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Fang “Stephanie” Fang April 15, 2015

Hungry for More:

The Effects of Grocery Store Density and SNAP Participation on U.S. Adult Obesity Rates

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An abstract of
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Abstract

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by Fang “Stephanie” Fang

Food access and affordability have been documented to influence consumption behaviors and subsequently weight outcomes. This study examines how access and affordability function as obesogenic factors with a focus on access to grocery stores and SNAP participation. Using data from the United States Department of Agriculture’s Food Environment Atlas, this study employs Ordinary Least Square models to observe the relationship between grocery store access and obesity outcomes in counties across the United States. As a secondary line of research, this study observes the interaction effect between grocery store access and SNAP participation on obesity outcomes. I find that grocery store access has a strong negative effect on obesity outcomes. The interaction of grocery store access and SNAP participation also has a negative effect on obesity outcomes, suggesting that areas with high food access and more food purchasing power experience lower obesity outcomes. These results have crucial policy implications for how government agencies administer programs that aim to increase food access and affordability.

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Acknowledgements

I thank my advisor, Dr. McCarthy, for his support and guidance throughout the thesis-writing process. Additionally, I thank the Economics department for truly defining my academic and intellectual experience at Emory. I thank my friends and roommates who have gracefully accepted “can’t – thesis” as a blanket excuse for many occasions during the past semester. Lastly, I thank Eminem, whose song “Lose Yourself” has proved inspirational throughout this entire process – fueling many late-night library visits.

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I. Introduction

Obesity remains a problem for a large part of the U.S. population, despite many efforts towards prevention and alleviation. These efforts have operated at both the individual and the institutional level. However, the Centers for Disease Control and Prevention (CDC) report that as of late 2014, more than 34.9% (or 78.6 million) of U.S. adults qualify as obese.[1] Additionally, the CDC reports that obesity increases the likelihood of and sometimes catalyzes other negative individual health outcomes such as type 2 diabetes and certain forms of cancer.[a] Obesity is also significant from an economic perspective. For example, obesity-related medical costs in the U.S. totaled $147 billion in 2008, and obese individuals typically paid $1,429 more in annual costs that year than normal-weight individuals.[2] Given the scope and severity of obesity and related health or economic problems, policymakers have an incentive to better understand obesogenic factors in order to more effectively manage them through shifts and improvements to certain policies.

One such obesogenic factor is an individual's diet or consumption of healthful foods, which can influence weight outcomes. Diet depends in part on access to and affordability of food. Individuals who lack diverse, nutritious options for food will frequently make less healthy consumption choices. This has the potential to adversely impact their weight. Morland et al (2006) have posited that such individuals will often adopt what is called an "energy-dense diet" that increases their intake of calories and carbohydrates. Moreover, it is likely that individuals who cannot afford healthy foods are also incentivized to choose less nutritious options, which are often less expensive. Morland et al have cited "energy-rich" foods such as sugars, breads, pastas

[a] To be classified as obese per CDC guidelines, an individual's body mass index (BMI) must exceed 30. BMI is calculated using the ratio of an individual's height and weight. Though BMI is an imprecise measure of weight-related health for some people, it is correlated to body fat for most and provides and standard means of understanding obesity in a quantitative capacity.

and prepackaged items as "especially attractive to people with limited incomes." According to their study, these foods have the potential to adversely impact weight outcomes, especially if they form the bulk of an individual's consumption. Consequently, healthier consumption and improved weight outcomes may result from increased food access and affordability.

In this study, I examine county-level food environment as a proxy for access as well as income and food purchasing power as a proxy for affordability. In particular, I observe the effects of grocery store density and Supplemental Nutrition Assistance Program (SNAP) participation to gauge how access and affordability may impact obesity outcomes. I choose to examine grocery store density in particular as a measure of food access because grocery stores by definition offer more options for healthy foods in comparison to competing types of food retailers.[b] I hypothesize that increased access to grocery stores will lead to lower obesity outcomes or a lower prevalence of obesity in a given area. Decreased access to grocery stores, on the other hand, will lead to higher obesity outcomes or a higher prevalence of obesity. I further hypothesize that increased affordability of foods as measured by SNAP participation will interact with grocery store density to improve or lower obesity outcomes in areas of high SNAP participation and high grocery store density.

Inherently, this research question has implications for certain programs that the government currently administers to combat problems of food access and affordability. For example, the government offers a number of grants and tax credits as an incentive for "healthy

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[b] According to the USDA's designations, grocery stores must contain "all the major food departments – including [but not limited to] fresh produce, fresh meat and poultry, dry and packaged foods, and frozen foods." The USDA derives this definition of grocery stores from the North American Industry Classification (NAIC) code and this definition includes larger supermarkets and delicatessens that sell what are considered general lines of foods. However, the definition excludes convenience stores, specialty stores, and supercenters/warehouse clubs. Expanded designations for these different types of food retailers are available on the USDA ERS website, under the data documentation for FEA.

food retail outlets" to locate in areas of low access.[c] Additionally, the government administers food and nutrition assistance programs such as SNAP to make purchasing food more affordable for households and individuals who fall under certain income and resource thresholds.[d] The results of this study may inform ongoing discussion about the efficacy of these programs and subsequent shifts to associated government policy. In particular, if the results indicate that grocery store density and SNAP participation interact to impact obesity outcomes, government agencies may wish to consider policies that aim to improve food access and affordability at the same time rather than independently.

I examine the research question with data from the current version of the Food Environment Atlas (FEA) compiled by the USDA's Economic Research Services (ERS) and supplemental health data from the CDC. The county level data from both sources examines food environments and health outcomes for populations in all 50 states with information dating from approximately 2007/2008 to 2012/2013.[3] Because this study operates at the county level, it is less granular than many previous studies that have operated at the city, census tract, neighborhood, or even household level. However, this study contributes innovatively to the existing body of knowledge in two ways. First, in terms of scope, it provides a comprehensive look at how food access as measured by grocery store density impacts obesity outcomes across the nation by synthesizing information from all 50 states. Second, it examines how food affordability, or food purchasing power, as measured by county SNAP participation and income interacts with food access to impact obesity outcomes in given counties.

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[c] Programs that support food access initiatives include the Community Economic Development Program, the Healthy Urban Food Enterprise Development Center, and the Rural Business Opportunity Grant Program among others. Additional examples may be found on the United State Departure of Agriculture (USDA) website.

[d] Other notable food and nutrition assistance programs include the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) as well as the Emergency Food Assistance Program (TEFAP). Other programs are listed on the USDA website.

I find that there is a strong negative and statistically significant correlation between the number of grocery stores per 1,000 people in a county and its obesity outcomes, controlling for certain exogenous factors. There is a small positive and statistically significant correlation between SNAP benefits per capita in each county and obesity outcomes. These results correspond with the findings of many past studies on the topics. Additionally, I observe a small negative and statistically significant correlation between obesity outcomes and the interaction of grocery store count with SNAP benefits. As suggested in the previous section, this interaction effect may have some bearing on how the government chooses to shape future policies to improve food access and affordability.

II. Literature Review

a. The Economic Case for Understanding and Treating Obesogenic Factors

Obesity is an economic problem due to the significant medical costs incurred each year by individuals treating comorbid health issues either caused by or associated with obesity. According to Wang et al (2011), obesity is related to the increased likelihood of developing type 2 diabetes, cardiovascular diseases, and several types of cancers. Wang et al have provided a conservative estimate of obesity-related healthcare costs, suggesting that treatment for obesity-related health issues accounts for approximately 2.8% of annual healthcare expenditures.[4] Øtsbye et al (2013) have observed that every unit increase in an individual's BMI corresponds with an increase in overall costs of healthcare for medical and pharmaceutical treatment. They have found that individuals in higher weight classes spend more on doctor's visits and drugs. In addition, they have found that BMI had the strongest effect on medical cost for men. Cawley and

Meyerhoefer (2012) have found that obesity relative to non-obesity[e] is associated with a $656 increase in medical expenditures on average for both men and women. Additionally, obesity is a negative externality for non-obese individuals who bear higher health insurance costs as a result of an increase in the number of obesity-related claims. Cawley et al also have found that obesity-related healthcare costs averaged $26 billion per year from 2000-2005 and that more than $23 billion of that cost was borne by what they called "third party payers" or those whose insurance costs were funding claims for obesity-related health procedures.

Moreover, studies have indicated that obesity may often cause a decrease in workplace productivity due to certain physical or health-related limitations. For example, Gates et al (2008) have found that moderately or extremely obese workers experienced the most difficulty completing workplace tasks on time due to health-related limitations in comparison to workers with lower BMIs.[f] They also had difficulty performing certain physical tasks necessitated by their jobs. Gates et al have observed a 4.2% "health-related loss in productivity" for moderately or extremely obese workers. They have found that this is the equivalent of a $506 annual loss in productivity per worker. Because obesity can lead to increases in medical costs and insurance costs as well as a decrease in labor market efficiency, it is not only a public health issue but also an issue of economic salience.

b. Studies of Food Environment and Obesity

A substantial amount of the literature that analyzes obesogenic trends has shown that the local food environment is correlated with obesity prevalence in given areas. This relationship may occur because the local food environment determines what kinds of foods are available for

[e] Non-obese individuals are considered those with a BMI less than 30.

[f] Moderately or extremely obese workers had BMIs that exceeded 35.

purchase. This may affect consumption behaviors and subsequently, weight control. Grocery stores, in particular, are linked to decreased obesity prevalence.

Larson et al (2009) have aggregated results from 54 research studies published between 1985 and 2008 that indicate a relationship between supermarket access, diet, and obesity prevalence. Their research results have demonstrated that access to supermarkets/grocery stores was negatively linked to obesity rates in given regions. On the other hand, obesity rates rose with increased access to food retailers that carried less healthful foods such as convenience stores or fast food restaurants. In their review, Larson et al have found that supermarkets on average offered "the greatest variety of high-quality products at the lowest cost" including fruits, vegetables, and other healthful foods. In comparison, other types of food retailers such as convenience stores often sold "mostly prepared, high-caloric foods and little fresh produce at higher prices." The studies included in Larson et al's review also demonstrated strong evidence of a relationship between supermarket/grocery store access and income as well as a relationship between access and race. Larson et al have written that their review findings showed "ZIP codes representing low-income areas had only 75% as many chain supermarkets available as ZIP codes representing middle-income areas." Additionally, "the availability of chain supermarkets in predominantly black neighborhoods was found to be roughly one half that in their counterpart white neighborhoods."

In a study measuring similar effects, Inagami et al (2006) have used individual-level data for adults in the neighborhoods of Los Angeles to observe the relationship between grocery store access and BMI. They have found that on average increases in the distance between an individual's home and the nearest viable grocery store were associated with increased BMI. Inagami et al have also indicated that BMI was typically higher for individuals who shopped at

grocery stores in low-income neighborhoods. This has suggested that the socioeconomic characteristics of a neighborhood may have some bearing on the quality of food available in any grocery stores in the area. Outside of the U.S., Spence et al (2009) have shown that for adults in neighborhoods of Edmonton, Canada, a lower ratio of fast-food restaurants and convenience stores to grocery stores and "produce vendors"[g] close to people's homes lowered the odds of obesity.

In terms of the geographic dispersion of grocery stores, Powell et al (2007) have found that rural and farm areas, in comparison to urban areas, tend to have fewer available food stores with "the greatest lack of availability for chain supermarkets." However, suburban areas have the most densely populated food environments in comparison to other types of areas, averaging "between one and one half to two times the number of available food stores compared to urban areas."

While many studies have noted that grocery store access reduces the prevalence of obesity outcomes, others suggest that the number and type of other non-grocery store food retailers may also have some bearing on the consumption and weight outcomes of individuals in an area. For example, Courtemanche et al (2015) have recently shown that "greater supercenter/warehouse club densities predict statistically significant weight gains." These gains occur in terms of changes to both average population BMI and to obesity prevalence. Additionally, Courtemanche et al have found that higher restaurant density also predicted higher BMI and obesity outcomes. In fact, their study finds that supercenter/warehouse club and restaurant density were the largest contributors to obesity of all the obesogenic factors they observed. They have shown that supercenter/warehouse club and restaurant density most

[g] "Produce vendors" constitute any food retailer that offers fresh produce.

strongly impacted BMI and obesity outcomes for those already in the tenth quantile for BMI. This means that these predictors were more significant for those already at a higher BMI in comparison to the rest of the population. Lastly, Courtemanche et al have shown a small negative association between grocery store density and obesity outcomes and similarly between convenience store density and obesity outcomes.

c. Studies of Affordability and Obesity

While local food environment can influence consumption and therefore weight outcomes in terms of access, affordability also plays a role in determining what individuals are able to purchase and eat. Certain government programs are designed to improve the food purchasing power of individuals and households that fall under designated income and resource thresholds. Most notably, the federal government's Food and Nutrition Services (FNS) work in conjunction with state agencies to administer SNAP benefits to qualifying households. See Appendix Table 1 for the gross monthly income and net monthly income thresholds that households may not exceed to qualify for the program. See Appendix Table 2 for the maximum monthly allotment of SNAP benefits for each household size.[h]

SNAP participation and income are often linked to household food insecurity, with SNAP benefits often thought to reduce food insecurity by increasing the affordability of certain foods. However, a significant amount of literature on the topic correlates SNAP participation with adverse weight outcomes and increased obesity prevalence. This may speak to the efficacy of the program and the subsequent need for policy improvements if increasing food affordability is not enough to drive healthy consumption.

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[h] The FNS makes the assumption that SNAP eligible households spend approximately 30% of their resources on food each month. Therefore, in order to determine a household's monthly allotment of SNAP benefits, state agencies subtract 30% of the household's net monthly income from the maximum monthly allotment possible given each household size. Details are available on the USDA FNS webpage.

Leung et al (2011) have performed a cross-sectional analysis of data from the National Health and Nutrition Examination Surveys (NHANES) in the years 2003-2006 to determine whether low-income households who used SNAP benefits experienced poorer health outcomes. Leung et al have estimated outcomes for approximately 2250 adults represented in NHANES whose income levels were equal to or lower than 130% of the federal poverty level, making them eligible to receive SNAP benefits. SNAP participation was marked by those in the sample who responded in the survey that they or a member of their household had been authorized to receive food stamp benefits in the last 12 months. According to survey results, 32.8% of low-income adults in the sample had used SNAP benefits during the past year. Leung et al have found that household SNAP participation was associated with obesity as well as other adverse health outcomes such as "[higher] waist circumference, elevated triglycerides, lower HDL cholesterol, elevated fasting glucose, and metabolic syndrome." These findings were consistent across sociodemographic groups and independent of household food insecurity.

Additionally, Townsend et al (2001) have found that women who received food stamp benefits also experienced higher weight outcomes on average. This may have resulted from what they called a "food stamp cycle hypothesis" whereby the food stamp distribution cycle induces individuals to shift between overeating and restricting consumption. According to the hypothesis, individuals overeat during the first part of the month when food stamp benefits are abundant and restrict towards the end of the month when they run out, a behavior that causes weight gain over time. Gibson (2003) has also found an association between long-term and ongoing participation in the food stamp program and obesity in women who are low income in particular, suggesting that food stamp benefits most profoundly impact the weight outcomes of women who are least able to obtain food through other means.

However, some of the literature on the topic suggests that the relationship between SNAP participation and obesity outcomes cannot necessarily be considered either positive or negative due to endogenous selection bias and instances of misreporting. First, individuals who participate in SNAP are already more likely to be overweight or obese prior to receiving program benefits. This is because SNAP eligibility is correlated with low income and often poverty. Previous studies have found that low-income households are more likely to experience adverse weight outcomes. For example, Bhattancharya et al (2004) have observed the relationship between poverty and obesity outcomes. They have used data from NHANES and the USDA to determine whether food insecurity and income independently and jointly served as predictors of poor nutritional or health outcomes. Their results have differed amongst different age groups such as pre-school children, school-age children, adults aged 18-64, and adults older than 65. According to Bhattancharya et al, "poverty is predictive of poorer nutritional outcomes" for adults and pre-school aged children but not children who are considered school age. Additionally, they have found that poverty was positively related to obesity in non-elderly poor adults. This result indicated that "poor Americans eat too much of the wrong calories, rather than getting insufficient calories overall." Bhattancharya et al have also found differences in the effects of food insecurity and income across race and ethnic groups. In adults that are aged 18-64, poverty had a greater impact on the nutritional and health outcomes of whites and blacks. Food insecurity was linked to poorer health outcomes in whites, blacks, and Hispanics. Lastly, their results have indicated that food insecurity tended to impact adult health outcomes more so than those of children, whereas poverty or low income impacts the health outcomes of young children more so than those of older children.

Second, the presence of underreporting and overreporting may confound any understanding of the relationship between SNAP participation and health outcomes. Using data from the National Health and Nutrition Examination Survey (NHANES), Vassilopoulos et al (2011) have found that that the likelihood of obesity for SNAP participating adults is 10.5% higher than for non-SNAP participating adults. However, they write that "this result is robust to functional form assumptions only when misclassification errors are 10% or less" and with misclassification errors of 15% or more, the effects of SNAP participation on obesity outcomes are no longer statistically significant.

III. Methods

This county-level study examines the obesity outcomes that result from variation in grocery store density, when controlling for SNAP participation as well as other factors that are potentially obesogenic. Based on the information available in FEA and from the supplemental CDC health data, I measure obesity outcomes as a percentage of total adult population in each county. Total adult population includes those who are 20 and older. I observe changes in the adult obesity rate and the age-adjusted obesity rate for two base years, 2010 and 2011. See Table 1 for the summary statistics of the different measures this study uses to predict obesity outcomes.

As mentioned, this study will primarily use data from FEA as well as some supplementary health data from the CDC. FEA includes data on food environment, SNAP participation, obesity outcomes, and sociodemographic characteristics of all counties across the U.S. ERS assembled the data in FEA from many different sources including the CDC, the National Cancer Institute, the USDA Agricultural Marketing Service, and the FNS among

others.[i] Data included in the set spans multiple years, from as early as 2000 to as late as 2013. Some data is only available for certain years and may not align with the years for which other data is available. Consequently, in this study, I will use data from different years, ranging from 2007 to 2011 for the most part. In some instances, this allows me to observe the lagged effects of certain variables on obesity outcomes. See Table 1 for sociodemographic summary statistics on income and race.

I will estimate iterations of the basic Ordinary Least Squares (OLS) models as follows:

(1) $OBESE_i = \beta_0 + \beta_1 GROCERY_i + \beta_2 SNAP_i + \beta_3 INCOME_i + \beta_4 RACE_i + \beta_5 FOODENVIRONMENT_i + u_i$

(2) $OBESE_i = \beta_0 + \beta_1 GROCERY_i + \beta_2 SNAP_i + \beta_3 GROCERY_i SNAP_i + \beta_4 INCOME_i + \beta_5 RACE_i + \beta_6 FOODENVIRONMENT_i + u_i$

where $OBESE_i$ corresponds with the adult obesity rate and age-adjusted obesity rate per county. $GROCERY_i$ is the measure of grocery store concentration. Specifically, it corresponds with the number of grocery stores in each county per 1,000 people. $SNAP_i$ is the measure of SNAP participation in terms of county SNAP benefits per capita. $INCOME_i$ comprises the variables that allow us to control for a county's socioeconomic profile. It includes the median household income and poverty rate per county. $RACE_i$ is the set of variables that allows us to control for a county's racial breakdown of white, black, Hispanic, and Asian members of the population. $FOODENVIRONMENT_i$ is the set of variables that allows us to determine the supplemental food environment in a given county. The food environment includes the number of

[i] Some food environment data is missing for certain counties in Alaska.

supercenter/warehouse clubs, convenience stores, specialized food stores, fast-food restaurants, and farmer's markets per 1,000 people. See Table 1 for food environment summary statistics across all counties represented in FEA in 2011 and 2007.

While Model (1) estimates the independent effects of grocery store density and SNAP participation on obesity outcomes, Model (2) estimates how they interact to impact obesity outcomes. This second model includes the term $GROCERY_i SNAP_i$, which represents the interaction effect.

IV. Results and Discussion

Table 2 displays the results of the first set of models I estimate. These models estimate the effects of grocery store density in 2007 on obesity outcomes in 2010 and 2011 with state-level fixed effects and robust standard errors clustered by state. All three models control for the effects of SNAP participation, income, race, and supplemental food environment. As mentioned, grocery store density is measured using the count of grocery stores per 1,000 people in each county. Obesity outcomes measure the prevalence of obesity for members of the population who are 20 years and older. The age-adjusted obesity rate for 2010 and 2011 is weighted by age. SNAP participation is measured in terms of SNAP benefits per capita for each county. Sociodemographic data is measured in 2010 whereas all food environment data is measured in 2007 except for farmer's market data, which is measured in 2009.[j] Table 1 displays the variable descriptions and summary statistics for all data included in these models. I use grocery and food environment data from 2007 because it is useful to observe any lagged effects on obesity outcomes a few years later, in 2010 and 2011. In other words, obesity outcomes may not

[j] 2009 is the only year available for farmer's market data. In designing these models, I make the assumption that the sociodemographic changes any county experiences between 2010 and 2011 are marginal. Because FEA: 2014 doesn't provide sociodemographic data at the county level for 2011, I use the most recent year available, 2010.

fluctuate instantaneously as a result of changes in grocery market concentration. It may take a few years to observe any effects of grocery store density on obesity outcomes. For comparison to these models, see Appendix Tables 3 and 4 for models that observe the effects of grocery store access and food environment in 2011 on obesity outcomes in 2011. It is noteworthy that even without a lagged effect, the negative effect of grocery store access on obesity outcomes is statistically significant and strong.

Table 3 displays the interaction effects between grocery store density and SNAP participation on obesity outcomes. The models here also control for state-level fixed effects and include robust standard errors, clustered by state. The first model displays results for the age-adjusted obesity rate in 2010 whereas the second and third models display results for the adult obesity rate in 2011 and the age-adjusted obesity rate in 2011, respectively. Grocery and food environment data for all three models come from 2007, except for 2009 farmer's market data. SNAP data and all sociodemographic data come from 2010. These models show whether the effect of grocery store density on obesity outcomes varies depending on the level of SNAP participation in a county.

The models in Table 2 indicate a statistically significant and strong negative relationship between the number of grocery stores per 1,000 people in the population and obesity outcomes. This association between increased access to grocery stores and lower obesity prevalence corroborates the findings of many past studies on the topic. Perhaps, increased access to grocery stores means that people in a given area have greater access to healthier, more nutritious foods and are less reliant upon other types of food retailers that stock less nutritious options. Most notably, convenience stores are an example of a retailer that often only carries shelf or packaged food options.

In Table 2, the first model suggests that the age-adjusted obesity rate in 2010 decreases by approximately .7850 percentage points with every unit increase in the number of grocery stores per 1,000 people in the county. The second model shows a .7059 percentage point decrease in 2011 adult obesity rate with every unit increase in grocery store count per 1,000 people whereas the third model shows a .5750 decrease in 2011 age-adjusted obesity rate with every unit increase in grocery store count per 1,000 people. The effect may be the strongest on average for obesity outcomes in 2010 because over time, other obesogenic factors may interact with grocery store concentration to impact observed obesity outcomes. For example, the effects of genetic predisposition towards obesity or higher weight outcomes as well as the effects of the surrounding food environment may be more pronounced with a greater lag. On another note, the discrepancy between obesity outcomes for adult obesity rate in 2011 and age-adjusted obesity rate in 2011 suggests that younger adults are less impacted by changes in grocery store count than older adults. This is because age-adjusted obesity rate is weighted most heavily for adults in the 20-44 age category or the youngest age category.

Additionally, the models in Tables 4 demonstrate a small positive and statistically significant association between SNAP benefits per capita and obesity outcomes in both 2010 and 2011. This corresponds with the results of past studies, which have suggested a positive correlation between SNAP participation and obesity outcomes. This indicates that food affordability alone may not induce healthy consumption, especially if individuals do not have access to food retailers such as grocery stores with options that enable health consumption. The positive association in this study may also be explained by the "food stamp cycle hypothesis" suggested by the literature whereby SNAP participants cycle between overeating after having just received their benefits at the beginning of the month and restricted eating as their benefits

dwindle by the end of the month. Within the field of psychology, literature on disordered eating such as the Field et al (2003) study of dieting behaviors have shown that continued cycling between periods of overeating and restricted eating often makes weight control difficult and contributes to weight gain.

Also of note is the strong positive relationship between supercenter/warehouse clubs and obesity outcomes in all both sets of models. Although this relationship is not statistically significant for the models in Tables 2 or 3, it aligns with what recent literature has indicated, such as the results of Courtemanche et al's study. Supercenters/warehouse clubs often offer food items in bulk at lower prices. However, the positive relationship between supercenter/warehouse club density and obesity outcomes indicates that food preferences may still cause certain households to choose less healthy, less nutritious options. Because supercenters/warehouse clubs frequently offer these options at lower prices and in larger quantities, consumption may increase. This would then increase the prevalence of obesity, all else equal.

The models in Table 2 and Table 3 display a positive relationship between convenience store count per 1,000 people and obesity outcomes. This relationship is statistically significant, often at the 1% level, for nearly every model and also aligns with what previous studies have found. Results from past literature such as the study from Bodor et al (2005) have indicated that increased access to convenience stores was correlated with increased obesity outcomes. This is due to the "energy-rich, snack foods" frequently offered at convenience stores, which can impact consumption. Additionally, convenience stores are often prevalent in areas that lack substantial access to grocery stores or food retailers that offer fresh, healthful products such as highly urban or highly rural areas. The correlation between convenience stores and obesity outcomes may further reflect how food access can impact consumption and weight, particularly for individuals

in low-access areas. Liese et al (2007) have found that food environments in rural areas included nearly five times as many convenience stores than supermarkets or grocery stores and there were proportionately more convenience stores in rural areas than in urban areas.

Both sets of models show a strong negative and statistically significant relationship between obesity outcomes and specialized food store count per 1,000 as well as fast food restaurant count per 1,000. Intuitively, this relationship makes sense for specialized food stores. By definition, these stores include bakeries, seafood/meat markets, and produce markets among others. As such, they often offer many varied, healthy food options, which could influence and improve consumption behaviors. However, this relationship intuitively does not make sense for fast-food restaurants, which typically serve more caloric, less nutritious foods. Many past studies have linked fast food restaurant access to higher weight outcomes. For example, Jeffery et al (2006) have found a positive association between eating at fast food restaurants and having children, a high fat diet, and a higher level of BMI for individuals in Minnesota. Additionally, they have found a negative relationship between fast food consumption and vegetable intake as well as physical exercise.

In this study, the negative association between fast food restaurant count per 1,000 people and obesity outcomes may result from a few different factors. First, fast food restaurant count does not necessarily indicate consumption and may only reflect market conditions for food retailers. Although there may be a high number of fast food restaurants in a given area, the population in that area may not necessarily be frequenting them. In fact, the same Jeffery et al study has shown that there was no relationship between fast food restaurant proximity to home and eating at fast food restaurants. The study also shows that there was no relationship between fast food restaurant proximity to home address and BMI, but that there was a significant negative

relationship for fast food restaurant proximity to work address and BMI for men in particular. Second, the fast food restaurants in a particular area tend to locate near schools, often within walking distance of campuses. If this is the case, we can make the assumption that the majority of fast food restaurant clientele are students and changes in access would most strongly impact those still in school or those associated with schools. Given the context of my study, this means that any variation in obesity resulting from access to fast food restaurants would not be captured in the obesity outcomes. This is because the measures of obesity in this study only capture those in the population who are 20 years or older. Third, FEA's definition of "fast food restaurant" may differ from what is traditionally thought. Often, fast food restaurants are thought of as providing limited menus with energy-dense, high caloric food options whereby patrons pay first before receiving their food. Restaurants like McDonald's, Taco Bell, or Burger King come to mind. However, FEA's designations for what constitute fast food restaurants are vague and may contribute to the discrepancy between this study's results and what is usually thought of the relationship between fast food access and weight outcomes. According to FEA, fast food restaurants provide "food services (except snack and nonalcoholic beverage bars) where patrons generally order or select items and pay before eating."[5] Because this FEA designation is so broad, it could reasonably include restaurants that have healthy, less caloric or energy-dense options on their menus. Increases in this type of "fast food" restaurant would intuitively lead to lower obesity prevalence.[k]

[k] These issues associated with interpreting the correlation between fast food restaurants and obesity outcomes would not generally apply to interpreting the correlation between grocery stores and obesity outcomes. This is because grocery stores stock significantly more numerous and more diverse options for food, thereby allowing for more variation in consumption. Additionally, because grocery stores may be more randomly distributed throughout residential areas, they likely serve a broader age range of clients, including adults whose weight outcomes would be captured by the adult obesity rates.

Table 3 shows how grocery store density and SNAP participation interact to impact obesity outcomes. The interaction effect between the two is negative and statistically significant for all three models in the table. The first model suggests that a unit increase in county-level grocery count per 1,000 people is correlated with a decrease in 2010 adult obesity rate if SNAP benefits per capita exceed approximately 11.6171 units. For all values greater than that, the marginal effect of grocery count on obesity outcomes will be negative. Conversely, the marginal effect of SNAP benefits per capita is negative if grocery count per 1,000 people exceeds 1.1970 units. If there were more than one grocery store per 1,000 people, any marginal increase in SNAP benefits per capita would lead to a decrease in obesity outcomes. For the 2011 adult obesity rate, the marginal effect of county-level grocery count per 1,000 people is negative if SNAP benefits per capita exceed 11.0899 units. The marginal effect of SNAP benefits per capita is negative if grocery count per 1,000 people exceeds 1.5377 units. Lastly, for the 2011 age-adjusted obesity rate, the marginal effect of grocery count per 1,000 people is negative if SNAP benefits per capita exceed 12.2535 units. The marginal effect of SNAP benefits per capita is negative if grocery count per 1,000 people exceeds 1.5640 units. Broadly speaking, these results indicate that the interaction of SNAP participation and grocery store density is correlated with lower obesity outcomes in areas of high participation and high density. The models in Table 3 suggest that access to grocery stores may not decrease weight outcomes if SNAP participation or food purchasing power is too low. Conversely, high SNAP participation may not lead to overall lower weight outcomes if access to grocery stores is too low.

V. Sensitivity Analysis

The models are designed to control for the effects of as many unobserved, exogenous factors as possible. Additional robustness checks ensure that the models do not suffer from misspecification and that the primary variable of interest, grocery store count, behaves consistently despite variation in model design. This study includes four main robustness checks to observe changes in the point estimate for grocery store count. The first three robustness checks respectively control for the effects of age-adjusted obesity rate in 2007, access to recreation/fitness centers in 2007, as well as the percentage of county households without a car and considered "low access" to the nearest grocery store or supermarket[l]. The last robustness check includes models that estimate how the effects of grocery store density differ in metropolitan and nonmetropolitan areas. These factors are all potentially correlated with the relevant obesity outcomes in 2010 and 2011. However, the primary models in this study do not specify for the effects of these factors because they are not explicitly related to either the primary variable of interest or the secondary variable of interest, SNAP benefits per capita.

Controlling for the age-adjusted obesity rate in 2007 may allow us to observe how access to grocery stores has impacted the change in obesity outcomes from the base year to 2010 and 2011. Table 4 shows that, when controlling for obesity outcomes in 2007, the effects of grocery store access become much weaker. Table 5 shows that the interaction effects between grocery store count and SNAP benefits per capita becomes weaker with the inclusion of obesity outcomes in 2007 in the models. These results indicate that obesity outcomes in the base year are predictive of obesity outcomes during later years, more so than other exogenous factors such as food environment or purchasing power.

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[l] Households without cars are considered low-access when they live more than a mile from a supermarket or large grocery store.

Controlling for access to recreation/fitness center may allow us to observe whether physical activity changes the effect that grocery store count has obesity outcomes. Access to recreation/fitness centers is the closest proxy for the level of physical activity in a given county because recreation/fitness centers such as gyms or YMCAs equip individuals with the facilities to exercise. These centers often include exercise equipment like machines or weights. FEA provides a measure of recreation/fitness center access in terms of count per 1,000 people in a given county.[m] Table 6 shows that the negative effect of grocery store access on obesity outcomes becomes slightly stronger when controlling for access to recreation/fitness centers. In both Tables 6 and 7, access to recreation/fitness centers has a large negative and statistically significant effect on obesity outcomes. This corresponds with what past studies have found in regards to the impact of recreation/fitness center access and subsequent physical activity on weight and obesity outcomes. For example, in a national study, Gordon-Larsen et al (2006) have found that increased presence of fitness facilities in census blocks was associated both with an increased likelihood of engaging in physical activity and a decreased prevalence of obesity outcomes.

The third robustness check controls for the percentage of households in each county without cars and that are considered low access to grocery stores or supermarkets in 2010. Low-access, no-car households may experience transportation barriers to shopping at local grocery stores and supermarkets and thus may do so less frequently than households with cars or that live closer to these food retailers. On average, approximately 23.5593% of households in a county do not have cars and are considered low-access. Table 8 shows that the effect of grocery store

[m] It is true that physical activity does not depend solely on access to facilities. For example, some individuals may exercise outdoors at or at home while others may remain physically active by frequently commuting by foot. However, recreation/fitness count per 1,000 people in each county is the only measure included in FEA that can estimate the effects of physical activity on obesity outcomes.

density becomes slightly weaker but moves in the same direction when controlling for this percentage. However, the effects of grocery store density on obesity outcomes in 2011 are not statistically significant. Table 9 shows that the interaction effect of grocery store density and SNAP benefits per capita becomes slightly stronger and moves in the same direction when the models control for low-access, no-car household percentage. The effects are statistically significant for all obesity outcomes in both years. Both Tables 8 and 9 display a slight negative relationship between the percentage of low-access, no-car households and obesity outcomes. Inagami et al (2006) have found that there was a positive association between BMI and car usage for individuals who lived far from grocery stores or supermarkets and must therefore travel longer distances to shop at these types of retailers. According to Inagami et al, this relationship may have occurred because "those who travel farther may purchase greater amounts of food in bulk, which has been associated with increased weight [outcomes]." However, this may not apply to low-access households that do not own cars, which could explain the relationship observed in Tables 8 and 9.

Lastly, Tables 10 and 11 display results for only metropolitan counties whereas Tables 12 and 13 display results for only nonmetropolitan counties. Though grocery store density effects change in magnitude and statistical significance from the initial models included in Tables 2 and 3, they continue to move in the same direction. First, Table 10 shows that the negative relationship between grocery store density and obesity outcomes becomes stronger and is no longer statistically significant when the sample only encompasses metropolitan counties. On the other hand, Table 12 shows that this relationship becomes weaker for a sample that is comprised only of nonmetropolitan counties. Here, the relationship between grocery store density and obesity outcomes is only statistically significant for 2010, at the 5% significance level. Second,

Table 11 shows that the interaction effect of grocery store density and SNAP benefits per capita becomes stronger and is consistently statistically significant at the 1% level for only metropolitan counties. Table 13 shows that the interaction effect is also consistently statistically significant at the 1% level for nonmetropolitan counties but becomes much weaker when the sample is limited as such. These results suggest that variation in grocery store density may have a stronger effect on obesity outcomes in metropolitan areas than in nonmetropolitan areas.

VI. Conclusion

This study finds that obesity outcomes are associated with access to and affordability of healthy food options as measured by grocery store density and SNAP participation. On the whole, the results indicate a negative relationship between grocery store count and obesity outcomes as well as a slight positive relationship between SNAP participation and obesity outcomes. However, when controlling for the interaction between grocery store count and SNAP participation, this study shows that neither access nor affordability alone influences lower weight outcomes, but that these two factors must both be present in order to do so.

The lag in time between food environment and obesity outcomes may enable us to consider the relationship between grocery store count and obesity outcomes as causal. First, the lag addresses potential endogeneity in the models. Measures of food environment are taken in 2007 for all models whereas measures of obesity outcomes are taken in 2010 and 2011. If the models estimated the relationship between food environment and obesity outcomes in the same year, reverse causality may have become an issue. This is because food retailers including grocery stores often base their decisions to locate in certain areas on the population at hand among other factors that would help them meet retail goals. For example, Powell et al (2007)

suggest a correlation between supermarket location and race as well as income. They find that lower-income neighborhoods have only 75% on average of the chain supermarkets available in middle-income neighborhoods. Additionally, predominantly African-American neighborhoods have 52% on average of the chain supermarkets available in predominantly white neighborhoods, with ever fewer available in urban areas. Because income and race both have the potential to influence weight outcomes, any bearing they have on grocery store location planning and subsequent access would cause endogeneity if the models measured food environment and obesity outcomes concurrently. Obesity outcomes may simply reflect how grocery stores choose to locate in areas with certain race or income demographics. Second, as mentioned previously, consumption-related effects of grocery store access may not manifest in obesity outcomes measured in the same year, even when controlling for the effects of exogenous factors. Because this is true, looking at the lagged effect of grocery store access on obesity outcomes may more appropriately allow for a casual interpretation of any correlation between the two. However, the results in Appendix Table 3 indicate that the effects of grocery store density on obesity outcomes measured concurrently move in the same direction and with a similar magnitude as the lagged effects.

Certain limitations of the data and model design may make it difficult to establish a truly causal relationship between grocery store density and obesity outcomes. All data is measured at the county level and is therefore unable to capture more granular variation in food environment or obesity outcomes. Moreover, the FEA designations for what constitute certain types of food retailers are so broad that it is difficult to determine the specific characteristics of each type that may contribute to obesity outcomes. Further studies may wish to use data that is similarly comprehensive in terms of scope but also operates at a more granular level and more specifically

delineates between types of food retailers. In terms of model design, the association between grocery store count and obesity outcomes may fall short of truly causal for two reasons. First, omitted variable bias may still exist despite efforts to control for as many exogenous and potentially obesogenic factors as possible. The data available in FEA does not allow the models in this study to control for obesogenic factors such as genetic predisposition towards obesity as well as pricing or quantity purchased of certain foods. These factors among others that are not included in the models may influence consumption behaviors and therefore drive obesity outcomes. Second, there may be an endogeneity problem resulting from reverse causality between grocery store count as the primary variable of interest and obesity outcomes, despite previously mentioned efforts to address this with a lagged effect. Some past studies have attempted to address reverse causality between measures of food environment and obesity outcomes by using an instrumental variables approach. For example, Courtemanche et al (2015) have instrumented for the effects of supercenter/warehouse club density and restaurant density using measures of distance from Bentonville, Arkansas and the count of interstate exits per 10,000 residents in a given state.[n] However, FEA does not include measures of any data that would serve as appropriate instruments for the measures of grocery count in this study. Thus, an instrumental variables approach is not a feasible method of addressing potential reverse causality.

Despite possible limitations in data and model design, this study contributes to the public understanding of food access and affordability in two ways. First, its findings corroborate those of previous studies that have found an association between grocery store density and obesity outcomes. Because this study uses county-level data for all states, it provides a more

[n] Courtemanche et al choose to measure distance from Bentonville, Arkansas because Wal-Mart, a prominent supermarket/warehouse club chain, is headquartered there.

comprehensive, macro-level examination of the research questions than many of those currently found in the existing body of literature. Second, this study provides suggestive and novel evidence that government agencies ought to consider how food access and affordability as measured primarily by grocery store environment and SNAP participation jointly impact obesity outcomes. Because healthful and adequate consumption is the ultimate goal of government policies relating to food access and assistance, obesity outcomes are a relevant measure of their efficacy. With an understanding of how access and affordability interact to affect obesity in certain areas, government agencies may be able to create new policies or improve current ones. This would enable them to more efficiently serve low-access, low-resource populations.

VII. Works Cited

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VIII. Tables

Table 1. Variable Descriptions and Summary Statistics

Variable	Description	Mean (Std. Deviation)	Min	Max	N
Age-Adjusted Obesity Rate (2007)*	Estimated percentage of persons aged 20 and older whose BMIs exceed 30; weighted for age	25.1978	12.3	37.9	3141
Age-Adjusted Obesity Rate (2010)	Estimated percentage of persons aged 20 and older whose BMIs exceed 30; weighted for age	30.5540 (4.2421)	13.1	47.9	3138
Adult Obesity Rate (2011)*	Estimated percentage of persons aged 20 and older whose BMIs exceed 30	30.6923 (4.3396)	12	48.1	3143
Age-Adjusted Obesity Rate (2011)*	Estimated percentage of persons aged 20 and older whose BMIs exceed 30; weighted for age	30.5598 (4.4360)	12	48.5	3143
Grocery (2007)	The number of supermarkets and grocery stores in a county per 1,000 residents	.2873 (.2425)	0	3.2311	3138
SNAP (2010)	The average monthly dollar amount of SNAP divided by the county population	19.4988 (9.8555)	.2190	93.8687	2753
Median HH Income (2010)	Median income by household	43144.87 (10742.29)	20577	119075	3142
Poverty Rate (2010)	Percentage of county residents with household income below the poverty threshold	16.7612 (6.2428)	3.1	50.1	3142
White (2010)	Percentage of county resident population that is non-Hispanic white	78.2947 (19.8882)	2.6679	99.1632	3143
Black (2010)	Percentage of county resident population that is non-Hispanic black or African American	8.7486 (14.4214)	0	85.4388	3143
Asian (2010)	Percentage of county resident	1.1367 (2.4698)	0	43.0147	3143

Hispanic (2010)	Percentage of county resident population that is of Hispanic origin	8.2837 (13.1909)	0	95.7448	3143
Supermarket/Warehouse (2007)	The number of supermarket/warehouse clubs selling generalized merchandise and food in a county per 1,000 residents	.0101 (.0175)	0	.2614	3138
Convenience Store (2007)	The number of convenience stores, with or without gasoline sales, in a county per 1,000 residents	.6407 (.3267)	0	4.8077	3138
Specialized Food Store (2007)	The number of specialized food stores in a county per 1,000 residents	.0663 (.0863)	0	1.2739	3138
Fast Food (2007)	The number of fast food restaurants in a county per 1,000 residents	.5920 (.3176)	0	6.9686	3138
Farmer's Market (2009)	The number of farmer's markets in a county per 1,000 residents	.03598 (.0702)	0	1.0199	3137
Population Estimate (2007)	Total resident population per county	95952.88 (308699.1)	54	9734701	3143
Recreation/Fitness (2007)	The number of recreation and fitness facilities in a county per 1,000 residents	.0869 (.0900)	0	1.4933	3141
Households, No Car and Low Access (2010)	The number of housing units in a county without a car and more than 1 mile from a supermarket or large grocery store.	25.5593 (20.2502)	0	100	3143
Metropolitan, Nonmetropolitan (2010)	Classification of counties by metro or nonmetro definition where metro areas include all counties containing one or more high-density urban areas with more than 50,000 people/ Nonmetro counties are outside the boundaries of metro areas and have no cities with 50,000 residents or more.	n/a	0	1	1167, 1976

Source: FEA (data and accompanying variable descriptions)

*This data comes from supplemental health data available on the CDC website.

Table 2. Impact of Grocery Store Density (2007) on Obesity Outcomes

	(1) Age-Adjusted Obesity Rate, 2010	(2) Adult Obesity Rate, 2011	(3) Age-Adjusted Obesity Rate, 2011
Grocery	-0.7850***	-0.7059**	-0.5750
	(0.2738)	(0.3468)	(0.3433)
SNAP	0.0760***	0.0926***	0.0895***
	(0.0203)	(0.0180)	(0.0173)
Income Effects			
Median HH Income	-0.0001***	-0.0001***	-0.0001***
	(0.0000)	(0.0000)	(0.0000)
Poverty Rate	-0.0571	-0.0802**	-0.0773**
	(0.0341)	(0.0311)	(0.0307)
Race			
White	-0.0558***	-0.0399**	-0.0375**
	(0.0199)	(0.0187)	(0.0174)
Black	0.0317	0.0459**	0.0448**
	(0.0196)	(0.0186)	(0.0176)
Asian	-0.2558**	-0.2446**	-0.2176*
	(0.1129	(0.1208)	(0.1144)
Hispanic	-0.0631***	-0.0499**	-0.0502***
	(0.0205)	(0.0187)	(0.0179)
Food Environment			
Supercenter/Warehouse	3.6572	1.9635	2.3991
	(3.0921)	(2.9478)	(3.1569)
Convenience Store	0.4347*	0.7978***	0.7853***
	(0.2214)	(0.2368)	(0.2299)
Specialized Food Store	-2.6502***	-3.1871***	-3.1205***
	(0.9548)	(0.9261)	(0.9180)
Fast Food	-1.1812***	-1.3236***	-1.3007***
	(0.2465)	(0.2521)	(0.2625)
Farmer's Market	-1.2957	-1.6958*	-1.9905*
	(0.9192)	(0.9918)	(1.0060)
R^2	.6711	.6592	.6662
N	2,753	2,753	2,753

Note: Robust standard errors, clustered by state, are in parentheses. This model includes state-level fixed effects.

* $p<0.1$; ** $p<0.05$; *** $p<0.01$

Table 3. Interaction Effects of Grocery Store Density (2007) and SNAP Participation on Obesity Outcomes

	(1) Age-Adjusted Obesity Rate, 2010	(2) Adult Obesity Rate, 2011	(3) Age-Adjusted Obesity Rate, 2011
Grocery	1.1501**	0.9260**	0.9668**
	(0.5212)	(0.4079)	(0.3936)
SNAP	0.1185***	0.1284***	0.1234***
	(0.0167)	(0.0166)	(0.0161)
Interaction: Grocery, SNAP	-0.0990***	-0.0835***	-0.0789***
	(0.0112)	(0.0135)	(0.0128)
Income			
Median HH Income	-0.0001***	-0.0001***	-0.0001***
	(0.0000)	(0.0000)	(0.0000)
Poverty Rate	-0.0600*	-0.0826**	-0.0797**
	(0.0334)	(0.0310)	(0.0307)
Race			
White	-0.0659***	-0.0485***	-0.0456***
	(0.0155)	(0.0160)	(0.0151)
Black	0.0199	0.0360**	0.0354**
	(0.0145)	(0.0156)	(0.0151)
Asian	-0.2828***	-0.2673**	-0.2391**
	(0.1020)	(0.1134)	(0.1078)
Hispanic	-0.0735***	-0.0587***	-0.0585***
	(0.0166)	(0.0164)	(0.0160)
Food Environment			
Supercenter/Warehouse	3.9125	2.1789	2.6025
	(2.8880)	(2.7331)	(2.9507)
Convenience Store	0.3561	0.7315***	0.7227***
	(0.2422)	(0.2520)	(0.2446)
Specialized Food Store	-2.7029***	-3.2316***	-3.1625***
	(0.9391)	(0.9058)	(0.9008)
Fast Food	-1.2012***	-1.3405***	-1.3167***
	(0.2389)	(0.2490)	(0.2584)
Farmer's Market	-1.5169	-1.8824*	-2.1667**
	(0.9499)	(1.0180)	(1.0306)
R^2	0.68	0.66	0.67
N	2,753	2,753	2,753

Note: Robust standard errors, clustered by state, are in parentheses. This model includes state-level fixed effects.

* $p<0.1$; ** $p<0.05$; *** $p<0.01$

Table 4. Robustness Check: Impact of Grocery Store Density (2007) on Obesity Outcomes (With Controls for Base Obesity Outcomes in 2007)

	(1) Age-Adjusted Obesity Rate, 2010	(2) Adult Obesity Rate, 2011	(3) Age-Adjusted Obesity Rate, 2011
Age-Adjusted Obesity, 2007	0.7050***	0.7088***	0.7074***
	(0.0585)	(0.0655)	(0.0658)
Grocery	-0.5971***	-0.5169*	-0.3864
	(0.1895)	(0.2702)	(0.2629)
SNAP	0.0438**	0.0603***	0.0572***
	(0.0172)	(0.0156)	(0.0150)
Income Effects			
Median HH Income	-0.0000***	-0.0000***	-0.0001***
	(0.0000)	(0.0000)	(0.0000)
Poverty Rate	-0.0343	-0.0573**	-0.0545
	(0.0277)	(0.0253)	-0.0545
Race			
White	-0.0130	0.0031	0.0054
	(0.0139)	(0.0133)	(0.0122)
Black	0.0136	0.0278**	0.0267**
	(0.0133)	(0.0128)	(0.0122)
Asian	-0.1275*	-0.1156	-0.0889
	(0.0739)	(0.0823)	(0.0755)
Hispanic	-0.0162	-0.0027	-0.0031
	(0.0143)	(0.0127)	(0.0121)
Food Environment			
Supercenter/Warehouse	3.8527	2.1601	2.5953
	(2.3701)	(2.1210)	(2.2624)
Convenience Store	0.1841	0.5458***	0.5339***
	(0.1475)	(0.1536)	(0.1448)
Specialized Food Store	-1.9184**	-2.4513***	-2.3861***
	(0.8058)	(0.8665)	(0.8656)
Fast Food	-0.7342***	-0.8742***	-0.8523***
	(0.1605)	(0.1729)	(0.1831)
Farmer's Market	-0.8452	-1.2429	-1.5384*
	(0.8363)	(0.8618)	(0.8670)
R^2	0.73	0.72	0.72
N	2,753	2,753	2,753

Note: Robust standard errors, clustered by state, are in parentheses. This model includes state-level fixed effects.

- $p<0.1$; ** $p<0.05$; *** $p<0.01$

Table 5. Robustness Check: Interaction Effect of Grocery Store Density (2007) and SNAP Participation on Obesity Outcomes (With Controls for Base Obesity Outcomes in 2007)

	(1) Age-Adjusted Obesity Rate, 2010	(2) Adult Obesity Rate, 2011	(3) Age-Adjusted Obesity Rate, 2011
Age-Adjusted Obesity, 2007	0.6884***	0.6961***	0.6958***
	(0.0572)	(0.0649)	(0.0654)
Grocery	0.7443*	0.5157*	0.5567**
	(0.3735)	(0.2855)	(0.2723)
SNAP	0.0741***	0.0836***	0.0785***
	(0.0163)	(0.0164)	(0.0158)
Interaction: Grocery, SNAP	-0.0689***	-0.0530***	-0.0484***
	(0.0097)	(0.0141)	(0.0133)
Income Effects			
Median HH Income	-0.0000***	-0.0000***	-0.0001***
	(0.0000)	(0.0000)	(0.0000)
Poverty Rate	-0.0368	-0.0593**	-0.0563**
	(0.0276)	(0.0256)	(0.0249)
Race			
White	-0.0210*	-0.0031	-0.0003
	(0.0112)	(0.0122)	(0.0115)
Black	0.0059	0.0219*	0.0212*
	(0.0109)	(0.0120)	(0.0117)
Asian	-0.1493**	-0.1324*	-0.1042
	(0.0658)	(0.0785)	(0.0724)
Hispanic	-0.0245**	-0.0091	-0.0090
	(0.0119)	(0.0117)	(0.0116)
Food Environment			
Supercenter/Warehouse	4.0257*	2.2933	2.7169
	(2.3134)	(2.0492)	(2.1878)
Convenience Store	0.1353	0.5082***	0.4995***
	(0.1579)	(0.1581)	(0.1492)
Specialized Food Store	-1.9722**	-2.4927***	-2.4240***
	(0.8035)	(0.8600)	(0.8606)
Fast Food	-0.7587***	-0.8930***	-0.8694***
	(0.1559)	(0.1724)	(0.1813)
Farmer's Market	-1.0095	-1.3694	-1.6540
	(0.8545)	(0.8811)	(0.8847)*
R^2	0.73	0.72	0.72
N	2,753	2,753	2,753

Note: Robust standard errors, clustered by state, are in parentheses. This model includes state-level fixed effects.

- $p<0.1$; ** $p<0.05$; *** $p<0.01$

Table 6. Robustness Check: Impact of Grocery Store Density (2007) on Obesity Outcomes (With Controls for Recreation/Fitness Access in 2007)

	(1) Age-Adjusted Obesity Rate, 2010	(2) Adult Obesity Rate, 2011	(3) Age-Adjusted Obesity Rate, 2011
Grocery	-0.8168***	-0.7385**	-0.6066*
	(0.2787)	(0.3513)	(0.3486)
SNAP	0.0763***	0.0929***	0.0898***
	(0.0199)	(0.0176)	(0.0170)
Recreation/Fitness	-2.9749***	-3.0523***	-2.9562***
	(0.7968)	(0.8532)	(0.8536)
Income Effects			
Median HH Income	-0.0001***	-0.0001***	-0.0001***
	(0.0000)	(0.0000)	(0.0000)
Poverty Rate	-0.0580*	-0.0811**	-0.0783**
	(0.0336)	(0.0307)	(0.0303)
Race			
White	-0.0539***	-0.0381**	-0.0357**
	(0.0197)	(0.0185)	(0.0172)
Black	0.0334*	0.0477**	0.0465**
	(0.0194)	(0.0183)	(0.0174)
Asian	-0.2576**	-0.2464**	-0.2193*
	(0.1122)	(0.1202)	(0.1138)
Hispanic	-0.0621***	-0.0489**	-0.0492***
	(0.0203)	(0.0186)	(0.0178)
Food Environment			
Supercenter/Warehouse	4.4728	2.8004	3.2096
	(3.0727)	(3.0134)	(3.2478)
Convenience Store	0.4087*	0.7711***	0.7594***
	(0.2287)	(0.2404)	(0.2334)
Specialized Food Store	-2.5129***	-3.0463***	-2.9841)***
	(0.8746)	(0.8531)	(0.8425
Fast Food	-1.0258***	-1.1642***	-1.1464***
	(0.2394)	(0.2525)	(0.2640)
Farmer's Market	-0.8324	-1.2204	-1.5301
	(1.0523)	(0.9604)	(0.9737)
R^2	0.67	0.66	0.67
N	2,753	2,753	2,753

Note: Robust standard errors, clustered by state, are in parentheses. This model includes state-level fixed effects.

- $p<0.1$; ** $p<0.05$; *** $p<0.01$

Table 7. Robustness Check: Interaction Effect of Grocery Store Density (2007) and SNAP Participation on Obesity Outcomes (With Controls for Recreation/Fitness Access in 2007)

	(1) Age-Adjusted Obesity Rate, 2010	(2) Adult Obesity Rate, 2011	(3) Age-Adjusted Obesity Rate, 2011
Grocery	1.0712**	0.8442**	0.8875**
	(0.5248)	(0.4122)	(0.3994)
SNAP	0.1177***	0.1276***	0.1225***
	(0.0164)	(0.0162)	(0.0157)
Recreation/Fitness	-2.8071***	-2.9117***	-2.8234***
	(0.7830)	(0.8464)	(0.8475)
Interaction: Grocery, SNAP	-0.0965***	-0.0809***	-0.0764***
	(0.0111)	(0.0131)	(0.0124)
Income Effects			
Median HH Income	-0.0001***	-0.0001***	-0.0001***
	(0.0000)	(0.0000)	(0.0000)
Poverty Rate	-0.0608*	-0.0835***	-0.0805**
	(0.0330)	(0.0307)	(0.0303)
Race			
White	-0.0639***	-0.0464***	-0.0436***
	(0.0154)	(0.0159)	(0.0150)
Black	0.0218	0.0380**	0.0373**
	(0.0144)	(0.0155)	(0.0150)
Asian	-0.2838***	-0.2684**	-0.2401**
	(0.1014)	(0.1129)	(0.1073)
Hispanic	-0.0723***	-0.0574***	-0.0573***
	(0.0166)	(0.0164)	(0.0161)
Food Environment			
Supercenter/Warehouse	4.6757	2.9705	3.3702
	(2.8845)	(2.8212)	(3.0623)
Convenience Store	0.3335	0.7080***	0.7000***
	(0.2496)	(0.2560)	(0.2485)
Specialized Food Store	-2.5721***	-3.0959***	-3.0309***
	(0.8598)	(0.8332)	(0.8260)
Fast Food	-1.0541***	-1.1880***	-1.1688***
	(0.2315)	(0.2490)	(0.2594)
Farmer's Market	-1.0741	-1.4231	-1.7214*

	(1.0729)	(0.9933)	(1.0051)
R^2	0.68	0.67	0.67
N	2,753	2,753	2,753

Note: Robust standard errors, clustered by state, are in parentheses. This model includes state-level fixed effects.

- $p<0.1$; ** $p<0.05$; *** $p<0.01$

Table 8. Robustness Check: Impact of Impact of Grocery Store Density (2007) on Obesity Outcomes (With Controls for Percentage of Low-Access, No-Car Households in 2010)

	(1) Age-Adjusted Obesity Rate, 2010	(2) Adult Obesity Rate, 2011	(3) Age-Adjusted Obesity Rate, 2011
Grocery	-0.6407**	-0.5631	-0.4321
	(0.2798)	(0.3548)	(0.3500)
SNAP	0.0717***	0.0884***	0.0852***
	(0.0208)	(0.0185)	(0.0177)
Low-Access, No-Car	-0.0098**	-0.0096**	-0.0097**
	(0.0043)	(0.0043)	(0.0041)
Income Effects			
Median HH Income	-0.0001***	-0.0001***	-0.0001***
	(0.0000)	(0.0000)	(0.0000)
Poverty Rate	-0.0569*	-0.0800**	-0.0772**
	(0.0335)	(0.0307)	(0.0302)
Race			
White	-0.0590***	-0.0432**	-0.0408**
	(0.0189)	(0.0181)	(0.0169)
Black	0.0305	0.0448**	0.0437**
	(0.0191)	(0.0183)	(0.0173)
Asian	-0.2622**	-0.2509**	-0.2240*
	(0.1093)	(0.1172)	(0.1109)
Hispanic	-0.0654***	-0.0521***	-0.0525***
	(0.0199)	(0.0184)	(0.0176)
Food Environment			
Supercenter/Warehouse	3.9771	2.2800	2.7160
	(3.0865)	(2.9503)	(3.1535)
Convenience Store	0.4621**	0.8248***	0.8124***
	(0.2190)	(0.2370)	(0.2302)
Specialized Food Store	-2.7118***	-3.2481***	-3.1815***
	(0.9864)	(0.9407)	(0.9314)
Fast Food	-1.1994***	-1.3416***	-1.3188***
	(0.2486)	(0.2567)	(0.2651)
Farmer's Market	-1.2379	-1.6387	-1.9333

R^2	0.67	0.66	0.67
N	2,753	2,753	2,753

* $p<0.1$; ** $p<0.05$; *** $p<0.01$

Table 9. Robustness Check: Interaction Effect of Grocery Store Density (2007) and SNAP Participation on Obesity Outcomes (With Controls for Percentage of Low-Access, No-Car Households in 2010)

	(1) Age-Adjusted Obesity Rate, 2010	(2) Adult Obesity Rate, 2011	(3) Age-Adjusted Obesity Rate, 2011
Grocery	1.3721***	1.1420***	1.1820***
	(0.4747)	(0.3746)	(0.3608)
SNAP	0.1150***	0.1250***	0.1199***
	(0.0167)	(0.0169)	(0.0163)
Low-Access, No-Car	-0.0110***	-0.0107***	-0.0107***
	(0.0039)	(0.0038)	(0.0037)
Interaction: Grocery, SNAP	-0.1021***	-0.0865***	-0.0819***
	(0.0107)	(0.0152)	(0.0145)
Income Effects			
Median HH Income	-0.0001***	-0.0001***	-0.0001***
	(0.0000)	(0.0000)	(0.0000)
Poverty Rate	-0.0599*	-0.0826***	-0.0796**
	(0.0327)	(0.0305)	(0.0301)
Race			
White	-0.0699***	-0.0523***	-0.0495***
	(0.0150)	(0.0158)	(0.0150)
Black	0.0183	0.0344**	0.0338**
	(0.0143)	(0.0157)	(0.0152)
Asian	-0.2909***	-0.2752**	-0.2470**
	(0.0988)	(0.1101)	(0.1046)
Hispanic	-0.0764***	-0.0615***	-0.0613***
	(0.0165)	(0.0165)	(0.0162)
Food Environment			
Supercenter/Warehouse	4.2811	2.5375	2.9598
	(2.8664)	(2.7222)	(2.9327)
Convenience Store	0.3845	0.7591***	0.7502***
	(0.2353)	(0.2491)	(0.2420)
Specialized Food Store	-2.7740***	-3.3008***	-3.2314***
	(0.9726)	(0.9190)	(0.9129)

Fast Food	-1.2224***	-1.3611***	-1.3372***
	(0.2419)	(0.2543)	(0.2613)
Farmer's Market	-1.4585	-1.8255*	-2.1102*
	(0.9586)	(1.0471)	(1.0624)
R^2	0.68	0.67	0.67
N	2,753	2,753	2,753

* $p<0.1$; ** $p<0.05$; *** $p<0.01$

Table 10. Robustness Check: Impact of Impact of Grocery Store Density (2007) on Obesity Outcomes (Metro Counties)

	(1) Age-Adjusted Obesity Rate, 2010	(2) Adult Obesity Rate, 2011	(3) Age-Adjusted Obesity Rate, 2011
Grocery	-2.3740	-2.5613	-2.5319
	(1.8242)	(1.6195)	(1.5966)
SNAP	0.1622***	0.1905***	0.1849***
	(0.0280)	(0.0246)	(0.0245)
Income Effects			
Median HH Income	-0.0001**	-0.0001***	-0.0001***
	(0.0000)	(0.0000)	(0.0000)
Poverty Rate	-0.1365***	-0.1740***	-0.1578***
	(0.0486)	(0.0445)	(0.0430)
Race			
White	-0.0871***	-0.0403	-0.0351
	(0.0287)	(0.0261)	(0.0272)
Black	-0.0124	0.0270	0.0285
	(0.0290)	(0.0256)	(0.0266)
Asian	-0.3548***	-0.3085***	-0.2817**
	(0.1102)	(0.1102)	(0.1058)
Hispanic	-0.1097***	-0.0673***	-0.0633**
	(0.0274)	(0.0233)	(0.0245)
Food Environment			
Supercenter/Warehouse	3.8089	9.4045	8.9286
	(8.6619)	(8.2054)	(8.7579)
Convenience Store	2.5957***	3.3902***	3.2818***
	(0.8468)	(0.7878)	(0.7757)
Specialized Food Store	-7.2867***	-5.7225**	-5.8683**
	(2.5258)	(2.3006)	(2.2574)
Fast Food	-1.5360*	-2.0163***	-1.8898**
	(0.7699)	(0.6995)	(0.7140)

Farmer's Market	1.2520	1.9941	1.8629
	(2.5623)	(2.5882)	(2.5684)
R^2	0.69	0.69	0.69
N	1,058	1,058	1,058

* $p<0.1$; ** $p<0.05$; *** $p<0.01$

Table 11. Robustness Check: Interaction Effect of Grocery Store Density (2007) and SNAP Participation on Obesity Outcomes (Metro Counties)

	(1) Age-Adjusted Obesity Rate, 2010	(2) Adult Obesity Rate, 2011	(3) Age-Adjusted Obesity Rate, 2011
Grocery	5.7688**	4.5071*	4.2874*
	(2.7802)	(2.4931)	(2.4658)
SNAP	0.2803***	0.2931***	0.2838***
	(0.0336)	(0.0365)	(0.0363)
Interaction: Grocery, SNAP	-0.4839***	-0.4200***	-0.4052***
	(0.1092)	(0.1098)	(0.1073)
Income Effects			
Median HH Income	-0.0001**	-0.0001**	-0.0001***
	(0.0000)	(0.0000)	(0.0000)
Poverty Rate	-0.1331***	-0.1711***	-0.1549***
	(0.0459)	(0.0427)	(0.0413)
Race			
White	-0.0424*	-0.0015	0.0023
	(0.0236)	(0.0299)	(0.0313)
Black	0.0343	0.0675**	0.0676**
	(0.0251)	(0.0299)	(0.0310)
Asian	-0.2972***	-0.2584**	-0.2334**
	(0.0971)	(0.1025)	(0.0989)
Hispanic	-0.0676***	-0.0307	-0.0281
	(0.0249)	(0.0281)	(0.0294)
Food Environment			
Supercenter/Warehouse	4.5903	10.0828	9.5830
	(8.5726)	(8.1044)	(8.6556)
Convenience Store	2.3888***	3.2107***	3.1086***
	(0.7300)	(0.7044)	(0.6970)
Specialized Food Store	-6.9217***	-5.4057**	-5.5626**
	(2.5162)	(2.2758)	(2.2265)
Fast Food	-1.8882	-2.3220	-2.1848

	(0.5543)***	(0.5045)***	(0.5261)***
Farmer's Market	-0.7037	0.2964	0.2250
	(2.5763)	(2.8248)	(2.8360)
R^2	0.70	0.70	0.70
N	1,058	1,058	1,058

* $p<0.1$; ** $p<0.05$; *** $p<0.01$

Table 12. Robustness Check: Impact of Impact of Grocery Store Density (2007) on Obesity Outcomes (Nonmetro Counties)

	(1) Age-Adjusted Obesity Rate, 2010	(2) Adult Obesity Rate, 2011	(3) Age-Adjusted Obesity Rate, 2011
Grocery	-0.4649**	-0.3947	-0.3019
	(0.1899)	(0.2679)	(0.2680)
SNAP	0.0535**	0.0651***	0.0628***
	(0.0211)	(0.0175)	(0.0165)
Income Effects			
Median HH Income	-0.0001*	-0.0001**	-0.0001***
	(0.0000)	(0.0000)	(0.0000)
Poverty Rate	-0.0320	-0.0584*	-0.0653**
	(0.0300)	(0.0300)	(0.0307)
Race			
White	-0.0682***	-0.0586***	-0.0570***
	(0.0193)	(0.0184)	(0.0170)
Black	0.0267	0.0437**	0.0413**
	(0.0173)	(0.0167)	(0.0160)
Asian	-0.0039	0.0288	0.0338
	(0.0681)	(0.0773)	(0.0732)
Hispanic	-0.0660***	-0.0555***	-0.0581***
	(0.0186)	(0.0183)	(0.0173)
Food Environment			
Supercenter/Warehouse	4.1374	1.2033	1.7773
	(3.1018)	(2.9213)	(3.0415)
Convenience Store	-0.0360	0.2326*	0.2233
	(0.1407)	(0.1318)	(0.1354)
Specialized Food Store	-1.5467*	-2.3370**	-2.2191**
	(0.7934)	(0.8788)	(0.8984)
Fast Food	-0.7904***	-0.8329***	-0.8431***
	(0.1377)	(0.1431)	(0.1497)
Farmer's Market	-1.6682*	-2.1377**	-2.4459**
	(0.8825)	(0.9956)	(1.0165)
R^2	0.70	0.68	0.68

N	1,695	1,695	1,695

* $p<0.1$; ** $p<0.05$; *** $p<0.01$

Table 13. Robustness Check: Interaction Effect of Grocery Store Density (2007) and SNAP Participation on Obesity Outcomes (Nonmetro Counties)

	(1) Age-Adjusted Obesity Rate, 2010	(2) Adult Obesity Rate, 2011	(3) Age-Adjusted Obesity Rate, 2011
Grocery	0.7822*	0.5563	0.5782*
	(0.4535)	(0.3423)	(0.3315)
SNAP	0.0833***	0.0878***	0.0838***
	(0.0210)	(0.0189)	(0.0178)
Interaction: Grocery, SNAP	-0.0636***	-0.0485***	-0.0449***
	(0.0124)	(0.0129)	(0.0118)
Income Effects			
Median HH Income	-0.0000*	-0.0001**	-0.0001***
	(0.0000)	(0.0000)	(0.0000)
Poverty Rate	-0.0363	-0.0616**	-0.0683**
	(0.0284)	(0.0297)	(0.0306)
Race			
White	-0.0741***	-0.0631***	-0.0612***
	(0.0167)	(0.0173)	(0.0161)
Black	0.0198	0.0384**	0.0364**
	(0.0142)	(0.0155)	(0.0151)
Asian	-0.0524	-0.0082	-0.0005
	(0.0562)	(0.0777)	(0.0732)
Hispanic	-0.0714***	-0.0596***	-0.0620***
	(0.0165)	(0.0175)	(0.0167)
Food Environment			
Supercenter/Warehouse	4.2534	1.2918	1.8591
	(2.9823)	(2.8253)	(2.9506)
Convenience Store	-0.0882	0.1928	0.1864
	(0.1720)	(0.1553)	(0.1562)
Specialized Food Store	-1.5647*	-2.3507**	-2.2318**
	(0.7810)	(0.8683)	(0.8898)
Fast Food	-0.7844***	-0.8284***	-0.8389***
	(0.1372)	(0.1460)	(0.1521)
Farmer's Market	-1.7988*	-2.2372**	-2.5380**
	(0.9114)	(0.9985)	(1.0198)
R^2	0.70	0.68	0.69

N	1,695	1,695	1,695

* $p<0.1$; ** $p<0.05$; *** $p<0.01$

IX. Appendix

Table 1. Income Thresholds for Household SNAP Eligibility, 2015

Household Size	Gross Monthly Income (130% of poverty) in dollars	Net Monthly Income (100% of poverty) in dollars
1	1265	973
2	1705	1311
3	2144	1650
4	2584	1988
5	3024	2326
6	3464	2665
7	3904	3003
8	4344	3341
Each additional member	+440	+339

Source: USDA: FNS

The FNS stipulates that households must pass the threshold tests for gross monthly income (total income, before any allowable deductions) and net monthly income (total income, minus any allowable deductions); however, this excludes households in two cases. First, households where all members receive other forms of government aid – Temporary Assistance for Needy Families (TANF), Supplemental Security Income (SSI), etc. – do not have to meet income tests. Second, households with an elderly member or a disabled member currently claiming disability payments do not have to meet the gross monthly income test.[6]

To pass the resource test, households may not have more than $2,250 in "countable" assets (excluding "house and lot" and, in some states, the household's primary vehicle). However, a higher resource threshold of $3,250 applies to households with at least one disabled or elderly member (60 ages or older). Additionally, the FNS specifies that this test excludes any

household resources from TANF, SSI, and most retirement/pension plans. Certain states have specialized rules regarding the resource test.[7]

Table 2. Maximum Monthly SNAP Allotment per Household Size, 2015

People in Household	Maximum Monthly Allotment
1	194
2	357
3	511
4	649
5	771
6	925
7	1022
8	1169
Each additional person	146

Source: USDA: FNS

Table 3. The Effects of Grocery Store Density (2011) on Obesity Outcomes in 2011

	(1) Adult Obesity Rate	(2) Age-Adjusted Obesity Rate
Grocery	-1.4194***	-1.3162***
	(.3132)	(.3180)
SNAP	.0929***	.0821***
	(.0114)	(.0115)
Income Effects		
Median HH Income	-.0001***	-.0001***
	(.0000)	(.0000)
Poverty Rate	-.1037***	-.0235***
	(.0232)	(.0095)
Race		
White	-.0383***	-.0399***
	(.0089)	(.0090)
Black	.0449***	.0442***
	(.0087)	(.0088)
Hispanic	-.0977***	-.0978***
	(.0094)	(.0095)
Asian	-.2871***	-.2722***
	(.0298)	(.0302)
Food Environment		
Supercenter/Warehouse	8.5610***	9.6708***
	(3.0960)	(3.1435)
Convenience Store	.3098	.3390
	(.2266)	(.2308)
Specialized Food Store	-5.3496***	-5.5739***
	(.8894)	(.9031)
Fast Food	-1.9778***	-1.9437***
	(.2294)	(.2329)
Farmer's Market	-.8819	-1.2763
	(.9516)	(.9662)
Observations	2753	2753
R-squared	.4724	.4797
Adjusted R-squared	.4699	.4772

Note: Robust standard errors, clustered by state, are in parentheses. This model includes state-level fixed effects.

* $p<0.1$; ** $p<0.05$; *** $p<0.01$

Table 4. Interaction Effects of Grocery Store Density (2011) and SNAP Participation on Obesity Outcomes in 2011

Variables	(1) Adult Obesity Rate	(2) Age-Adjusted Obesity Rate
Grocery	-.1958	-.0700
	(.4404)	(.4472)
SNAP	.1189***	.1086***
	(.0131)	(.0133)
Interaction: Grocery, SNAP	-.0630***	-.0642***
	(.0160)	(.0162)
Income Effects		
Median HH Income	-.0001***	-.0001***
	(.0000)	(.0000)
Poverty Rate	-.1095***	-.0987***
	(.0231)	(.0235)
Race		
White	-.0481***	-.0499***
	(.0092)	(.0093)
Black	.0351***	.0342***
	(.0090)	(.0091)
Hispanic	-.1073***	-.1075***
	(.0097)	(.0098)
Asian	-.3036***	-.2890***
	(.0300)	(.0304)
Food Environment		
Supercenter/Warehouse	8.7552***	9.8685***
	(3.0882)	(3.1356)
Convenience Store	.2431	.2711
	(.2266)	(.2301)
Specialized Food Store	-5.3879***	-5.6129***
	(.8871)	(.9007)
Fast Food	-1.9918***	-1.9579***
	(.2288)	(.2323)
Farmer's Market	-.9372	-1.3327
	(.9492)	(.9637)
Observations	2753	2753
R-squared	.4753	.4826
Adjusted R-squared	.4727	.4800

Note: Robust standard errors, clustered by state, are in parentheses. This model includes state-level fixed effects.

* $p<0.1$; ** $p<0.05$; *** $p<0.01$

X. Footnotes

[1] "Adult Obesity Facts," last modified September 9th, 2014, http://www.cdc.gov/obesity/data/adult.html

[2] Ibid

[3] "Food Environment Atlas: Data Access and Documentation Downloads," last modified August 28, 2014, http://www.ers.usda.gov/data-products/food-environment-atlas/data-access-and-documentation-downloads.aspx

[4] Ibid

[5] Ibid

[6] "Supplemental Nutrition Assistance Program (SNAP)," last modified November 20, 2014, http://www.fns.usda.gov/snap/supplemental-nutrition-assistance-program-snap

[7] Ibid