)	18.555*** (5.32)	15.589*** (22.18)	12.319*** (2.70)
Chi-squared value (overidentification)	9.4033		20.8227		1.7348	
P-value (Durbin-Wu- Hausman exogeneity)	0.2530		0.4690		0.0526	
R-squared	0.11	-	0.12	-	0.13	-
Sample size	28,696	28,696	13,996	13,996	14,700	14,700

Note: All regressions include state and year dummies. All regressions employ NHANES sample weights. Absolute values of t-ratios are reported in parentheses. Robust standard errors on which they are based allow for state clustering.

\*Significant at the 10% level, \*\*Significant at the 5% level, \*\*\*Significant at the 1% level.

**Table 3**

Body Mass Index Regressions, By Race,  
Persons 17 Years of Age and Older

Independent Variables	White Non-Hispanic		Black Non-Hispanic		Hispanic	
	(1) OLS	(2) TSLS	(1) OLS	(2) TSLS	(1) OLS	(2) TSLS
Activity-adjusted caloric intake	0.0003*** (3.35)	0.002 (1.25)	0.001*** (4.62)	0.012 (1.45)	0.0004*** (3.53)	0.002 (1.09)
Smoking	-1.280*** (14.07)	-3.394 (1.06)	-1.746 *** (7.35)	4.237 (0.52)	-1.139*** (3.17)	-5.780*** (2.91)
Male	0.726*** (4.37)	-0.294 (0.26)	-2.127*** (11.27)	-8.256* (1.80)	-0.541* (1.78)	-0.630 (0.72)
Elementary	0.228 (1.01)	0.218 (0.62)	0.082 (0.15)	-1.847 (0.94)	-0.962*** (3.20)	-0.799** (2.10)
Some high school	0.248 (1.41)	0.222 (0.70)	0.036 (0.07)	-1.484 (1.02)	0.086 (0.47)	0.341 (1.16)
High school graduate	0.119 (0.65)	-0.111 (0.35)	-0.560 (1.18)	-2.094 (1.59)	-0.225 (0.62)	-0.397 (0.72)
Some college	-0.384* (1.79)	-0.792* (1.90)	-0.787 (1.46)	-1.972 (1.50)	-0.914*** (3.81)	-1.227** (2.60)
College graduate	-1.180*** (5.25)	-1.688*** (2.71)	-1.151** (2.52)	-1.335 (1.22)	-2.002*** (4.76)	-2.387*** (3.73)
Married	0.442* (1.93)	0.620*** (3.03)	0.557 (1.66)	0.110 (0.27)	0.507* (1.71)	0.680** (2.14)
Divorced	-0.034 (0.14)	0.310 (0.75)	-0.615 (1.60)	-1.651 (1.31)	1.040*** (2.97)	1.644*** (5.14)
Widowed	0.547* (1.78)	0.741* (1.89)	0.920** (2.25)	-0.796 (0.49)	1.345** (2.05)	2.409** (2.41)
Household income	-0.256*** (3.20)	-0.353** (2.58)	0.020 (0.11)	0.313 (0.69)	0.060 (0.24)	-0.170 (0.67)
Household income squared	0.018** (2.25)	0.027** (2.21)	-0.006 (0.28)	-0.011 (0.26)	0.002 (0.05)	0.027 (0.88)
Age	0.339*** (15.23)	0.370*** (7.79)	0.473*** (12.55)	0.356* (1.78)	0.408*** (11.78)	0.453*** (9.88)
Age squared	-0.003*** (13.87)	-0.003*** (4.76)	-0.005*** (10.70)	-0.002 (0.60)	-0.004*** (10.17)	-0.004*** (11.25)

**Table 3 (continued)**

Body Mass Index Regressions, By Race,  
Persons 17 Years of Age and Older

Independent Variables	White Non-Hispanic		Black Non-Hispanic		Hispanic	
	(1) OLS	(2) TSLS	(1) OLS	(2) TSLS	(1) OLS	(2) TSLS
Intercept	16.533*** (32.21)	14.792*** (5.00)	17.795*** (11.85)	2.546 (0.21)	18.031*** (8.07)	22.876*** (7.95)
Chi-squared value (overidentification)	10.0428		5.5792		14.6120	
P-value (Durbin-Wu- Hausman exogeneity)	0.2618		0.0238		0.1411	
R-squared	0.11	0.01	0.14	-	0.16	-
<b>Instruments</b>	<i>Activity- adjusted caloric intake</i>	<i>Smoke</i>	<i>Activity- adjusted caloric intake</i>	<i>Smoke</i>	<i>Activity- adjusted caloric intake</i>	<i>Smoke</i>
F-values on instruments	128.51	25.90	14.59	40.49	25.75	286.94
Significance of instruments	p < 0.001	p < 0.001	p < 0.001	p < 0.001	p < 0.001	p < 0.001
Sample size	17,881	17,881	5,837	5,837	4,580	4,580

Note: All regressions include state and year dummies. All regressions employ NHANES sample weights. Absolute values of t-ratios are reported in parentheses. Robust standard errors on which they are based allow for state clustering.

\*Significant at the 10% level, \*\*Significant at the 5% level, \*\*\*Significant at the 1% level.

**Table 4**

First-Stage Regressions, Whole Sample and By Gender,  
Persons 17 Years of Age and Older

Independent Variables	Whole Sample		Males		Females	
	(1) Caloric intake	(2) Smoke	(1) Caloric intake	(2) Smoke	(1) Caloric intake	(2) Smoke
Restaurant price	-137.990 (0.99)	0.071 (0.93)	-245.330 (0.93)	-0.024 (0.25)	4.318 (0.03)	0.235* (1.96)
Restaurant price squared	22.966 (1.50)	-0.011 (1.40)	34.678 (1.30)	-0.004 (0.42)	4.850 (0.34)	-0.024** (2.05)
Cigarette tax	-3.257 (0.50)	-0.009** (2.48)	-0.041 (0.00)	-0.008 (1.45)	-5.509 (0.96)	-0.012** (2.41)
Cigarette tax squared	0.104 (0.76)	0.000*** (3.06)	0.033 (0.19)	0.000** (2.07)	0.141 (1.02)	0.000** (2.62)
January temperature	0.216*** (4.57)	-0.000 (0.96)	0.200*** (3.00)	-0.000 (1.04)	0.219*** (5.63)	-0.000 (0.61)
January temperature squared	-0.000* (1.71)	0.000*** (3.03)	-0.000 (0.56)	0.000* (1.85)	-0.000*** (2.80)	0.000** (2.03)
July temperature	0.443 (0.71)	0.000** (2.33)	0.245*** (3.16)	0.000 (0.87)	-0.106 (1.68)	0.000*** (2.79)
July temperature squared	-0.000 (1.53)	-0.000*** (3.38)	-0.000*** (2.98)	-0.000 (0.72)	-0.000 (0.49)	-0.000*** (3.09)
Government indoor air law	-46.067 (0.86)	0.026 (1.33)	-74.164 (1.02)	0.007 (0.21)	-29.149 (0.70)	0.041 (0.87)
Private indoor air law	108.474** (2.31)	-0.020 (0.74)	120.435** (2.23)	-0.000 (0.00)	86.306 (1.65)	-0.042 (1.24)
Restaurant indoor air law	-88.877*** (3.86)	0.013 (0.47)	-73.959** (2.42)	0.025 (0.71)	-100.233*** (3.17)	-0.004 (0.16)
Other indoor air law	-14.480 (0.35)	-0.019 (0.75)	-50.244 (0.99)	-0.017 (0.47)	31.395 (0.85)	-0.017 (0.44)
F-value on instruments	25.59	15.99	43.31	24.90	66.92	23.52
Significance of instruments	p < 0.001	p < 0.001	p < 0.001	p < 0.001	p < 0.001	p < 0.001
R-squared	0.19	0.12	0.09	0.12	0.07	0.13
Sample size	28,696	28,252	13,996	13,810	14,700	14,442

Note: All regressions include state and year dummies, as well as controls for race/ethnicity, age, gender, education, and household income. All regressions employ NHANES sample weights. Absolute values of t-ratios are reported in parentheses. Robust standard errors on which they are based allow for state clustering.

\*Significant at the 10% level, \*\*Significant at the 5% level, \*\*\*Significant at the 1% level.

**Table 5**

Body Mass Index and the Percentage Obese,  
Persons 17 Years of Age and Older,  
By Activity Intensity in Various Activities in NHANES III

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Activity Intensity (measured as the ratio of metabolic rate when engaged in the activity to resting metabolic rate)	Percent of Sample	Body Mass Index	Percentage Obese
No intensity	23.22	27.44	28.46
0.1~49.9	28.02	26.99	25.81
50~99.9	12.11	26.12	20.03
100~149.9	11.56	25.82	18.85
150~199.9	9.16	25.74	15.25
200~299.9	7.78	25.68	16.73
Greater than 300	8.14	25.04	14.42

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Survey weights are employed in all computations.