Does Rural Residence Cause Weight Gain?:
Longitudinal Evidence of BMI Change in a Nationally Representative Cohort

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NOTE: Paper prepared for presentation at the 2019 annual meetings of the Population Association of America. This work benefitted from support from the Minnesota Population Center, which receives core support from the Eunice Kennedy Shriver National Institute of Child Health and Human Development via grant P2C HD041023. I thank John Robert Warren and Deborah Levison for helpful suggestions and feedback. However, all errors and omissions are my responsibility. Please direct correspondence to me at leex6611@umn.edu.

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ABSTRACT

A disproportionate number of residents in rural America carry excess body weight. This public health issue adds stress to overburdened rural healthcare systems. Previous studies have established that compositional differences between rural and urban areas alone do not explain this disparity. However, these cross-sectional associations cannot distinguish between causal contextual effects and selection bias since they do not track people over time. In the current study, I aim to reduce the threat of selection bias by estimating the effect of rural residence on two-year BMI change using panel data from a nationally representative sample. Results suggest a greater increase in BMI for rural residents than urban residents over a two-year observation period after controlling for socio-demographic confounders. This is the first longitudinal evidence supporting a causal relationship between rural residential environments and weight gain. Further research should investigate the mechanisms that produce this effect.

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Despite urbanization in the 20th-century, a substantial portion of Americans continue to live in rural areas. According to the 2010 census, rural areas contained approximately 60 million people, roughly 19% of the population. Americans living in rural areas tend to experience health disadvantages compared to their urban peers (Eberhardt et al. 2001; Mainous and Kohrs 1995; Sparks 2012). One such disparity is excess body weight. Several national studies have documented a disproportionate concentration of obesity among rural adults (Befort et al. 2012; Bennett et al. 2011; Jackson et al. 2005; Patterson et al. 2004; Sobal et al. 1996; Wen et al. 2018) and children (Lutfiyya et al. 2007). Obesity is a key indicator of population health because it has been linked to a host of other chronic diseases and mortality (Must et al. 1999). Disproportionate obesity prevalence could therefore increase the overall health burden in rural areas, which is exacerbated by relatively few resources compared to urban areas and high barriers to health care access (Goins et al. 2005).

Rural communities have expressed concern about increasing body weight. In a national survey, rural health stakeholders identified nutrition and weight status as the second most important health priority (behind access to quality health services) for rural communities (Bolin et al. 2015). However, the reasons why rural residents tend to be more overweight is not well understood. Identifying the mechanisms underlying this pattern is essential to prescribing effective policy interventions.

Researchers have identified two broad types of factors contributing to regional health disparities: composition and context (Macintyre 2002). Composition refers to the individual characteristics of the people living in an area (e.g., age, sex, race, education, etc.), while context refers to the characteristics of the built environment (e.g., public transportation, grocery stores, air quality, etc.). Previous studies have demonstrated that both composition and context contribute to the excess body weight among rural residents; however, these studies have been cross-sectional and therefore unable to distinguish between causal effects and selection bias. I contribute to this literature by tracking changes in body mass index and rural-urban residence over time in a nationally representative cohort to estimate the unbiased contextual effect of rural areas on weight gain.

RURAL-URBAN DIFFERENCES IN OBESITY

Rural and urban areas differ in their population compositions. Rural residents are more likely to be older, to be married, to live in poverty, and to be US-born. They are less likely to be college educated or to meet recommended physical activity and nutrition standards compared to urban residents (Patterson et al. 2004). These factors also are also linked to excess body weight. One might hypothesize that the link between rurality and excess body weight is simply an artefact of these compositional differences. However, several studies have rejected this claim. Using measured height and weight from the 2005-2008 National Health and Nutrition Examination Survey (NHANES), Befort and her colleagues (2008) found that rural residents had significantly greater odds (OR=1.18, p=0.03) of obesity after controlling for age, gender, marital status, race, education, income, physical activity, and diet. Similarly, using data from the 1998 National Health Interview Survey, Patterson et al (2004) found that rural residence continued to be associated with obesity status after controlling for race, sex, region, age, education, income, functional limitations, self-rated health, smoking, and physical activity. In both studies, the residual association between rural residence and obesity net of these individual characteristics was attributed to unmeasured contextual factors.

Two studies have sought to uncover the underlying contextual factors driving excess body weight in rural areas. That is, they have sought to understand the causal effect of living in a rural place. Bennett and colleagues (2011) linked individual data from the 2005 Behavioral Risk Factor Surveillance System to county-level data from the Area Resource File. Consistent with previous studies, they found that the effect of rural residence on odds of obesity was reduced (from OR=1.20 to OR=1.11) after controlling for demographics, health status, diet, and exercise. This residual effect was reduced to non-significance after including county-level measures of food accessibility (such as the percentage of stores accepting SNAP vouchers, among others). The authors concluded from this finding that food supply was the most important contextual correlate of obesity in rural areas.

In a similar study, Wen and colleagues (2018) linked individual data from 2003-2008 NHANES with tract-level data from the 2000 U.S. Census. Again, the effect of rural residence on odds of obesity was reduced, though not eliminated, after controlling for age, race, country of origin, education, and income. Next, the researchers included tract-level measures of park accessibility and commuting preferences (e.g., walking or biking compared with driving to work). These community factors reduced the effect of rural residence on obesity to non-significance. The authors concluded that changing the built environment in rural areas to better accommodate physical activity would reduce the rural concentration of obesity.

Previous studies suggest a theoretical framework that is causal. The link between rural residence and obesity is mediated through a compositional pathway (education, age, income, etc.) and through a contextual pathway (access to healthful food, recreation, and transportation options). These can influence the health behaviors of a population, including diet, physical activity, and substance use, which subsequently effect the density of obesity prevalence. The policy implication of this framework suggests that altering the built environment (e.g., opening more grocery stores, building bike paths, etc.) will reduce obesity prevalence in rural areas, and therefore reduce the rural-urban disparity in obesity.

However, this is not the only possible way that rural residence and obesity could be linked. As Feng and colleagues (2010) highlight, where people reside is not random. Residential decisions are made with consideration of lifestyle preferences. Therefore, a cross-sectional association between park access and physical activity in a neighborhood may result from physically active people sorting themselves into areas that accommodate exercise. This unmeasured confounding variable introduces bias to the model. Previous neighborhood studies suggest that controlling for activity preference significantly reduces the effect of built-environment on activity levels and obesity (Frank et al. 2007; Handy et al. 2006). Other scholarship has investigated the role of selective migration on geographic health disparities (Norman et al. [2005] is an excellent example). However, this sort of design has not yet been applied to regional variations in body weight in the U.S. context. This is despite Sobal and colleagues' (1996) speculation over two decades ago that "different patterns of migration from rural to urban areas may be occurring, with thinner people more likely to move to urban areas leaving a residual rural obese population" (p. 300). Previous studies using cross-sectional data have acknowledged but not explicitly tested how differential selection might bias their results. I use longitudinal data to reduce potential selection bias.

CURRENT STUDY

I build on previous work by testing whether the association between rural residence and obesity is confounded by selection of lower-BMI people into urban areas. Longitudinal data is best suited to accomplish this task since it enables me to establish a sequence of events (i.e., whether the weight gain occurred before or after the person became a rural resident). I rely on the National Longitudinal Study of Youth, 1979 cohort (NLSY79). The NLSY79 began with a representative sample of 12,686 youth aged 14-22 in 1979 when the survey began. The study is operated by the Bureau of Labor Statistics (BLS). Data were collected annually through 1994, then every other year through 2014. Respondents were asked to report body weight every other year beginning in 1986. I use this along with their height (reported in 1985 and assumed stable) to calculate BMI at two-year intervals. I also used the geocoded data provided by the BLS to ascertain whether respondents lived in a rural or urban county during each interview. I can also observe relevant socio-demographic variables every other year between 1988 and 2014. In this analysis, I include all observations for which respondents have valid measures of all independent and dependent variables for two consecutive surveys. This generates a sample of 86,651 observations of BMI and metropolitan status for 10,539 nationally representative participants. These data allow me to order rural residence and weight increase chronologically across a significant portion of the life span.

To reduce the risk of selection bias, I model change in BMI over a two-year period as a function of rural residence. This approach allows me to estimate the effect of residing in a rural context on a change in BMI between observations. If the association between rurality and obesity is an artifact of selective migration, then we should not observe rural residents gaining more weight over time than their urban counterparts after controlling for potential confounders. However, if the causal framework is legitimate, rural residents and those who move to a rural area should experience significantly more weight gain than their urban peers.

Hypotheses

I derive several hypotheses based on the causal framework:

1. Those living in a rural area consecutively over two years will gain more body weight than those living consecutively in an urban area.
2. Those who move from an urban to a rural area during a two-year period will gain more body weight than those living consecutively in an urban area.

Variables

Weight gain is the main dependent variable in this study. This is measured in units of body mass index (BMI) to standardize body weight and height. BMI is calculated from self-reported height and weight. To be comparable, regression estimates of within-person change require that the dependent variable is measured at equal intervals. Respondents' weight was recorded every other year between 1986 and 2014. This allows me to measure change in BMI beginning in 1988. Each respondent's height is assumed to be constant after 1985 (mean age 23.6), which was the last year this was reported. Height and weight were used to calculate BMI using the formula $\frac{weight\ (lbs)}{[height\ (in)]^2}$ X 703.

The main independent variable in this study is two-year metropolitan status, meaning whether a person lived in an urban or rural area at the beginning and end of each consecutive observation. Metropolitan status is a county-level measure. County of residence is determined for every participant at each observation using geocoded data available from the Bureau of Labor Statistics. I linked these counties to their 2013 Urban Influence Codes, which is a classification scheme developed by the US Department of Agriculture to distinguish metropolitan and non-metropolitan counties by their population size. These codes were then dichotomized to separate metropolitan counties (those with an urbanized population of at least 50,000 and/or adjacent counties with strong commuting ties) from non-metropolitan counties. Hereafter, I will use the terms urban and rural to refer to metropolitan and non-metropolitan counties respectively. Since metropolitan status is measured twice, this variable has four relevant categories: consecutive urban residents, consecutive rural residents, rural to urban movers, and urban to rural movers. In my analysis I treat this as a categorical variable with consecutive urban residents as the referent group.

In addition to these main variables, I control for time-variant and time-invariant socio-demographic variables that may confound the relationship between rural residence and obesity. These include age, sex, race/ethnicity, region, marital status, years of education, and family income. Family income was transformed to represent 2014 dollars and logged at each observation. Each of the time-dependent variables were measured consistently between 1988 and 2014, though there is some missing data due to nonresponse. Those with missing data were excluded from the model using listwise deletion. Finally, I included dummy variables for each year except 1988 (not shown) to control for time-varying historical variables.

In Table 1, I show descriptive statistics for each variable. Since individuals are observed multiple times (on average 8.2 observations per individual), I distinguish time-varying from time-constant variables. For time-varying continuous variables, the mean represents the average of all observations. The standard deviation of this mean can be calculated across all observations and analyzed between and within individuals. Except for age, all continuous variables have a greater variation between than within individuals. An average BMI of 27.6 indicates that this sample is slightly overweight. They are also slightly heavier than the national average, which was 26.6 in the year 2000. Participants also on average have only some post-secondary education and a mean family income of approximately $49,000.

For the time-varying categorical variables I indicate the frequency and percentage of observations within each category and the frequency and percentage of individuals who are ever observed within each category. Since these are time-variant, individuals can inhabit more than one category across observations. Therefore, the percentages in the individual column exceed 100. For instance, 36 percent of individuals were observed as “never married”, 71.4 percent were observed as “married”, and 41.5 percent were observed as separated, divorced, or widowed at least once. More observations occurred in the south than in other regions. Although a large majority (87.5 percent) of the sample resided in an urban area consecutively at least once, about 20 percent were observed living consecutively in a rural area and about 9 percent were observed making both potential moves between county types.

The only time-constant variables in my models are race/ethnicity and sex. The NLSY intentionally oversampled black and Hispanic participants. I use weights in my regression to account for this survey design and for attrition. The sample is basically split evenly between men and women.

<< TABLE 1 >>

Analytic Strategy

I aim to distinguish between contextual influence and selection bias in the relationship between rural residence and body weight. Regression analysis assumes that the error term (which includes the effects of all unmeasured variables) is randomly distributed and uncorrelated with any of the measured predictors. Therefore, to conclude that the cross-sectional relationship between rural residence and excess weight is not spurious, one must assume that rural residence is uncorrelated with all variables not explicitly measured in the model. The selection framework challenges this assumption by suggesting that unmeasured factors (such as lifestyle preference) may be correlated with rural residence and body weight, thus biasing the model. The methodological challenge then becomes how to control for variables that are not measured.

I solve this problem by introducing a lagged measure of BMI when predicting BMI two years later. So, for instance, BMI measured in 1986 is used to predict BMI measured in 1988. This lagged BMI coefficient effectively absorbs the influence of any unmeasured variable by using each person as his or her own control. The coefficients for all other independent variables then become estimates of the effect each variable has on a change in BMI over the observation period. This allows me to estimate the unbiased “treatment effect” of exposure to a rural environment on BMI better than cross-sectional data. The data are weighted so these estimates can be generalized to the larger population of American adults during this time period.

To demonstrate the difference between the cross-sectional method of investigating this association and my longitudinal method, I estimate two regression models. The first resembles previous studies, in which current BMI is regressed on rural residence and other contemporaneous socio-demographic measures. In my second model I introduce the lagged measure of BMI and replace the dichotomous rural indicator with the categorical indicator of whether the participant lived in a rural or urban county consecutively or moved between them during the observation period. All coefficients in the second model represent the average two-year increase in BMI attributable to each factor.

Because I use multiple observations clustered within individuals, my analysis must account for data correlation. There are several ways of approaching this. I first estimated models that included fixed effects for each independent variable and a random intercept for each individual. Examining the intraclass correlation revealed that almost none of the variation in observed BMI increases was explained by differences between people. Therefore, I abandoned this strategy. Instead, I clustered the standard errors of my estimated coefficients on individual ID.

PRELIMINARY RESULTS

First, I explore the bivariate relationship between rural residence and BMI in my sample. Figure 1 displays the BMI across age using a Loess smoother to generate the line for rural and urban residents. Rural residents consistently carry more body weight than their urban counterparts from the early-20s to mid-50s. Figure 2 displays the two-year BMI change across age using a Loess smoother to generate the line for consecutive urban residents, consecutive rural residents, and those who move between rural and urban areas. Each group tends to gain weight during each observation. Those who move from an urban to a rural area experience a greater increase in BMI than others, particularly between the ages of 30 and 45. Consecutively rural and urban residents tend to experience roughly even BMI change, though after age 40 rural residents gain slightly more weight at each observation. Those who move from a rural to an urban area report less weight gain than other groups.

<< FIGURE 1 >>

<< FIGURE 2 >>

I present findings from two regression models in Table 2. The first model resembles previous cross-sectional studies of rurality and body weight. I observe that in an OLS regression of BMI, without controlling the lagged dependent variable, rural residents report 0.585 greater BMI units than urban residents after controlling relevant socio-demographic confounders. In the case of a six-foot tall person, this roughly corresponds to the difference between 165 pounds and 169 pounds. While this estimate is robust ($p < 0.001$), it is insufficient evidence of a causal relationship between rurality and body weight because it does not account for selection into a rural or urban area.

In my second model I observe that living in a rural area consecutively or moving to one during a two-year period predicts an increase in BMI greater than that experienced by consecutive urban residents. Controlling for a lagged measure of BMI reduces the magnitude of the estimated coefficients for each variable compared to the first model. This is expected, since within-person changes in BMI over two years are small relative to the differences between people that emerge over a lifetime, which is what cross-sectional studies measure. If the link between rural residence and BMI observed in the first model were driven by unmeasured selection into rural or urban environments and not by some contextual mechanisms, then the predicted change in BMI should not significantly differ between rural and urban residents. In fact, living in a rural are does significantly predict BMI increase. Although this increase is relatively small (0.054 BMI units), exposure to a rural environment over many years could play a role in the substantial differences between rural and urban residents that previous studies have demonstrated.

<< TABLE 2 >>

Participants who move from an urban to a rural county experience an even greater increase in BMI than consecutive rural residents. An estimated BMI increase of .195 units means that a six-foot tall 165-pound person living in an urban county who moves to a rural county is predicted to gain two extra pounds over two years if everything else is held constant. This substantial initial weight increase may be explained by the body's initial reaction to its new rural environment, while the subtler increases for consecutive rural residents reflects the body's adaptation and homeostasis.

Other socio-demographic characteristics also predicted a significant change in BMI. Those who were older; separated, divorced, or widowed (compared to never married); lived in the west (compared to the south); and those with more education experienced less BMI increase than their peers. Blacks and Hispanics experienced gained more body weight than other race-ethnic groups. However, these compositional differences do not eliminate the significant effect of rural residence. This suggests that the rural context does contribute to excess weight.

DISCUSSION AND CONCLUSION

Previous studies describing the link between rurality and body weight have acknowledged that cross-sectional data is inadequate to infer causal effects because of potential selection bias. This is the first study to date examining the longitudinal relationship between rural residence and weight gain. Based on causal framework suggested by other researchers, I hypothesized that consecutive rural residents and those who move from an urban to a rural area would experience a greater body weight increase over two years than consecutive urban residents. The evidence I have presented supports both hypotheses. This suggests that a causal relationship between the rural context and body weight is plausible.

While this finding represents a significant contribution to the literature, there are several limitations to my study. First, I rely on self-reported height and weight, rather than measured, to calculate BMI. Previous studies have found that self-reports of weight are not always accurate. While this is problematic, I have reduced the risk of this biasing my results by including the lagged measure of BMI in my regression. If individuals are consistently over- or under-reporting their weight, controlling previous BMI should implicitly control for this.

Another limitation is that I have used 2013 county-level definitions to identify rural and urban areas across all observations from 1986 to 2014. Since the Office of Management and Budget updates the criteria for qualifying as metropolitan statistical area periodically, 2013 definitions are not comparable with previous versions. Therefore, I was unable to use 1993 or 2003 definitions to identify rural and urban counties in earlier observations. It is possible that some counties switched between rural and urban status over the decades of observation, and I am unable to detect these changes. Another critique is that county level definitions of rurality ignore heterogeneity within and between rural counties, rendering the nature of the "treatment" unclear. This objection is well-taken, though may not be as serious as it appears since previous studies using the same definitions have found a consistent relationship between rural counties and excess body weight.

I have not identified any contextual mechanisms that mediate the increase in BMI for rural residents. Two previous cross-sectional studies have attempted this, finding that access to healthful food, accessibility of parks, and commuting behavior explains most of the association (Bennett et al, 2011; Wen et al, 2018). Future studies should investigate the longitudinal association between these factors and weight gain to identify the best potential policy solutions.

As others have noted, even though some of the relationship between rurality and body weight is attributable to contextual factors, a larger portion is driven by differences in compositional differences. Policies addressing education and income attainment of rural residents may be most important to reducing rural-urban disparities. However, this study suggests that the effects of the rural "built environment" should not be ignored. Even after controlling for these socio-demographic characteristics, rural residents gain body weight faster than their urban counterparts. Those concerned with the health of rural communities should work to resolve this.

Future Improvements

While these preliminary analyses have generated interesting results, I plan to extend and refine them in several ways before presenting at the PAA. First, instead of using listwise deletion, I will impute missing data for cases that participated in a survey year but did not report some information, such as family income or marital status. I will also examine whether people are more likely to become overweight and obese while living in rural compared to urban areas, since these categorical outcomes may have greater public health concern than mean shifts in BMI for rural and urban populations. I will also investigate heterogeneous effects of the rural context across age, sex, income, and body weight levels. For instance, the rural environment may have more impact on the BMI change of older people, men, those in poverty, or those who are already overweight. Identifying the populations most effected by the rural environment is important for targeting public policy interventions.

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TABLES AND FIGURES

Figure 1: Smoothed BMI by Age of Urban and Rural Residents

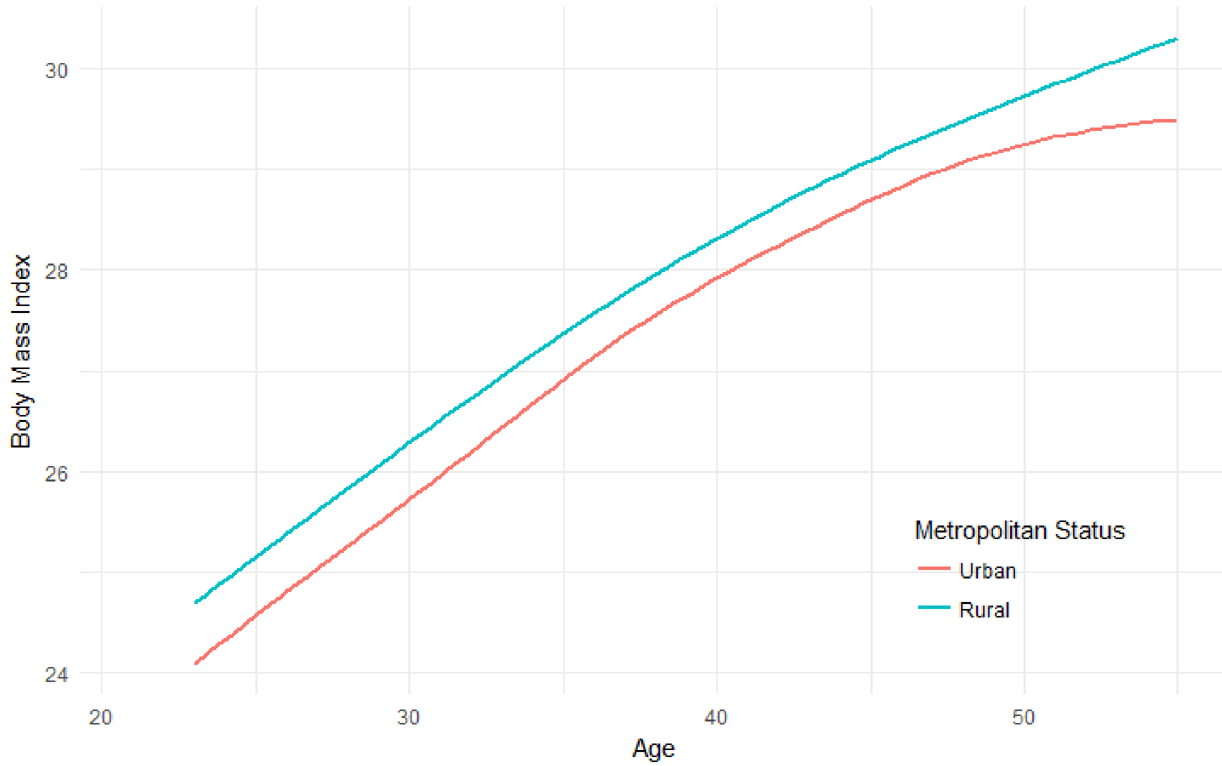

Figure 2: Smoothed Two-Year BMI Change by Age based on Two-Year Metropolitan Status

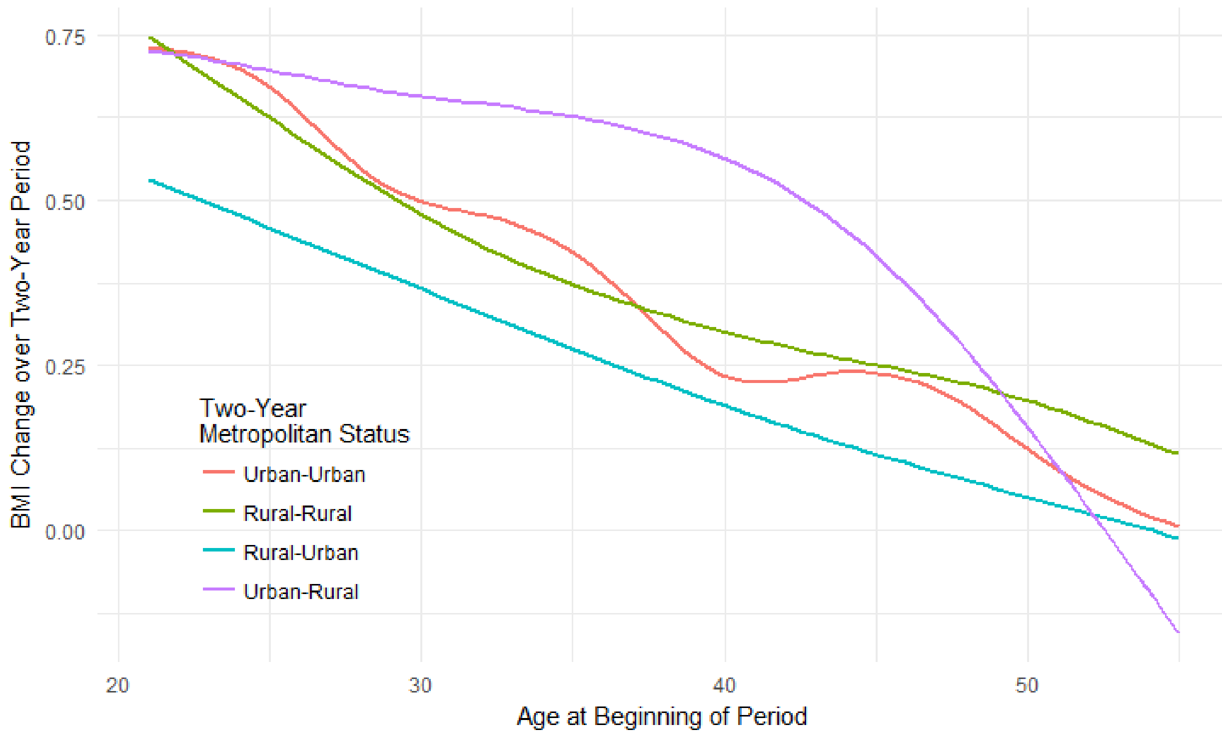

Table 1. Descriptive Characteristics of NLSY79 Cohort, 1988-2014

Time-Varying Continuous Variables

Variable	**Mean**	**Standard Deviation**			**Min.**	**Max.**	**Individuals**	**Observations**
		Overall	**Between-Person**	**Within-Person**				
BMI	27.6	5.9	5.4	2.6	7.6	94.1	10,539	86,651
Age	39.3	8.5	5.6	7.5	23	58	10,539	86,651
Education	13.2	2.5	2.5	0.5	0	20	10,539	86,651
Log. Inc.	10.8	1.0	0.9	0.6	0.1	14.2	10,539	86,651

Time-Varying Categorical Variables

Variable	**Observations**		**Individuals**	
	%	**N**	**% (Ever)**	**N (Ever)**
Marital Status				
Never Married	21.0	18,163	36.0	3,798
Married	55.9	48,467	71.4	7,527
Separated/Divorced/Widowed	23.1	20,021	41.5	4,371
Region				
Northeast	15.6	13,529	19.5	2,056
Midwest	24.5	21,268	26.0	2,742
South	40.0	34,660	45.1	4,755
West	19.8	17,194	22.4	2,358
Metropolitan Status (2-year)				
Consecutive Urban	82.5	71,508	87.5	9,222
Consecutive Rural	15.0	13,015	19.9	2,102
Rural to Urban	1.2	1,078	9.1	961
Urban to Rural	1.2	1,050	8.9	935

Time-Constant Categorical Variables

Variable	**Observations**		**Individuals**	
	%	**N**	**%**	**N**
Race/Ethnicity				
Non-Black, Non-Hispanic	54.9	47,566	56.5	5,957
Black, Non-Hispanic	27.3	23,656	26.6	2,805
Hispanic	17.8	15,429	16.9	1,777
Sex				
Female	50.9	44,136	50.5	5,324
Male	49.1	42,515	49.5	5,215

Table 2. OLS Regression of Body Mass Index

	(1) Current BMI		(2) 2-Year BMI Change	
Current Metropolitan Status				
(Urban)				
Rural	0.585***	(0.167)		
2-Year Metropolitan Status				
(Consecutive Urban)				
Consecutive Rural			0.054*	(0.024)
Rural to Urban			-0.141	(0.088)
Urban to Rural			0.195*	(0.085)
Age	0.050	(0.028)	-0.013***	(0.004)
Marital Status				
(Never married)				
Married, spouse present	-0.034	(0.175)	0.040	(0.026)
Separated/Divorced/Widowed	-0.775***	(0.199)	-0.072*	(0.029)
Sex				
(Female)				
Male	1.041***	(0.130)	-0.005	(0.017)
Race/Ethnicity				
(Non-Black, Non-Hispanic)				
Non-Hispanic Black	2.031***	(0.163)	0.248***	(0.024)
Hispanic	1.509***	(0.178)	0.135***	(0.024)
Region				
(South)				
Northeast	-0.103	(0.181)	-0.036	(0.024)
Midwest	-0.109	(0.162)	-0.012	(0.021)
West	-0.420*	(0.186)	-0.069**	(0.024)
Education (Years)	-0.184***	(0.026)	-0.012**	(0.004)
Logged Wages (2014 dollars)	-0.240***	(0.057)	-0.023	(0.013)
Lagged Body Mass Index			0.933***	(0.003)
Constant	27.393***	(0.919)	2.864***	(0.170)
Year Fixed Effects	Yes		Yes	
Observations	86,651		86,651	
Individuals	10,539		10,539	
R-squared	0.108		0.844	