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Active Transport, Public Transportation, and Obesity in Metropolitan Areas of the United States.

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Abstract

There is a well established relationship between exercise and weight in individuals. Recently, relationships between less urban sprawl and more leisure exercise and between certain urban characteristics usually associated with less sprawl and exercise for transportation have been found. This paper completes the less-sprawl-more exercise for transportation-lower weight sequence by finding that counties in metropolitan areas where more people complete their journey to work by walking, biking, or taking public transportation have fewer people who are overweight.

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Active Transportation, Public Transportation, and Obesity in Metropolitan Areas of the United States.

Introduction

Obesity has become a public health problem in the United States and many other nations. Inexpensive, calorie dense food, a shift away from physical labor, reductions in school-based physical education, and the increase in the amount of leisure time spent sitting in front of a television or a computer have all received partial blame for the increase in the proportion of the population that is overweight. Suggested policy actions to combat the problem have been as varied as the changes in society that have received blame for the problem, but the incidence of obesity keeps rising. Changes in the built environment, especially the increase in suburban sprawl, have also received partial blame. The theoretical link between sprawl and obesity is that sprawl results in less physical activity which results in more obesity.

In the United States today, obesity rates continue to climb. It was reported as recently as 2006 that greater than 34% of adults and nearly 20% of adolescents and teens in the United States were obese [CDC Report, 2008]. Additionally, participation in regular, recommended physical activity is alarmingly low. In a 2007 report on physical activity prevalence rates published by the Centers for Disease Control and Prevention (CDC), less than half of the population (48.8%) participates in sufficient, regular physical activity to derive health benefits including chronic disease prevention and weight management. Of the remaining population, 37.7% does not participate in sufficient physical activity and 13.5% is inactive. Additionally, nearly 25% of the respondents reported no participation in leisure time physical activity at all [CDC Report, 2007]. Taking into light the impact physical activity has on weight management and disease prevention, the need for physical activity derived from means other than planned leisure pursuits is increasing in importance. These data have led the CDC to recommend increasing health-related physical activity through population-based initiatives [CDC Report, 2008].

Physical activity can take a variety of forms and participation in physical activity can have many underlying motivations. Physical activity may be planned as part of leisure time activity like jogging, going to a fitness facility, or participating in organized sports. It may be part of a job like a postal employee walking from door to door to deliver mail. It may be part of completing activities of daily living like climbing stairs, scrubbing a floor or mowing the lawn. Physical activity may also include active transportation like biking to school or walking to a shop. Empirically, there is a well established connection between the form of the built environment and participation in planned or leisure time physical activity (LPTA). There is enough literature about this connection, that there are not only review articles, but there is also a critical appraisal of those review articles [Gebel, Bauman, Petticrew, 2007]. Overall, there is convincing evidence that places that are less sprawling are places where more people engage in leisure time physical activity.

The use of active transport (AT) is also sensitive to the built environment. Researchers have proposed that the attributes identified with lower levels of sprawl like mixed uses, more street connectivity, greater population density and the existence of sidewalks and bike paths, make active transport more convenient and pleasant, and result in more people using active transport. There is good empirical evidence for this connection between the form of the built environment and more use of active transport [Craig, Brownson, Cragg and Dun 2002; Saelens, Sallis and Frank 2003, Zlot and Schmid 2005, Winters, Friesen, Koehoorn, and Teschke 2007 are examples]. It is not just biking or walking trips that involve active transport. Using public transit also often involves some active transport, be it walking, biking, etc., for at least a few blocks at both the beginning and end of the journey, and Besser and Danner [2005] found that transit users in the United States averaged 19 minutes a day of walking as part of their journeys using transit. A recent study of rail transit users in Montreal found that most integrated LPTA and AT, and engaged in sufficient physical activity, at least on weekdays [Lapierre, Lessard, Lewis and Carlier, 2008]

Less sprawl is also associated empirically with less obesity [Strum and Cohen 2004; Ewing, *et al* 2003]. While the correlations between less sprawl and more physical activity and between less sprawl and less obesity lead to the obvious conclusion that reducing sprawl will improve public health by encouraging physical activity and thereby reducing obesity, the direction of causation is not clear and should be confirmed before policy recommendations are made. If active people choose to live near parks and bike paths, then it is not clear that adding parks and bike paths will increase participation in physical activity. If fit people are the only ones who consider using active transportation, then policies to make it a more attractive alternative will do little to improve public health. Before suggesting the implementation of policies aimed at reducing sprawl because they will improve public health, the causation, as well as the correlation, must be explored.

Unfortunately, endogeneity makes it difficult empirically to determine the direction of these relationships. If obese people are unlikely to become active, then the causation for the relationship between the incidence of obesity and participation in physical activity will run both ways. Similarly, if people who are already active tend to choose to live in built environments with certain characteristics, then the relationship between the form of the built environment and participation in physical activity will run in both directions.

In a recent article in this journal, Handy *et al* [2008] used a set of carefully selected samples to show that people's tastes for physical activity do not determine where they choose to live. Instead, neighborhoods which are more conducive to physical activity seem to cause more residents to engage in "neighborhood physical activity." The implication is that public policies that change the form of the built environment can result in people becoming physically active (and fewer becoming obese).

Our purpose here is to establish another causal link from the built environment through physical activity to the incidence of obesity. While Handy *et al* have established that the causality runs from form to physical activity when physical activity is measured by

"…exercise somewhere in the neighborhood hard enough to breathe somewhat harder than normal for at least 10 minutes" (p. 351), here we will look at physical activity in the form of active transportation in the journey to work. Using publicly available data from counties in Metropolitan Statistical Areas of the United States and two-stage least squares (instrumental variables) regression, we will show that the form of the built environment affects the use of active transportation which then affects the incidence of obesity. When combined with the results of Handy *et al*, the causal link from form to activity to health receives strong support.

Theory

Our theory is based on a model developed by Goldfarb, Leonard and Suranovic [2006] (referred to as GL&S) to explain dieting behavior. GL&S follow the basic logic of the indifference curve/budget constraint model of consumer utility maximization. Their model modifies the shape of the indifference curves and introduces a different constraint, resulting in a model that graphically looks different than the traditional one.

Consider a utility function where the arguments are calories consumed and actual weight compared to the consumer's ideal weight:

$$U = f(\text{calories}, |\text{weight}_{actual} - \text{weight}_{ideal}|)$$

where:
$\delta U/\delta\text{calories} > 0$ and $\delta U/\delta|\text{weight}_{actual} - \text{weight}_{ideal}| < 0$.

The axes of the indifference map are calories consumed and weight, with weight on the horizontal axis and calories consumed on the vertical. The indifference curves show the pyschological trade off between calories and weight and are U-shaped rather than convex to the origin. Holding weight constant, and moving from fewer to more calories consumed, utility rises, so being farther from the weight axis means greater utility at any constant weight. Holding calories constant, moving from left to right as weight increases, utility will at first increase as weight approaches the individual's ideal weight, and then decrease as weight passes that ideal. This makes the indifference curves U-shaped, with the lowest (least calorie) point on each curve being at the consumer's ideal weight.

The slopes of the indifference curves will also play a role in our argument. As calories increase at a fixed level of weight, MU of calories will fall as MU of weight stays constant. Moving vertically upward, crossing higher indifference curves at the same weight, the absolute values of the slope, $|MU_{actual\ weight}/MU_{calories}|$, will rise. At any constant weight, the indifference curves become steeper as calories consumed rises.

The constraint has a positive slope and intercept. The "Food weight production frontier" (FWPR) , as GL&S call it, acts like a budget constraint showing the calorie-weight combinations that are obtainable by the consumer, *given his or her level of physical activity.* The position of the constraint depends on the physiological trade-off between calories consumed and weight. The slope depends on metabolism and the intercept depends on the amount of energy required for simply existing and the amount of physical activity:

$$\text{Calories} = a + b(\text{weight}); \ a \text{ and } b > 0$$

Physical activity plays the role that income plays in the standard utility maximization model, with increases in activity causing upward shifts in the FWPR as the amount of calories that can be consumed becomes greater before weight is gained. The FWPR will have a positive intercept since some calories are needed simply to exist. Each FWPR will have a positive slope since, at a given level of activity, more calories consumed means a higher weight. A consumer can shift their FWPR upward by engaging in more physical activity since exercise burns calories and means that the same weight can be maintained while more calories are consumed. It can be argued that more activity will increase muscle mass relative to body weight, making the FWPRs steeper at higher levels of exercise since muscle mass takes more calories to maintain than fat. Our argument does not depend on changing slopes, but the effect would be to reinforce the effects modeled.

Figure 1 illustrates the utility maximization process. At the level of physical activity implied by the lower FWPR, the consumer will choose the weight-calorie combination at point A, where the FWPR is tangent to an indifference curve. At this point, the physiological trade-off between calories and weight shown in the FWPR equals the psychological trade-off shown in the indifference curve, and the consumer will be maximizing his or her utility, given the level of physical activity. Note that consumers will choose to be above their ideal weight.

Permanently shifting the FWPR upward by increasing the amount of physical activity requires a change in habits, since the increase in activity must be continuing or the FWPR will shift back downward. Changing habits is not always easy, and restructuring one's daily routine to include physical activity may be especially difficult. Since lower FWPRs result from less physical activity, consumers who get little exercise will be farther above their ideal than those who get more exercise as the tangency between the FWPR and an indifference curve is farther to the right along lower FWPRs.

People with jobs have to journey to work in any case, and the choice of transportation mode is probably habitual. The choice of active or passive transport to and from work depends largely on which mode is least costly in both money and convenience. Changing from passive to active transport for the journey to work will increase the level of physical activity, shift the FWPR upward, and reduce the utility-maximizing level of weight. In figure 1, this is shown by a movement from point A to point B. If active transport is a reasonable alternative to passive transport, then it may be easy to change habits and shift from passive transport to work to active transport to work. If active transport is made less expensive, in convenience or money terms, in an area, then more people will adopt active transport for their journey to work, see their FWPRs shift upward, and "choose" to be closer to their ideal weight. This occurs whether the decision was made considering the health effects or not.

Our purpose here is to explore the relationship between urban form and obesity, and determine the direction of causation. If urban form affects the relative costs of active and passive transportation, the theory presented here provides a mechanism that describes the effects on physical activity leading to changes in the incidence of obesity. Areas that sprawl are designed to make automobile use (passive transportation) convenient and

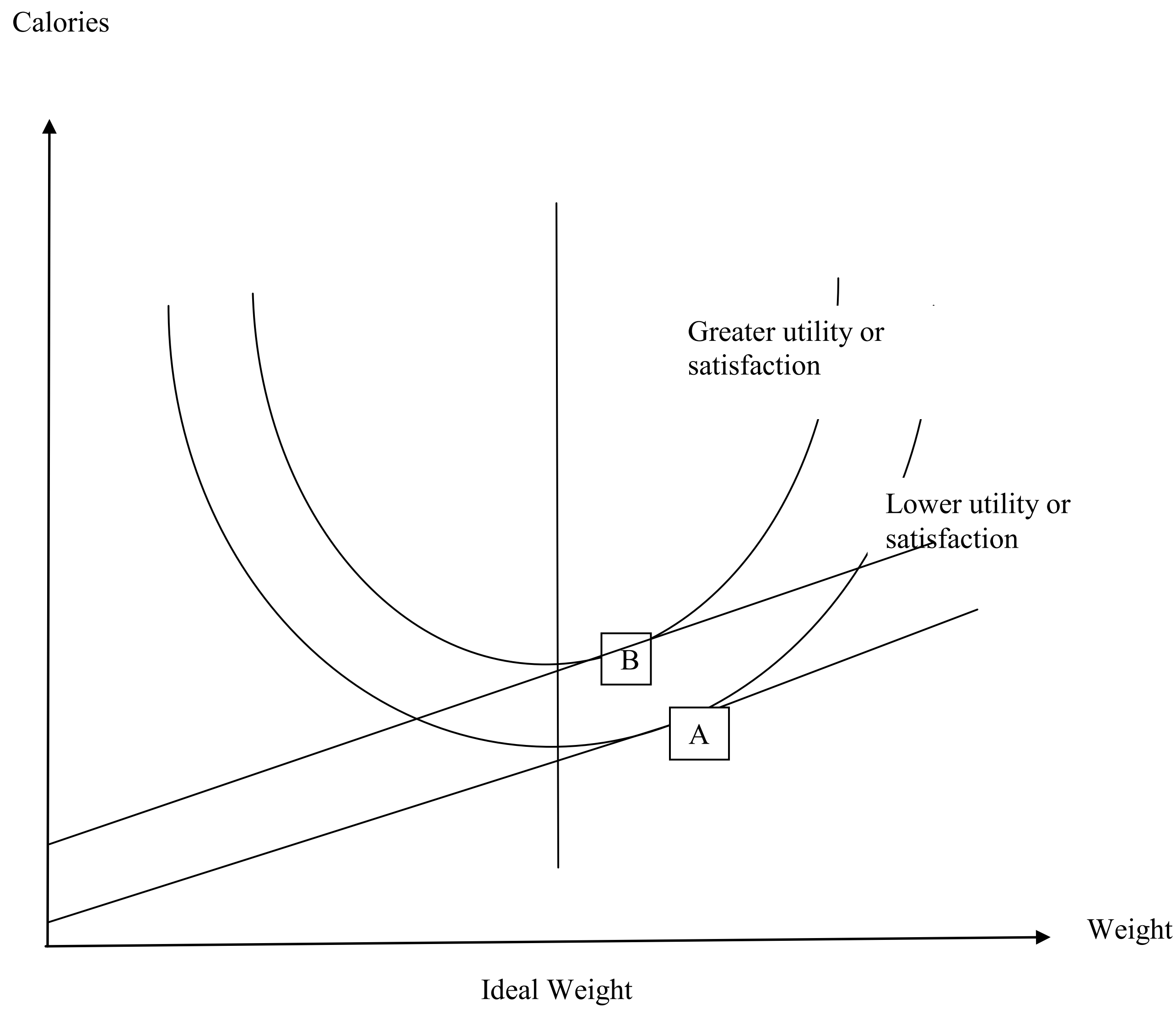

Fig. 1. A set of indifference curves. Utility, or satisfaction, is constant along any one curve, but increases with movement to higher curves. At any level of calorie consumption, utility is the greatest when weight is at the ideal level. At any given weight, utility is greater with more calories. If exercise increases due to a change from passive to active transport for the journey to work, The FWPR shifts up and the new equilibrium is a B, with a lower weight.

thereby relatively low cost. Large single family homes with attached garages, in cul-de-sac subdivisions, office parks set back from the road, big box stores each connected with the other only by using four or six lane connector roads make driving door-to-door the only reasonable mode of transportation. Distances are too great and traffic moves too quickly along the connector road for a pedestrian or bike rider to feel comfortable. Using public transportation requires long, unpleasant walks to and from the stop, usually on connector roads and through parking lots--spaces designed for automobiles.

At the other extreme, a dense street network with mixed uses and multifamily housing or single family homes on narrow lots will make active transport a good alternative, as well as making better public transportation with greater frequency and more routes less costly to provide. Higher population density, greater street connectivity, sidewalks, bike paths, slower automobile traffic, and greater perceived safety, all make active transportation a more likely choice, and we should expect less sprawl to result in less obesity because there will be greater use of active transportation. It should be possible to explain the extent of the use of active transportation by the form of the built environment. The use of active transportation should then partially explain the incidence of obesity.

There is empirical evidence that urban form does affect the amount of exercise for transportation people choose. Zlot and Schmid [2005] found more walking and biking for transportation in communities with more parks, while Craig *et al* [2002] found that various community characteristics, like the number and variety of destinations and traffic threats, affect the decision to walk to work. Frank, Andresen and Schmid [2004] found that land use mix, intersection density, and residential density, all dimensions of urban form, all affect distances walked and time spent in a car for residents of metropolitan Atlanta. Policies that affect urban form should also affect the use of active transport.

Methods

The model is estimated for a cross section of 176 counties in the United States. All of the counties are in Metropolitan/Micropolitan Statistical Areas (MMSA), and, as explained in the data section below, are the counties for which the complete data needed was available. Because the model has an intermediate step, going from the form of the built environment through use of active transport to get to the incidence of obesity, we use two-stage least squares (instrumental variables) regression to estimate the model. The first stage estimates participation in active transportation as a function of urban form. The second stage then estimates the incidence of obesity. The data was analyzed with the STATA software package.

County level data was used because data is collected from two different public use data sets, and counties are the smallest geographic area for which data from both sets are available. Though one of the data sets is available for individuals, multi-level analysis was not used. The instrumental variable, population density, and the independent variable of interest, mode of journey to work, are available only at the county level, and we were reluctant to estimate a model for individuals with these important variables available only at the aggregate level.

Data

Data was collected from two sources. Health data was collected from the Behavioral Risk Factor Surveillance System (BRFSS) of the Center for Disease Control and Prevention, using their SMART: Selected Metropolitan/Micropolitan Area Risk Trends website (http://apps.nccd.cdc.gov/BRFSS-SMART/SelMMSAPrevData.asp). The raw data is collected through a telephone survey, and is self-reported. BRFSS data is available at the county level only if the county is in a MMSA (Metropolitan/Micropolitan Statistical Area). This is not an important limitation because most active transport takes place in metropolitan areas, especially active transport associated with public transit use. CDC does not release county level data for all counties in all MMSAs because of their sampling technique. In order for data for a county to be available, the county must be in an MMSA where at least 500 interviews were completed, AND there must be a minimum number of completed interviews in each of 12 to 24 weighting classes in the county in that year. For some counties data is available in some years and not in others. Our final data set included 176 counties, with data for some from 2002, for some for 2003, and for others for 2004. More information about the sampling technique and data availability is at www.cdc.gov/brfss/smart/faqs.htm.

BRFSS data was collected for the percentage of the adult population with BMI>25, our measure of the incidence of obesity. This serves as the dependent variable in the final, second stage, regressions. Some of the control variables were also collected from the BRFSS: the percentage of the adult population that uses tobacco, the percentage of the population that has "any kind of health care coverage," and the percentage of the population that during the past month participated in "any kind of physical activity."

Data was also collected from the 2000 Decennial Census. The census was the source of the variable of interest, use of active transport, constructed from the "journey to work" questions in the 1 in 6 Long Form sample that is included in Summary File, SF3. For each member of the work force in each of the sampled households, the respondent is asked "How did this person usually get to work LAST WEEK?" There are a number of choices, and we collected the percentage of the work force in each sample county that walked, bicycled, or used one of the listed forms of public transit. We constructed three measures of active transport: the percentage of workers which walked or biked to work; the percentage which walked, biked or used public transportation to get to work; and the percentage which used public transportation for their journey to work. One control variable was collected from the census, median household income in 2000. In instrumental variables used in the first stage regression, population density and the percentage of the population that was white in 2000 are from census data.

Because the incidence of obesity has been growing across time, and some of the BRFSS data is from 2002, some from 2003, and some from 2004, dummy variables were added for 2002 and 2003.

Results

The model is analyzed in two stages, following the theory. The first stage is to connect urban form with use of active transport. The second stage is to connect active transport behavior with weight. Remember that the measures of active transport are limited to journey to work. The first stage of the model is:

Active transport = f(urban form, demographics, controls)

This is estimated by:

$$AT = \alpha + \beta_1 Density + \beta_2 White + \beta \mathbf{X} + \varepsilon$$

Where:

AT is one of the three journey to work measures of the use of active transport.
Density is the population density of the county in 2000, our measure of the form of the built environment.
White is the percentage of the county's population that is white, a measure of demographics, and (regrettably), a proxy for income distribution.
X is the vector of control variables.

By using the predicted values for active transport from the first stage as one of the independent variables in the second stage, only that part of the variation in active transport that is due to urban form is used to explain obesity and causation can be established. It is expected that the coefficient for density will be positive, since greater density means shorter journeys, more convenient public transportation, and usually goes along with more sidewalks and more mixed use neighborhoods. These attributes are expected to lead to more use of active transport. The coefficient on white will probably be negative. Median household income is a control variable, and with that controlled statistically, a larger white population probably means a smaller low-income population. If lower income people are more likely to use active transport because they cannot afford automobiles, a higher percentage of whites will result in less use of active transport.

We chose to use raw population density as our measure of urban form. A "sprawl index" is available for the counties in the sample from Ewing *et. al.* [2003]. Their index was originally conceived for metropolitan areas and was constructed with multiple measures of each of four dimensions of urban form—a total of 22 variables. For their county index, measures of only two of the dimensions were available and only six variables makeup the index. Population density is highly correlated with their final index (ρ=.846), and we used the simpler measure.

The results for the first stage are presented in figure 2:

Figure 2. First stage regression results

Measure of Active Transport	WalkBike	Transit	WalkBikeTransit
F	4.26	52.24	17.62
Partial R^2	.2634	.8460	.7868
Test of excluded instruments F-score (2,167)df	4.49	142.19	50.44
p>F	0.013	0.00	0.00

The summary statistics show that the instruments, population density and white, effectively explain much of the variation in all of the measures of active transport, especially so in the measures which include transit use. The F-tests for the excluded instruments show that the hypothesis that instruments have been excluded will be rejected at any reasonable level of significance. The first stage does a good job of predicting active transport use based on population density, our measure of the form of the built environment. In all three versions, the coefficient on population density was positive and statistically significant at $\alpha = .05$ (the t-scores for density were 2.60 in the WalkBike regression; 9.64 in WalkBikeTransit; and 16.77 in Transit). The coefficients for white were all negative, though statistically significantly so only in the Transit equation. Population density, our measure of the form of the built environment, seems to better explain transit use than it explains walking or biking to work.

The second stage then uses the predicted values for active transit use from the first stage as the variable of interest in a regression explaining the incidence of obesity, so the incidence of obesity is being explained by that part of the value of active transport that is explained by density (and white). Because there are three measures of the use of active transport, there are three estimates: All are of the same form:

obesity = g (active transport, other health attributes, income, year)

This is estimated by:

$$\% \text{ BMI}>25 = \alpha + \beta_1\text{AT} + \beta_2\text{Tobacco} + \beta_3\text{Healthcare} + \beta_4\text{LPTA} + \beta_5\text{Income} + \beta_6\text{Yr2002} + \beta_7\text{Yr2003} + \varepsilon$$

Where:

- Our measure of the incidence of obesity is the % of the population with BMI>25.
- AT is active transport use measured by the *predicted* level of WalkBike, Transit, or WalkBikeTransit from the first stage regressions.
- Tobacco is the percent of adults who use tobacco.
- Healthcare is the percent of the population with health care coverage.
- LPTA is the percent of the population that engages in leisure time physical activity.
- Income is the median household income in 2000 (in 1999 dollars).

- Yr2002 is a dummy variable for those counties where the BRFSS data is from 2002.
- Yr2003 is a dummy variable for those counties where the BRFSS data is from 2003.

From the theory, we expect that higher predicted values for the use of active transport from the first stage estimations should have a negative coefficient: more people using active transport should result in fewer who are obese. For the controls, we expect that tobacco use will have a positive coefficient, healthcare a negative coefficient, LPTA a negative coefficient, and income a negative coefficient. Because obesity has risen across time, we expect that the year dummy variables will have negative coefficients, since the missing value is 2004. There are three measures of use of active transport, so there are three estimated models. The results appear in Figure 3.

Figure 3. Second stage regression results. The dependent variable is the percentage of the population that has BMI>25. Z-scores in parentheses.

Active Transport measure	WalkBike	Transit	WalkBikeTransit
Constant	63.63 (9.97)	66.42 (9.57)	66.00 (9.66)
WalkBike	-0.67 (-3.04)		
Transit		-0.12 (-2.19)	
WalkBikeTransit			-0.10 (-2.35)
Tobacco	0.32 (4.10)	0.35 (4.59)	0.35 (4.35)
Healthcare	0.09 (1.24)	0.08 (1.05)	0.08 (1.08)
LPTA	-0.14 (-2.09)	-0.22 (-2.98)	-0.21 (-2.89)
Income	-0.13 (-3.20)	-0.00 (-1.92)	-0.00 (-2.16)
Year 2002	-2.96 (-3.66)	-3.22 (-3.89)	-3.18 (-3.87)
Year 2003	-0.75 (-0.89)	-0.94 (-1.08)	-0.91 (-1.05)
F (7,168)	17.55	15.22	15.68
R^2	.99	.99	.99
Hansen's J for overidentification	0.23	0.198	0.206
Chi-Sq p-value	0.63	0.66	0.65

The empirical results confirm most of the hypotheses, including that greater use of active transport, including public transit, results in lower incidence of obesity. The R^2 in each model is high and the F scores are all different from 0 at the 0.01 level. The measure of Active Transportation use, WalkBike, Transit, or WalkBikeTransit, has a statistically significant, negative coefficient in each model at the 0.05 level. Tobacco use has the expected positive coefficient, one that is significant at 0.01. Healthcare has coefficients with signs opposite of that expected, but the coefficients are not statistically different from zero. Exercise and Income have the expected negative signs, and the coefficients are statistically significant at 0.05. The dummy variables for 2002 and 2003 have negative coefficients, with the coefficient for 2002 being farther from zero, though the 2003 coefficients are not statistically significant. The Hansen's J statistic shows that instruments chosen for the first stage are uncorrelated with the error terms in the second stage regressions, so that they are valid instruments.

Limitations and further research.

Though this study adds confirmation to the theoretical link from less urban sprawl through more physical activity to less obesity, it has its limitations. The most serious is that only one dimension of sprawl, population density, was used. Similar studies using other measures of sprawl like the proportion of the population that lives in highly dense areas, street connectivity, or the prevalence of mixed uses, if they revealed similar results would bolster the confidence of the path of causation and provide further guidance to policy makers as to how to shape urban form.

While our use of county-level data allowed us to look broadly across the United States at low cost, the county is a rather high level of aggregation for this type of study. There is much variation within most counties, especially counties that cover large land areas. More studies that look at the connections between form, activity, and incidence of obesity at the zip code, census tract, or even block level within a single metropolitan area region of the country will continue to help policy makers understand the relationship between their actions and public health.

A final suggestion is to conduct multi-level analyses using individuals as the unit of observation, but measuring urban form at the zip code, census tract level, or other finer level, a different approach to answering the same basic question asked here.

Conclusion

The coefficients on the measures of Active Transport are of magnitudes that make sense. The coefficient for WalkBike (-0.67) implies that a one-percentage point increase in walking or biking to work will result in 2/3 of a percentage point decrease in obesity. The coefficients on use of active transportation that include public transit, Transit and WalkBikeTransit, show much smaller effects, but that should be expected, for a few blocks of walking to and from the transit stop will usually involve much less physical activity than walking or biking for the whole journey to work. Even so, policies that make using active transport, including the use of public transit, more convenient will have an effect on public health. Though the effect of increasing the use of public transit seems small at first, it is about half of the decrease in obesity that would result from increasing participation in LTPA by the same number of percentage points.

Building on the findings of Handy *et al* the results presented here should give policy makers more confidence that the incidence of obesity can be decreased by policies that modify the built environment. Though two studies are not conclusive, two very different methods have been applied to two very different data sets to test to see if the causation runs from the form of the environment through activity to less obesity. In both studies, the direction of causation was confirmed; participation in physical activity, whether neighborhood physical activity or use of active transportation, can be increased by changing the built environment. Policies aimed at reducing urban sprawl should also reduce the incidence of obesity. Our finding that increases in transit use result in reductions in the incidence of obesity are especially interesting as gasoline prices rise about $4 per gallon and more people begin to use transit.

Public health professionals looking for public policy actions that can help reduce the incidence of obesity should look for allies among new urbanists and others who advocate mixed use planning, energy efficiency, farmland preservation, and other changes that will decrease sprawl in urban and suburban areas. The effect on public health alone is probably not sufficient to argue for altering the built environment, but when combined with other public goals, reducing obesity can be part of the benefits of more compact, connected built environments.

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