The Effects of Urban Sprawl on Body Mass Index: Where People Live Does Matter?

This study examined the effects of urban sprawl on body weights among U.S. adults using quantile regression that is less sensitive to outliers and the skewed distribution of body weights. Significant variations in the effects of urban sprawl on different levels of body weights were found. Holding all other variables constant, the body mass index of the 25% quantile in Harvey County, KS is 1.01 kg/m^2 higher than that of the 25% quantile in New York County, NY while the difference is much larger, 1.75 kg/m^2 in the 75% quantile. However, urban sprawl has no significant effect on individuals at the 95% quantile. Consumer policy implications are discussed.

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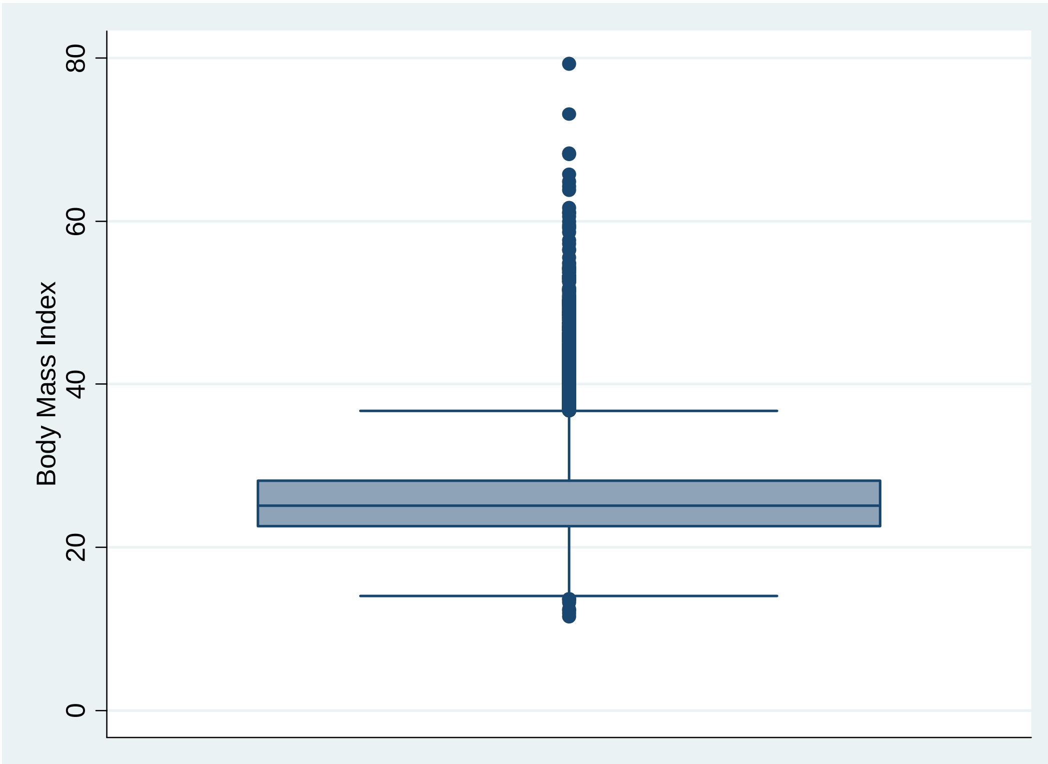
Introduction

A study by the Centers for Disease Control and Prevention (CDC) shows that the obesity epidemic spread rapidly during the 1990s across all states, regions, and demographic groups in the U.S. (CDC, 1999). The percentage of obese consumers among American adults increased from 12% in 1991 to 17.9% in 1998 (Mokdad, Serdula, Dietz, Bowman, Marks, & Koplan, 1999). While monitoring the quantity and quality of diets is a logical part of the fight against obesity, recent findings also show that physical inactivity, a major contributor to obesity, has not changed substantially between 1991 and 1998 (Mokdad, Serdula, Dietz, Bowman, Marks, & Koplan, 1999). The links between physical activity and health have been well established (U.S. Department of Health and Human Services, 1996). The effects of environmental factors on physical inactivity, obesity, and related diseases have been evaluated (Humpel, Owen, & Lesli, 2002; King, Castro, Wilcox, Eyler, Sallis, & Brownson, 2000; Sallis & Owen, 2002; Schmid, Pratt, & Howze, 1995; Yen, Shaw, & Eisworth, 2004). Several studies have focused on environmental determinants of physical activities (Berrigan & Troiano, 2002; Brownson, Baker, Houseman, Brennan, & Bacak, 2001; Craig, Brownson, Craig, & Dunn, 2002; King, Jeffery, Fridinger, Dusenbury, Provence, Hedlund, & Spangler, 1995; Ewing, Schmid, Killingsworth, Zlot, & Raudenbush, 2003). Urban planning and urban sprawl have been found to be significant environmental determinants of physical activities among urban residents. Researchers have concluded that more sidewalks, denser interconnected streets, and a mix of business and residential uses lead to consumers walking longer distances than otherwise (Berrigan & Troiano, 2002). Consumers living in more sprawling areas were likely to walk less and weigh more than those who live in less sprawling areas (Ewing, Schmid, Killingsworth, Zlot, & Raudenbush, 2003). There is an association between urban sprawl and consumer obesity (Lopez, 2004).

Health impacts of urban sprawl are the focus of this study. It extends the work of Ewing, Schmid, Killingsworth, Zlot, & Raudenbush (2003) by considering the conditional distribution of BMI given the extent of urban sprawl and the levels of other covariates. For example, using data from the Behavioral Risk Factor Surveillance System (BRFSS) for 2000 conducted by the Centers for Disease Control and Prevention (CDC), Figure 1 is a box-plot of BMIs. Note that there is a long tail of large values for BMIs. Conventional statistical procedures such as ordinary least squares (OLS) regression are not well suited to outliers or skewed distributions.

Quantile regression is used to examine the relationship between urban sprawl and the conditional quantiles of BMI because the quantile regression is known to obtain parameter estimates that are less sensitive to outliers and skewness than is OLS. The rest of the paper is organized as follows. Section 2 outlines the statistical procedure. Section 3 describes the data. Results are presented in section 4, and the last section provides one consumer policy implication.

Figure 1
Box-plot of BMIs.



Statistical Procedure

The relationship for consumer i between BMI (yi) and explanatory variables (xi) can be expressed as

$$y_i = f(x_i\beta, \varepsilon_i) \qquad (1)$$

where β is a vector of parameters and ε_i is a random disturbance term. Previous studies have assumed a linear functional form in which BMI is regressed on consumer physical attributes, education, diet and exercise habits, regional differences, and urban sprawl. Physical attributes including race, sex, and age served as control variables and were significant (Chen, Yen, & Eastwood, 2005; He & Baker, 2004; Wolf, Gortmaker, Cheung, Gray, Herzog, & Colditz, 1993).

Education level has been found to affect BMI (Chen, Yen, & Eastwood, 2005), as have diet and lifestyle variables, such as smoking habits, fruit and vegetable consumption, frequency of regular exercise and regional variables.

Although there is generally no theoretical guidance for an appropriate functional form for the regression function in equation (1), it is clear that BMI outliers need particular attention due to the long tail of large values for BMIs observed in the Figure 1. Quantile regression is found to be robust to the presence of outliers (Koenker & Bassett, 1978). It allows for a covariate effect when a set of percentiles is modeled, and unlike traditional approaches, it makes no distributional assumption about the error terms (Chen, 2005).

Estimation procedures and statistical properties of quantile estimators, such as the least absolute deviation estimator, are surveyed by Narula and Wellington (1982). In quantile regression estimation, the parameters β are obtained by solving

$$\min_{\beta} \sum_{i=1}^{n} (y_i - x_i\beta)[\alpha - 1(y_i - x_i\beta < 0)] \tag{2}$$

where α is the quantile used and $1(\cdot)$ is a binary indicator function. When α equals 0.5, in which the 50% quantile (i.e., median) of the dependent variable is estimated, the procedure reduces to least absolute deviation regression.

Data

The BRFSS was initiated in 1984 by 15 states, and the number of states participating in the survey has increased over time. Computer assisted interviews for BRFSS 2000 were conducted in 53 geographical areas. The purpose of the survey was to collect uniform, state-specific data on preventive health practices and risk behaviors that are linked to chronic diseases, injuries, and preventable infectious diseases in the adult consumer. Factors assessed by the BRFSS include tobacco consumption, health care coverage, HIV/AIDS, physical activities, and fruit and vegetable consumption. Interviewees were U.S. civilian non-institutionalized adults aged 18 years or older. About 150,000 respondents were randomly chosen from the 50 states, the District of Columbia and the Commonwealth of Puerto Rico.

Data for the county sprawl index for 448 metropolitan counties in the U.S. were obtained from the Appendix of a report by McCann and Ewing (2003). Constructed for Smart Growth America, the index is a linear combination of six variables. They are: (1) county gross population density in persons per square mile; (2) percentage of a county's population living in densities below 1,500 persons per square mile; (3) percentage of a county's population living in densities greater than 12,500 persons per square mile; (4) county population divided by the amount of urban land in square miles; (5) average block size in square miles; and (6) percentage of county blocks with areas less than 1/100 of a square mile or less (about 500 feet on a side, a traditional urban block). The six variables were combined into one index representing the degree of urban sprawl within a county using principal component analysis (Ewing, Schmid, Killingsworth, Zlot, & Raudenbush, 2003). The county sprawl data were merged with BRFSS 2000 by respondents' addresses. The reason for the use of BRFSS of the year 2000 instead of the most recent year is that the county sprawl index is based on density information from 2000 U.S. Census. Thus, the data merged for the BRFSS 2000 and the sprawl index based on 2000 U.S. Census in the model is concurrent. Because the county sprawl index is available only for 448 metropolitan counties, BRFSS observations for non metropolitan counties were deleted along with those having missing observations. Out of the 184,450 original observations from BRFSS, 50,388 observations were used in the analysis.

Results

Definitions of the variables used in this study are given in Table 1. Descriptive statistics in Table 2 show that the average BMI was around 26. About 20% of survey respondents were smokers at the time of the survey, and about 68% ate fruits or vegetables three or more times a day. A typical respondent exercised at the recommended physical activity levels every other day. Note that the descriptive statistics reported in Table 2 are for the sample observations of the metropolitan counties that were used for the regression analysis while the descriptive statistics of the entire BRFSS 2000 are slightly different. For example, smokers increase to 22%, fruits or vegetable consumers at three or more times a day decreases to 63% for the entire BRFSS 2000 data. The differences do not reflect the bias of the sample observation but signify the difference between the data for entire country and the sub-sample of metropolitan counties.

Results from the quantile regressions for five different quantiles (5th, 25th, 50th, 75th and 95th percentiles) of the BMI distribution are presented in Table 3, along with OLS results for comparison. There is no evidence that residing in the South affects BMI. Other races, cigarette smoking, fruit and vegetable consumption, regular exercise

Table 1
Definitions of Variables.

Variables	Definition
Dependent variable	
BMI	Body mass index (kg / m^2)
Physical variables	
Male	Dummy variable for gender (1 = male)
Black	Dummy variable for black and non-Hispanic (1 = black, non-Hispanic)
Hispanic	Dummy variable for Hispanic (1 = Hispanic)
Other race	Dummy variable for other race (1 = other race)
White	Dummy variable for white (1 = white) (reference)
Age 30−44	Dummy variable for age 30 to 44 (=1 if age 30–44)
Age 45−64	Dummy variable for age 45 to 64 (=1 if age 45–64)
Age 65−74	Dummy variable for age 65 to 74 (=1 if age 65–74)
Age ≥ 75	Dummy variable for age 75 or greater (=1 if age ≥ 75)
Age ≤ 30	Dummy variable for age below 30 (reference)
Education	
< High school	Dummy variable for less than high school (1 = less than high school)
High school	Dummy variable for high school graduate (1 = high school graduate)
Some college	Dummy variable for some college (1 = some college)
College	Dummy variable for college graduate (reference)
Diet and exercise habit	
Smoker	Dummy variable if currently smoking (1 = currently smoking)
Fruits & veg.	Dummy variable for fruit or vegetable consumption (1 = consume fruits and vegetables three or more times a day)
Exercise	Frequencies of recommended physical activity per day: Recommended amount is 30 minutes of moderately intense physical activity
Regions	
South	Dummy variable for South region (1 = Delaware, District of Columbia, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia, Alabama, Kentucky, Mississippi, Arkansas, Louisiana, Oklahoma, Texas)
Midwest	Dummy variable for Midwest region (1 = Indiana, Illinois, Michigan, Ohio, Wisconsin, Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota)
Northeast	Dummy variable for Northeast region (1 = Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont, New Jersey, New York, Pennsylvania)
West	Dummy variable for West region (reference)
Urban sprawl	
Sprawl	County sprawl index

Note: All dummy variables are defined as 1 = yes and 0 otherwise.

Table 2
Sample Statistics of Variables.

Variables	Mean	Std. Dev.
Dependent variable		
BMI	25.79	4.87
Physical variables		
Male	0.44*	–
Black	0.10*	–
Hispanic	0.08*	–
Other race	0.08*	–
White	0.74*	–
Age 30−44	0.35*	–
Age 45−64	0.30*	–
Age 65−74	0.09*	–
Age ≥ 75	0.06*	–
Age ≤ 30	0.20*	–
Education		
< High school	0.07*	–
High school	0.25*	–
Some college	0.29*	–
College	0.40*	–
Diet and exercise habit		
Smoker	0.20*	–
Fruits & veg.	0.68*	–
Exercise	0.46	0.29
Regions		
South	0.31*	–
Midwest	0.17*	–
Northeast	0.30*	–
West	0.22*	–
Urban sprawl		
Sprawl	115.67	27.27

Note: Sample size is 50,388. Asterisks (*) indicate sample proportions.

Table 3
Parameter Estimates of OLS and Quantile Regression.

		Quantile				
Variables	OLS	5%	25%	50%	75%	95%
Intercept	24.14*** (0.13)	18.64*** (0.14)	20.89*** (0.11)	23.24*** (0.12)	26.48*** (0.18)	32.80*** (0.49)
Physical variables						
Male	1.62*** (0.04)	2.10*** (0.05)	2.31*** (0.04)	2.02*** (0.04)	1.42*** (0.06)	–0.15 (0.16)
Black	2.04*** (0.07)	0.65*** (0.08)	1.37*** (0.06)	1.90*** (0.67)	2.54*** (0.10)	3.53*** (0.28)
Hispanic	0.87*** (0.08)	0.49*** (0.10)	0.80*** (0.07)	0.84*** (0.08)	0.95*** (0.11)	1.13*** (0.31)
Other race	−0.54*** (0.08)	–0.58*** (0.09)	–0.57*** (0.07)	−0.51*** (0.08)	–0.54*** (0.11)	–0.94*** (0.30)
Age 30−44	1.38*** (0.06)	0.88*** (0.07)	1.07*** (0.05)	1.21*** (0.06)	1.50*** (0.08)	2.30*** (0.22)
Age 45−64	2.10*** (0.06)	1.39*** (0.07)	1.76*** (0.05)	2.01*** (0.06)	2.35*** (0.08)	2.93*** (0.23)
Age 65−74	1.72*** (0.09)	1.27*** (0.10)	1.74*** (0.07)	1.90*** (0.08)	1.90*** (0.12)	1.31*** (0.33)
Age ≥ 75	0.26*** (0.10)	0.40*** (0.11)	0.72*** (0.08)	0.68*** (0.10)	0.24* (0.14)	–1.19*** (0.39)
Education						
< High school	1.74*** (0.09)	0.17* (0.10)	0.70*** (0.08)	1.46*** (0.09)	2.27*** (0.13)	3.89*** (0.36)
High school	1.07*** (0.06)	0.16*** (0.06)	0.63*** (0.05)	0.95*** (0.05)	1.31*** (0.08)	2.14*** (0.21)
Some college	0.84*** (0.05)	0.20*** (0.06)	0.50*** (0.04)	0.73*** (0.05)	1.03*** (0.07)	1.54*** (0.20)
Diet and exercise habit						
Smoker	−0.84*** (0.05)	–0.65*** (0.06)	–0.71*** (0.04)	−0.77*** (0.05)	–0.83*** (0.08)	–0.96*** (0.21)
Fruits & veg.	−0.37*** (0.05)	–0.07 (0.05)	–0.19*** (0.04)	−0.32*** (0.04)	–0.47*** (0.06)	–0.91*** (0.18)
Exercise	−0.68*** (0.07)	–0.26*** (0.09)	–0.47*** (0.06)	−0.75*** (0.07)	–0.88*** (0.10)	–0.77*** (0.30)

Table 3 (Continued)

		Quantile				
Variables	OLS	5%	25%	50%	75%	95%
Regions						
South	0.04 (0.06)	–0.13* (0.07)	–0.00 (0.05)	0.07 (0.06)	0.06 (0.08)	–0.01 (0.23)
Midwest	0.37*** (0.07)	0.15** (0.08)	0.25*** (0.06)	0.40*** (0.06)	0.39*** (0.10)	0.21 (0.26)
Northeast	0.09 (0.06)	0.09 (0.07)	0.13** (0.05)	0.16*** (0.06)	0.01 (0.08)	–0.11 (0.23)
Urban sprawl						
Sprawl $(\times 100^{-2})$	−0.47*** (0.08)	–0.23** (0.09)	–0.36*** (0.07)	−0.48*** (0.08)	–0.63*** (0.11)	–0.41 (0.30)
Pseudo R^2	0.09	0.07	0.08	0.06	0.05	0.04

Note: Asterisks ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

and urban sprawl have adverse effects on BMI. Residing in the Northeast has a significantly positive effect on BMI only for the 25 and 50% quantiles. Seniors (age ≥ 75) are associated with higher BMI for the OLS regression and all but the 75% quantile, for which being a senior has an adverse effect on BMI.

Overall, men have higher BMIs than women, except for the 95th percentile. The average BMI was higher for blacks than whites, and it was higher for Hispanics than non-Hispanics. Positive BMI coefficients for black are twice as large as those for Hispanics for all but the two lowest quantiles. The positive coefficients for age groups over 30 years lead to inferences that people in these age groups have higher BMIs than those under 30, with the exceptions of the age ≥ 75 groups for the two highest quantiles. The largest coefficients are for the age 45-64 groups. All the education coefficients are positive, and their magnitudes decline as education increases.

Smoking had negative effects on BMI. Individuals who consumed three or more servings of fruits and vegetables a day and those who exercised more frequently had lower BMIs. Residents of the Midwest and the Northeast typically had higher BMIs than those in the West. Coefficients of the Midwesterners were more than twice as high as those of the Northeasterners.

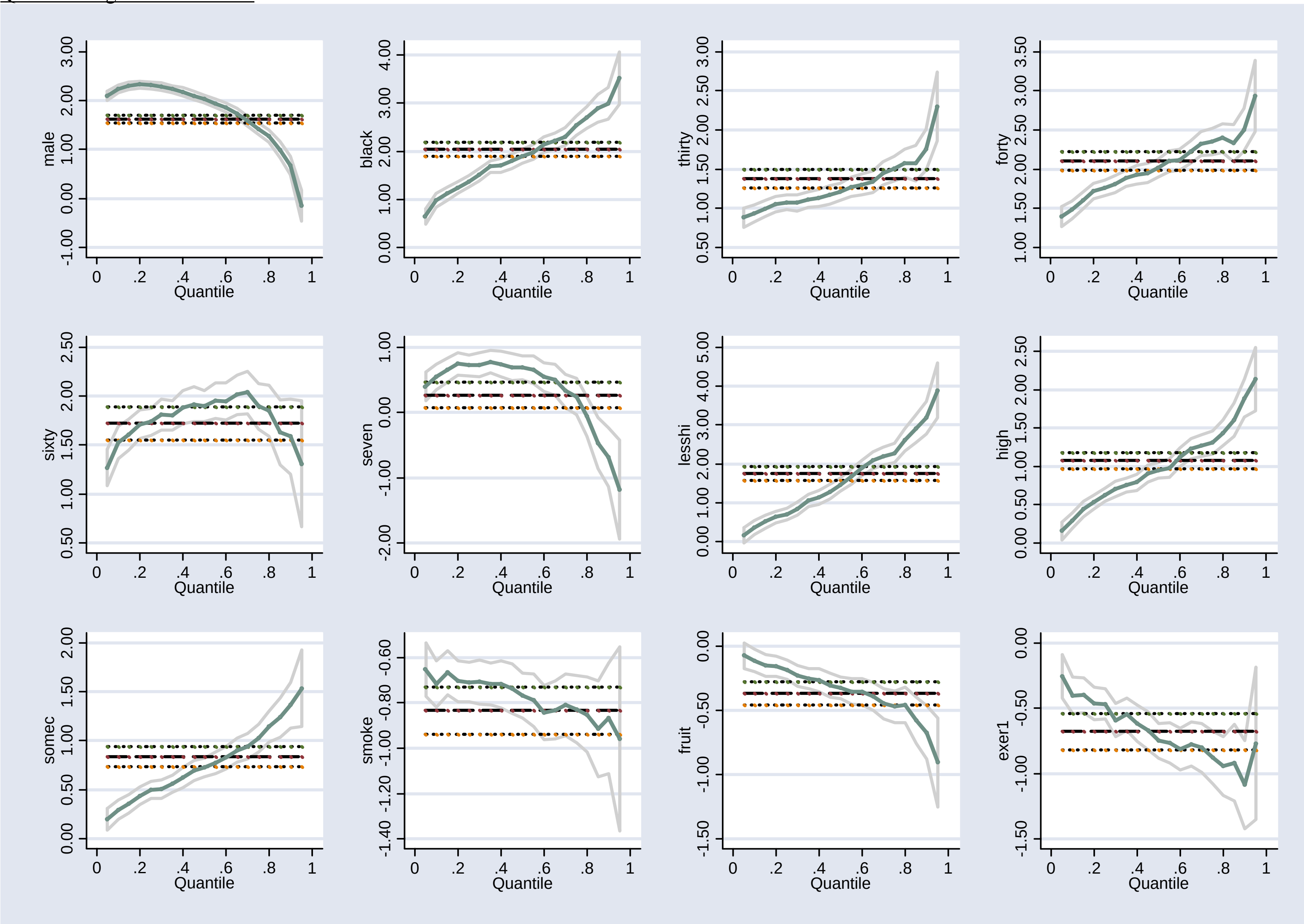
The absolute values of the coefficients of black, Hispanic, age 30-44, age 45-64, less than high school, high school, some college, smoker, and fruits & vegetable increase as the quantile of BMI increases. The coefficient for black for the 95% quantile is more than five times larger than that for the 5% quantile. On average, being a Hispanic increases BMI by about 0.8 over a non-Hispanic in the 25% quantile, and increases to 1.0 in the 75% quantile. Having less than a high school education typically increases the BMI by about 0.7 versus someone who had more than high school education in the 25% quantile, and it increases to 2.3 for the 75% quantile. Smoking is estimated to decrease BMI by 0.7 for the 25% quantile, and its effect is −0.8 for the 75% quantile. The negative effect of fruits and vegetable consumption increases about fivefold from −0.2 for the 25% quantile to −0.5 for the 75% quantile. Except for the 95% quantile, men typically had higher BMIs than women. Midwest residents had higher BMIs for all but the 95th quantile.

After controlling for the effects of physical activity, education, diet and exercise habits, and regional variables, the urban sprawl index is found to have statistically significant effects on BMI except for the 95% quantile. Ceteris paribus, residents of Harvey County, KS with the highest sprawl level would have 1.30 kg/m2 higher BMIs than residents of New York County, NY with the lowest sprawl level on average (A higher value of the sprawl index indicates less sprawling). Significant variations in the effect of urban sprawl on different levels of BMI occurred. The BMI of the 25% quantile in Harvey County is 1.01 kg/m2 higher than that of the 25% quantile in New York County, NY while the difference is much larger, 1.75 kg/m2 in the 75% quantile. The effect of urban sprawl on BMI increases for individuals who have higher BMIs up to the 75% quantile (i.e., 25% quantile is greater in absolute value than 5%, 50% is greater than 25%, 75% is greater than 50%). However, urban sprawl has no significant effect on individuals at the 95% quantile.

Figure 2 displays the coefficient estimates for different quantiles of male, black, age 30-44, age 45-64, age 65-74, age ≥ 75, less than high school, high school, some college, smoker, fruits, and exercise. The three dotted parallel lines are the OLS estimates and their corresponding 95% confidence intervals. Note that the quantile regression coefficients do not exactly fall into the 95% bounds of OLS estimates. This suggests that the quantile regression with its more realistic assumptions provides estimates of consumer behavior that are different from those of OLS.

The graphs reveal some additional insights. The quantile regression estimates of the male coefficients are decreasing over the quantile, which suggests that although males are generally heavier than females, the difference shrinks and finally diminishes when BMIs are extremely high (fall in the 95% quantile). Meanwhile, the quantile estimates of the black coefficients are increasing, which suggests that blacks may be more likely to be severely overweight. The first two age variables display an increasing pattern of coefficients as well, while the last two age variables have nonlinear patterns over quantiles. These are consistent with the common expectation that bodyweight increases with age but may decrease after reaching certain age (e.g., sixty). An alternative explanation is that an obese individual has a shorter life than that of a normal-weight individual. Compared to individuals with college education, those with less education generally are heavier, and the difference is greater at the extreme end of the bodyweight distribution. Exercise has an effect that decreases over quantiles, which suggests that it is more effective in reducing bodyweight among overweight population.

Figure 2
Quantile Regression of BMI.



Conclusions

This study is consistent with the earlier results of Ewing et al. (2003) that there is a significant effect of urban sprawl on BMI and further provides a more comprehensive picture of the relationship by using quantile regression. Progressively larger coefficients of urban sprawl up to the 75% quantile of BMI indicate that urban sprawl affects BMI more for heavier individuals, with the exception of those who are highly obese.

Because exercise controls for the effects of recommended physical activities, sprawl captures the effects of other physical activities. Walking to a destination as a part of daily routine, not necessarily with the intention of exercising, is a good example. Poor accessibility is a common characteristic of urban sprawl. Very few destinations are within walking distance if there is severe urban sprawl. The significant impact of urban sprawl on body weight reflects the practicability of the other physical activities of place of residence.

The effect of urban sprawl on BMI has important consumer policy implications. Higher medical costs associated with higher BMIs and higher prevalence of consumer obesity are incentives to manage sprawl to reduce related health care costs. Because diet and exercise habit are mostly individual choices, there are limited options for public intervention to control BMI (or obesity). The results suggest that consumer advocates need to encourage growth policies that discourage urban sprawl. Such efforts will help in the long-run to constrain medical costs through reduced obesity. The results also indicate which demographic groups are most likely to be overweight, so policy efforts to reduce sprawl can be targeted to areas that are most apt to benefit.

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