Master of Arts in Economic Policy Analysis: Capstone Project

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Living in a Food Desert and Health Outcomes

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Abstract: Nearly 45 million Americans live without access to healthy and affordable food. That lack of access may have a negative effect on dietary quality, which could lead to a higher incidence of obesity, diabetes, and hypertension. This study investigated whether living in a food desert has an adverse effect on rates of these diet-related diseases. In addition, an analysis tested whether elderly people are affected differently than people under 65 from living in a food desert. Individual level data from respondents to the Medical Expenditure Panel Survey (MEPS) was merged with the USDA Food Access Atlas at the census tract level. Regression procedures that incorporate matching were conducted to test the above hypotheses. Results show that there is a statistically significant but small effect of living in a food desert on rates of obesity (3.9%-4.2%) and hypertension (3.4%-3.6%), and no consistent effect on rates of diabetes. In addition, there were no significant and consistent effects on DRD prevalence of elderly living in a food desert.

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## Introduction

Nearly 45 million low-income Americans live without access to healthy and affordable food.[[1]](#footnote-1) That lack of access may have a negative effect on dietary quality, which could lead to a higher incidence of diet related diseases, like obesity, diabetes, and hypertension. This research investigated whether living in a food desert has an adverse effect on rates of these diseases. In addition, whether elderly people are affected differently than people under 65 from living in a food desert was tested. Individual level data from respondents to the Medical Expenditure Panel Survey (MEPS) was merged with the USDA Food Access Atlas at the census tract level. Regression procedures that incorporate matching were conducted to test the above hypotheses.

## Background

### What is a food desert?

#### General definition

The simplest definition of a food desert comes from the 2008 Farm Bill, which defines a food desert as an “area in the United States with limited access to affordable and nutritious food, particularly such an area composed of predominantly lower income neighborhoods and communities” (Title VI, Sec. 7527).[[2]](#footnote-2) This definition requires clarification to be useful in quantitative research. Specifically, the following questions need to be answered:

1) What is the geographic “area” that can be considered a food desert?

2) What is the definition of “limited access”?

3) What is “affordable and nutritious food”?

4) Are there any other criteria besides “lower-income neighborhoods” that are needed for an adequate definition of “food desert”?

#### Different analytic definitions of a “food desert”

One of the best measurements of a person’s access to affordable and nutritious food is the distance between that person’s house and the nearest place that serves this food. However, since personal addresses are often unavailable, many researchers use predefined geographical units such as a ZIP code, census tract, or block as a substitute. Due to the varying size of zip codes and census tracts, researchers using these units of analysis can either measure from the center of the area, define a threshold percentage of residents in the area without access to the food source, or determine an average distance threshold from a resident to food source as counting as a food desert.[[3]](#footnote-3) [[4]](#footnote-4) A definition should also account for the differences between urban food deserts and rural food deserts due to the lack of public transportation and greater spatial dispersion of resources.[[5]](#footnote-5) A number of studies set the threshold for urban and rural food deserts at 1 mile and 10 miles or more, respectively, from a supermarket.[[6]](#footnote-6) [[7]](#footnote-7)

As shown above, the current field standard for defining access to “affordable and nutritious food” is distance to a large grocery store or supermarket. This distinguishes these stores from corner stores, convenience stores, and fast food restaurants, which are more common than large grocery stores in low-income urban areas and rarely offer affordable and healthy food.[[8]](#footnote-8) Distance to a grocery store is used as the measure of access to affordable and nutritious food source because it is nearly certain that grocery stores will carry affordable and nutritious food, while many corner stores may not.

According to the Food Bill, a “food desert” is also defined as a “predominantly low-income” area. Low-income populations are believed to be more ‘vulnerable’ to the effects of low food access than high-income communities.[[9]](#footnote-9) Lower-income urban residents have less money to spend and may have less time to travel to a grocery store that is not within walking distance.[[10]](#footnote-10) Low-income areas are often defined as areas with a high proportion of the population below a threshold, usually a percentage of the federal poverty line. For example, the Baltimore Food Policy Initiative specifies that the median income should be at or below 185% of the federal poverty line.[[11]](#footnote-11) Another component of the definition of a food desert is vehicle ownership. Dutko, Ploeg, and Farrigan found that those living in urban food deserts are 24% to 38% less likely to have access to a vehicle than other residents.[[12]](#footnote-12) This compounds the lack of time and money to travel to get food. One of The Baltimore Food Policy Initiative’s criteria for a food desert is that 30% or more of the residents have no access to a vehicle. Access to a vehicle makes grocery stores that are more than a mile away much more accessible and may negate the effects of living in a food desert. Although there are additional criteria that could be measured, low income and low vehicle access are the most common.

#### Definition to be used in this study

The food desert data that will be used for this study comes from the Unites States Department of Agriculture (USDA) Food Access Research Atlas. Although this data includes several definitions that could be used for analysis, the most comprehensive one is called “low income and low access using vehicle access.” The definition is “a low-income tract in which at least one of the following is true: at least 100 households are located more than ½ mile from the nearest supermarket and have no vehicle access; or at least 500 people or 33 percent of the population live more than 20 miles from the nearest supermarket, regardless of vehicle availability.”[[13]](#footnote-13) A low-income tract is one where “the tract’s poverty rate is 20 percent or greater; or the tract’s median family income is less than or equal to 80 percent of the state-wide median family income; or the tract is in a metropolitan area and has a median family income less than or equal to 80 percent of the metropolitan area's median family income.”[[14]](#footnote-14) This measure was chosen because it encompasses the distance measure to the nearest supermarket from a small geographic area, differentiates between rural and urban areas, and incorporates both the low income and low vehicle access measures. Another measure [Low income and low access at 1 mile (urban) and 10 miles (rural)] was tested for sensitivity of results, which will be presented later.

### Who lives with low food access?

Using this definition, the USDA estimates that 44.8 million Americans (14.5% of all Americans) live in a food desert. In addition, areas with low food access are also more likely to be high-minority areas than areas with high or medium access.[[15]](#footnote-15) [[16]](#footnote-16)

Food access does not differ for elderly vs. non-elderly people. However, the elderly who are living in food deserts (approximately 5.5 million people) face additional issues such as mobility and fixed income that could compound the effects of low food access.[[17]](#footnote-17)

### Theoretical model

While the purpose of this paper is to determine the health effects of living in a food desert, the effect of food environment on health outcomes is not direct. It is theorized by researchers that living in a food desert affects the food you buy and eat. If this is the case, food desert residents may have a higher risk of negative diet-related health outcomes. For the theory behind this study to be valid, both of these links must be true: that living in a food desert causes lower dietary quality, and that lower dietary quality causes diet related disease. This theoretical model is presented in Figure 1 below.

**Figure 1: Theoretical Model**

Non-diet related factors (genetics, exercise, etc.)

Non-access related factors (preferences, income, etc.)

### Effect of living in a food desert on diet

Multiple studies have found that access to fruits and vegetables, a key part of a healthy diet, significantly increases consumption in both children and adults. [[18]](#footnote-18) [[19]](#footnote-19) [[20]](#footnote-20) However, results are not consistent. [[21]](#footnote-21) [[22]](#footnote-22) In addition to fruits and vegetables, residents are more likely to follow various dietary guidelines if they have access to a grocery store.[[23]](#footnote-23) [[24]](#footnote-24)

Evaluations of food desert policy interventions have shown that a significant amount of food desert residents will shift their shopping to a new store if opened, and that a new supermarket has a positive effect on dietary quality of residents.[[25]](#footnote-25) [[26]](#footnote-26) [[27]](#footnote-27) However, one study could not statistically attribute the increase in dietary quality to shopping at the new store.[[28]](#footnote-28) Interventions aimed at introducing and marketing nutritious foods in *existing* stores have also found that sales of these food items increased significantly.[[29]](#footnote-29) [[30]](#footnote-30)

Some researchers consider access to healthy food less important to dietary quality than access to unhealthy food. Numerous studies have found that there is greater concentration of unhealthy food stores in lower-income and high-minority areas, and that greater proximity to these stores decreases dietary quality.[[31]](#footnote-31) [[32]](#footnote-32) The presence of these stores may “exert a greater influence on the diets of low-income families because there are fewer healthy alternatives in their immediate neighborhoods.”[[33]](#footnote-33) While both access to unhealthy food and low access to healthy food may affect dietary quality, policy solutions tend to focus on giving access to positive goods rather than taking away access to negative goods. In addition, a moral argument could be made that everyone should have a choice between healthy and unhealthy food, which is not the case in a food desert.

While the research is not definitive, it suggests that the lack of access to healthy foods, coupled with increased access to unhealthy foods, has a negative effect on the dietary quality of food desert residents.

### Effect of living in a food desert on health outcomes

#### Diet related diseases

There is a well-established and consistent causal link between consuming certain nutrient-deficient food and drink and developing chronic diseases.[[34]](#footnote-34) Three of the most studied ‘diet-related diseases’ (DRDs) are: obesity, type-2 diabetes, and hypertension (high blood pressure). These three diseases accounted for 26% of the deaths in the US between 1990 and 2010, and cost nearly $400 billion per year in direct and indirect costs.[[35]](#footnote-35) [[36]](#footnote-36) [[37]](#footnote-37) The prevalence of these conditions has been rising for decades, and is projected to continue rising for at least the next 15 years.[[38]](#footnote-38) Other factors can lead to these diseases, but nearly 80% of the cases are preventable through healthy diet and lifestyle choices.[[39]](#footnote-39)

Obesity is the disease most directly related to poor diet. Poor diets are low in plant-based food and grains, and are high in processed foods and soft drinks.[[40]](#footnote-40) The most common measure of obesity is Body Mass Index (BMI), which takes into account a person’s weight and height. This measurement lacks precision, but it does provide a consistent, easy, and inexpensive measurement.[[41]](#footnote-41) Patients with diabetes exhibit a lack of insulin control, which regulates the amount of glucose in the blood. Type-2 diabetes is a reduction in insulin production that occurs later in life and is closely associated with poor diet and obesity.[[42]](#footnote-42) [[43]](#footnote-43) Hypertension (high blood pressure) is caused by age, genetics, diet, obesity, and diabetes. Like diabetes, hypertension is treatable but very hard to reverse, and people with hypertension or diabetes are at higher risk for cardiovascular disease (CVD), stroke and death than those without it.[[44]](#footnote-44)

#### Food deserts and diet related disease

People living in food deserts may have a higher risk of diet-related diseases due to the lack of access to healthy food. However, there is not consistent research on this link. Most studies have found a relationship between lack of access to a supermarket and higher obesity in adults, adolescents and children.[[45]](#footnote-45) [[46]](#footnote-46) [[47]](#footnote-47) For example, Morland et al. found that the presence of a supermarket in a census tract correlated with a lower prevalence of obesity in four states.[[48]](#footnote-48) However, as noted above, some studies have not found an association. [[49]](#footnote-49) [[50]](#footnote-50)

The effect of living in a food desert on the prevalence of diabetes and hypertension is less studied, perhaps because they are much more difficult to measure reliably than obesity. Two studies found that proximity to fast food restaurants did not have any effect on diabetes or hypertension.[[51]](#footnote-51) [[52]](#footnote-52) However, some studies have found a link between the prevalence of diabetes and hypertension and the local ‘food balance’ (ratio of the number of fast food restaurants and convenience stores to grocery stores in a particular area). [[53]](#footnote-53) [[54]](#footnote-54) [[55]](#footnote-55) For example, a study in California found that adults in areas with a balance ratio above three have a significantly higher prevalence of diabetes.[[56]](#footnote-56) No other studies were found testing the effect of local food environment on diabetes and hypertension.

#### Elderly in food deserts and health outcomes

The effects of living in a food desert on DRDs may be more significant for elderly Americans than for the non-elderly population. Many elderly people are on a fixed income and have a difficult time affording consistent and healthy food.[[57]](#footnote-57) At least 40% of seniors have limited mobility, which may limit their ability to cook at home, and walk or drive to the store.[[58]](#footnote-58) Elderly people are also more susceptible to diet related illnesses than younger people due to slower metabolisms and difficulty meeting nutrient requirements.[[59]](#footnote-59) Finally, elderly people move much less often than younger people, which could allow slow developing diseases like diabetes and hypertension to take hold.[[60]](#footnote-60) All of these factors could compound each other to worsen the health effects of low food access for seniors. However, only one study was found that tested the effect of living with low food access on diet related diseases in the elderly. Hanabuchi et al. found no statistical relationship between distance to a supermarket and BMI among Japanese seniors.[[61]](#footnote-61)

#### What this study adds

This research tests if there is an effect of living in a food desert on all three of the DRDs. It also tests whether or not the effect is stronger on elderly food desert residents. This will add to the current literature on the effect of food access on health outcomes. The four most relevant studies are Morland et. al., Zick et. al., Bodor et al., and AlHasan et. al., which were cross-sectional studies that examined sub-national geographic areas. [[62]](#footnote-62) [[63]](#footnote-63) [[64]](#footnote-64) [[65]](#footnote-65) This study is the only cross-sectional study to use a large national sample and data from the MEPS. Using this large national data source is advantageous because areas within the U.S. vary widely in geographic and demographic characteristics; therefore, this data set provides a more representative view of the United States as a whole.

This study is also the only one on this topic that will use matching to better approximate a random experiment. Most studies on this relationship, including this one, use cross-sectional data, which makes it more difficult to show a causal relationship than using longitudinal or panel data. Matching increases the likelihood that results are causal because respondents are matched on all relevant observable characteristics other than the treatment variable. Analytically, most studies in the field use linear, generalized linear, or logit regression models. For sensitivity of the analysis, all three of these regression methods were used in this study after the matching procedures.

This is also the first study to test the effect of living in a food desert on DRD prevalence in the elderly in the United States. A limitation in this study is a lack of precision in the measurement of a food desert due to the tract unit of analysis. It does not map each respondent’s specific food environment, unlike some localized studies. For example, Bodor et al. mapped how far each respondent’s address was from the nearest food stores in New Orleans.[[66]](#footnote-66) Another limitation is that this study will not account for access to unhealthy food, only access to healthy food. While access to both is relevant, lack of data availability and practical concerns prevent this study from utilizing access to unhealthy food sources.

## Methods

### Data sources

This study used two data sources, The Medical Expenditures Panel Survey (MEPS) and the USDA Food Access Research Atlas, to test if people living in food deserts experience a higher rate of diet-related diseases than people not living in food deserts. The MEPS, administered by the U.S. Agency for Healthcare Research and Quality, is a set of large-scale surveys of families and individuals, their medical providers (doctors, hospitals, pharmacies, etc.), and employers across the United States. The household component of the survey, which was used in this study, collects nationally representative data on “demographic characteristics, health conditions, health status, use of medical care services, charges/payments, access to care, satisfaction with care, health insurance coverage, income, and employment.”[[67]](#footnote-67) Full-year consolidated data files from three years (2010-2012) of MEPS respondents were pooled to achieve an eligible cross-sectional sample size of approximately 43,000 respondents.

To determine if each respondent is living in a food desert, the census tract where each MEPS respondent lives was merged with the USDA Food Access Research Atlas. This publically available data source contains data on all of the approximately 70,000 census tracts in the U.S based on the 2010 Decennial Census, the 2010 list of supermarkets, and the 2006-2010 American Community Survey. [[68]](#footnote-68) The data contains multiple food access measures, including the food desert definition used in this study called “low income and low access using vehicle access.” After the merge with the MEPS data, this dummy variable was used in the analysis to determine the prevalence of DRDs in food deserts in both the elderly and the general population.

Due to the potentially identifiable nature of the MEPS data, the merge and all data analysis was conducted in AHRQ’s secure data center in Rockville, MD.

### Unit of analysis

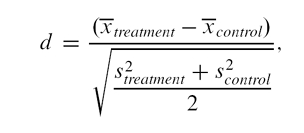
The unit of analysis for this study is the individual MEPS respondent at the one point in time that they were surveyed. DRDs develop over many years, so this study cannot prove *causality* between living in a food desert and having a DRD. However, using the matching procedures described below, this study has a stronger case for causality than previous cross-sectional studies on the topic.

### Matching methodology

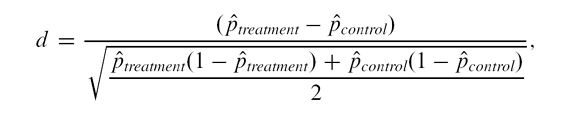
This study is the first to use matching to examine the food desert-DRD relationship. Matching is a statistical process used to approximate a Randomized Control Trial (RCT) in observational (non-randomized) data. The RCT is the ‘gold standard’ of research because participants are randomized into the treatment or control group before the study, which ensures that there is no selection bias on the groups. However, randomized controlled trials are expensive and are often not possible to conduct due to ethical or practical considerations. RCTs also often suffer from issues of generalizability. However, in this study (much like other observational studies), participants are not randomly selected to live in a food desert or not. This introduces bias because where they live is likely influenced by personal or environmental characteristics.[[69]](#footnote-69) As a result, the people that live in a food desert are probably different than the people that do not, which makes it harder to claim that living in a food desert has an objective effect on DRDs. This difference in characteristics is confirmed in table 3 below, showing the need for matching. Matching approximates an RCT by matching each treatment (food desert) observation to a control (non-food desert) observation based on a set of observable characteristics, and omitting all non-matched observations. By doing this, the treatment and control groups are ‘balanced’ on these characteristics. If the treatment and control groups are observably the same, the observed outcome differences are likely to be the result of the treatment, rather than any personal or environmental characteristics.[[70]](#footnote-70) However, it is important to note that matching only removes bias from observable characteristics, whereas an RCT controls for bias on both observable and unobservable characteristics. Because of this, these analyses improve upon prior analyses, but may still suffer from bias due to unobservable variables.

In this study, two of the most common types of matching will be conducted: propensity score matching (PSM) and Mahalanobis distance matching (MDM). After both matching procedures, balance statistics will be examined to determine which method will be used in the analysis. The ‘treatment’ variable for all matching procedures is whether or not the respondent lives in a food desert as defined above. PSM, the most common matching method, uses a logit regression to calculate each observation’s ‘probability’ of being treated based on specified explanatory variables. Each treatment case is matched with a control case with the closest probability of being treated.[[71]](#footnote-71) [[72]](#footnote-72) MDM is arguably more precise than PSM because it matches on all explanatory variables individually, rather than taking an average and then matching.[[73]](#footnote-73) Many studies have found that MDM usually produces better variable balance than PSM.[[74]](#footnote-74) [[75]](#footnote-75) In studies with a large sample size, like this one, it is common to match a treatment case to multiple control cases to improve the match and increase the sample size. For both matching methods, up to three control cases (people not living in a food desert) were matched to each treatment case (people living in a food desert). The *psmatch2* package in STATA 14 was used for all matching methods.

The following variables will be used to match food desert observations with non-food desert observations: gender, race/ethnicity, age, income, education, physical activity, marital status, and insurance status. If matched observations are the same or very close on all of these variables, this study argues that any significant variation in outcome means (DRDs) should only be a result of living in a food desert. However, it is important to note again that this study does not control for bias from unobservable variables. The means and standardized biases of the matching variables in the matched and unmatched samples were tested visually and analytically. The equation for the standardized bias in continuous variables is



where  denote the sample mean of the covariate in treated (food desert) and untreated (non-food desert) subjects, respectively, and s2treatment and s2control denote the sample variance of the covariate in treated and untreated subjects, respectively. For dichotomous variables, the standardized bias is defined as



where  denote the prevalence or mean of the dichotomous variable in treated and untreated subjects, respectively. The standardized bias compares the difference in means in units of the pooled standard deviation. Furthermore, Austin notes that “it is not influenced by sample size and allows for the comparison of the relative balance of variables measured in different units.”[[76]](#footnote-76)

### Analysis

#### Outcome (dependent) variables

All three DRDs in this study are represented by questions in the MEPS. The Body Mass Index (BMI) variable (BMINDX53) is constructed based on the reported height and weight of all respondents over age 18, based on the standard BMI formula.[[77]](#footnote-77) While the BMI will be tested separately in the means comparison and OLS regression, all analyses will also be stratified by the standard categories to test the effect on rates of obesity (BMI>30).[[78]](#footnote-78) The diabetes variable (DIABDX) is based on whether each person (age 18 or older) had ever been told by their health care provider that they have diabetes (excluding gestational diabetes). Similarly, the hypertension variable (HIBPDX) is if a person (age 18 or older) has ever been diagnosed with high blood pressure (excluding during pregnancy). Respondents are also asked later in the survey to confirm their diagnoses of diabetes and hypertension, reducing the chance of mistaken answering.

#### Indicator variables

The two indicator variables to be used in all analyses will be the general food desert dummy variable and an interaction dummy variable between the food desert variable and a variable for elderly (age>65). These variables will be in separate regressions to be able to test both if living in a food desert has an effect on the specified DRD for the entire population, and if being elderly and living in a food desert has an effect on the specified DRD. In the elderly regression models, the elderly interaction coefficient will be added to the general food desert coefficient to determine the effect on elderly people living in a food desert.

#### Means comparison

After the matching procedures, the means of the three outcome variables were compared. In an RCT, regression models are not necessary to control for other variables because all other relevant variables are balanced, on average, among participants. Therefore, a comparison of the outcome variable means between the treatment and control groups is sufficient to show if the treatment had a significant effect on the outcome. While this study is not a complete RCT, this means comparison is the first measure of the effect of living in a food desert on the rates of obesity, diabetes, and hypertension.

#### Regression analyses

Additional regression analyses were conducted to control for remaining variation between the two groups that was not accounted for in the matching procedure. Methodologists argue that it is optimal to use matching methodologies in combination with regression analysis in observational studies.[[79]](#footnote-79) [[80]](#footnote-80) These models also provide sensitivity analysis on the findings. The dependent variables for all models are the same as those listed above.

The matching procedure was incorporated with an importance weight in STATA 14 based on how many times each observation was matched with another observation (more matches, lower weight), and non-matched observations were not included. As a sensitivity analysis, I ran the matching procedure without importance weight and the results were the same.

##### Independent variables

The following demographic and socio-economic variables were included in each of the regression models to control for any residual effects: gender, race, age, poverty level, education, physical activity, marital status, number of residents in the household, and insurance status. Physical activity is defined as spending an hour or more doing moderate to vigorous physical activity at least five times a week. With the exception of marital status, number of residents in the household, and insurance status, this set of control variables is used in many similar studies.[[81]](#footnote-81) [[82]](#footnote-82) [[83]](#footnote-83) Marital status and size of household are included based on the possibility that married couples and larger families are more willing to travel to get food than single people and smaller families. Insurance status is included to capture some of the effect that access to health care has on prevalence of DRDs. It is also important to note the variables that cannot be controlled for, due to lack of data: family history of disease, diet composition, and food delivery and preparation services.

##### Regression models

Three separate regression models were tested for each of the three DRD outcomes: Ordinary Least Squares (OLS), Logit, and log-binomial generalized linear model (LB-GLM). These three models were all used in at least one of the similar studies, so they were all conducted in this study for sensitivity analyses. As noted earlier, there will be two separate models, one to test the effect on the entire populations, and one to test the effect on elderly people. The latter regressions will include the elderly interaction variable (B2 below), and the former will not. While the statistical methods of each model are different, the structure of all of the equations is the same.

***Outcome* = Β0 + B1\*(Food Desert) + [Β2\*(Food Desert\*Elderly)] + Β3\*(Female) + Β4\* (Black) + B5\* (Hispanic) +Β6\*(Asian) + Β7\*(Poverty level) + B8\* (Years of education) + B9\*(Physical activity) + B10\*(Married) + B11\*(Household size) + B12\*(Uninsured) + ε**

Both the logit model and the LB-GLM model are designed for modeling dichotomous outcome variables, like the DRD measures in this study. To be directly comparable to OLS results, the *margins* command was used in STATA 14 after both of these regressions. This command outputs the marginal effects of the right hand side (RHS) variables on the outcome variable.

### Interpretation

Because of the large sample size (~43,000) in this study, there is a greater chance that the results will be highly statistically significant, even for small differences in outcomes between the groups. The smallest effect in similar studies was a 7.2% higher rate of obesity in Bodor, et al. Therefore, I will use that as a benchmark to help decide if results are of practical significance. I will also consider if results are consistent at the 1% significance level across the three models, and those that do not change substantially when using the other matching method, and when using an alternative definition of food desert. If I consistently find a large and significant effect on the food desert variable, I can suggest that there is a causal relationship between living in a food desert and prevalence of that DRD. Similarly, if there is a large and significant effect on the food desert variable and the elderly interaction variable, I can suggest that there is a causal relationship between being elderly and living in a food desert and prevalence of that DRD. But if some models find a significant effect and others do not, or if magnitudes are small, I will not be able to conclude that there is an effect of either of these variables on DRD prevalence. It is also possible that I will find consistent significant effects for some DRDs, but inconsistent or small results for the other DRDs, in which case, I can suggest a causal relationship between food deserts and some DRDs, but not all three.

## Results

### Descriptive statistics

After merging all three years of MEPS data and dropping observations without complete data (n=64,164), the final observation count is 42,969. The yearly breakdown is presented in table 1 and descriptive statistics are presented in table 2.

**Table 1: Number of Observations by Year**

|  |  |  |
| --- | --- | --- |
| Year | Freq. | Percent |
| 2010 | 16,180 | 37.66 |
| 2011 | 17,379 | 40.45 |
| 2012 | 9,410 | 21.9 |
| **Total** | **42,969** | **100** |

**Table 2: Descriptive Statistics**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Mean | Standard Deviation | Minimum | Maximum | Skewness | Kurtosis |
| Food Desert | 17.24% | 0.38 | 0 | 1 | 1.73 | 4.01 |
| High Blood Pressure | 32.09% | 0.47 | 0 | 1 | 0.77 | 1.59 |
| Diabetes | 9.81% | 0.30 | 0 | 1 | 2.70 | 8.30 |
| BMI | 27.95 | 6.37 | 8.1 | 103 | 1.33 | 6.95 |
| Obese | 30.82% | 0.46 | 0 | 1 | 0.83 | 1.69 |
| White | 38.84% | 0.49 | 0 | 1 | 0.46 | 1.21 |
| Hispanic | 24.14% | 0.43 | 0 | 1 | 1.21 | 2.46 |
| Black | 25.90% | 0.44 | 0 | 1 | 1.10 | 2.21 |
| Asian | 10.63% | 0.31 | 0 | 1 | 2.55 | 7.52 |
| Female | 53.49% | 0.50 | 0 | 1 | -0.14 | 1.02 |
| Elderly | 15.96% | 0.37 | 0 | 1 | 1.86 | 4.46 |
| Uninsured | 20.00% | 0.40 | 0 | 1 | 1.50 | 3.25 |
| % of Federal Poverty Level | 334.03 | 306.47 | 0 | 3095.8 | 2.19 | 10.30 |
| Engages in Physical Activity | 52.09% | 0.50 | 0 | 1 | -0.08 | 1.01 |
| Age | 45.41 | 17.70 | 18 | 85 | 0.34 | 2.23 |
| Years of Education | 12.69 | 3.04 | 0 | 17 | -1.04 | 5.15 |
| Urban | 83.49% | 0.37 | 0 | 1 | -1.80 | 4.25 |
| Married | 48.06% | 0.50 | 0 | 1 | 0.08 | 1.01 |
| Members in Household | 3.01 | 1.69 | 1 | 14 | 1.06 | 4.65 |

Approximately 17% of individuals in the sample live in a food desert as defined above. This is slightly higher than the estimated 14.5% of Americans that live in a food desert. However, that measure did not take into account vehicle access and rural/urban differences.[[84]](#footnote-84) The rates of obesity, diabetes, and high blood pressure in the sample (30%, 32%, and 10% respectively) are all very close to the national averages.[[85]](#footnote-85) [[86]](#footnote-86) [[87]](#footnote-87) All three minority groups (Blacks, Hispanics, and Asians) are overrepresented compared to national estimates, while women and the elderly are accurately represented.[[88]](#footnote-88)

**Table 3: Variable Means by Food Desert Status**

|  |  |  |  |
| --- | --- | --- | --- |
|  | Food Desert | Non-Food Desert | Total |
| Percentage | 17.24% | 82.76% | 100.00% |
| High Blood Pressure | 35.59%\*\*\* | 31.36% | 32.09% |
| Diabetes | 12.32%\*\*\* | 9.29% | 9.81% |
| BMI | 28.83\*\*\* | 27.76 | 27.95 |
| Obese | 36.54%\*\*\* | 29.63% | 30.82% |
| White | 23.94%\*\*\* | 41.95% | 38.84% |
| Hispanic | 26.51%\*\*\* | 23.65% | 24.14% |
| Black | 37.51%\*\*\* | 23.48% | 25.90% |
| Asian | 11.66%\*\*\* | 10.42% | 10.63% |
| Uninsured | 24.69%\*\*\* | 19.03% | 20.00% |
| Female | 56.19%\*\*\* | 52.92% | 53.49% |
| Poverty Level | 223.51\*\*\* | 357.06 | 334.03 |
| Engages in Physical Activity | 49.17%\*\*\* | 52.69% | 52.09% |
| Age | 43.68\*\*\* | 45.77 | 45.41 |
| Years of Education | 11.88\*\*\* | 12.86 | 12.69 |
| Urban | 88.54%\*\*\* | 82.43% | 83.49% |
| Elderly | 14.90%\*\*\* | 16.18% | 15.96% |
| Married | 37.02%\*\*\* | 50.36% | 48.06% |
| Members in Household | 2.96\*\* | 3.02 | 3.01 |

\*\*\* - P<0.01 \*\* - P<0.05

Table 3 stratifies the means of the variables by the food desert variable. Based on t-tests in the unmatched sample, respondents living in food deserts are significantly more likely to suffer from the three DRDs. Most notably, the rate of obesity is 7% higher in food deserts residents than in non-food desert residents. Food desert residents are also significantly more likely to be lower income, minority, uninsured, unmarried, and living in an urban area. While these are not regression results, they give us some preliminary evidence that living in a food desert is associated with the health of residents.

### Matching results

People living in a food desert were matched to up to three people not living in a food desert on the variables listed in the methods section above using both PSM and MDM methods. Table 4 below shows the mean differences of the matching variables in the unmatched sample, after PSM matching, and after MDM matching. Figure 2 shows this graphically. Table 5 shows the standardized bias in the matching variables and Figure 3 shows this graphically. A perfect match would be zero mean difference, no statistically significant difference in means, and zero standardized bias.

**Table 4: Matching Mean Balance Statistics**

|  |  |  |  |
| --- | --- | --- | --- |
| Variable | Mean Difference | | |
| Unmatched | PSM | MDM |
| Observations | 43,930 | 22,239 | 19,779 |
| Hispanic | 2.86%\*\*\* | -0.39% | -0.17% |
| Black | 14.03%\*\*\* | 4.77%\*\*\* | 5.04%\*\*\* |
| Asian | 1.24%\*\*\* | -0.159% | 0.54% |
| Female | 3.27%\*\*\* | 0.82% | 0.77% |
| Poverty Level | -133.55\*\*\* | -30.46\*\*\* | -23.05\*\*\* |
| Physical Activity | -3.52%\*\*\* | -0.59% | -0.91% |
| Age | -2.09%\*\*\* | -0.45\* | -0.10% |
| Years of Education | -0.97\*\*\* | -0.250%\*\*\* | -0.27\*\*\* |
| Marital Status | -13.34\*\*\* | -4.11%\*\*\* | 3.83%\*\*\* |
| Insurance Status | 5.66%\*\*\* | 1.07%\* | -1.73%\*\*\* |

\*\*\* - P<0.01 \*\* - P<0.05 \*-P<0.10

**Figure 2: Matching Mean Differences**

|  |  |
| --- | --- |
| Variable | Mean Difference (Food Desert – Non-Food Desert) |
| Hispanic |  |
| Black |
| Asian |
| Female |
| Poverty Level |
| Physical Activity |
| Age |
| Years of Education |
| Marital Status |
| Insurance Status |
|  |

The matching procedures eliminated over half of the sample size, from 43,000 to about 20,000. Both procedures reduced the mean difference in all the variables, and achieved statistical balance (no significant difference in means) on five variables. There is no clear advantage in the PSM or the MDM based on means comparisons; five variables have lower mean differences with MDM, and four have lower mean differences with PSM.

**Table 5: Matching Standardized Biases**

|  |  |  |  |
| --- | --- | --- | --- |
| Variable | Standardized Bias | | |
| Unmatched | PSM | MDM |
| Observations | 43,930 | 22,239 | 19,779 |
| Hispanic | 6.6 | 0.0 | -0.6 |
| Black | 30.8 | -1.2 | -1.9 |
| Asian | 4.0 | -0.5 | 5.2 |
| Female | 6.6 | -0.9 | -1.8 |
| Poverty Level | -49.7 | -1.5 | 3.8 |
| Physical Activity | -7.1 | 1.8 | -0.2 |
| Age | -11.8 | 0.6 | 5.6 |
| Years of Education | -32.8 | 0.0 | -6.5 |
| Marital Status | 25.4 | -0.9 | -2.3 |
| Insurance Status | 13.7 | -1.0 | 2.9 |
| Psuedo R2 | 0.062 | 0 | 0.003 |
| Median Bias | 18.8 | 0.9 | 3.1 |
| Mean Bias | 12.8 | 0.9 | 2.6 |

**Figure 3: Matching Standardized Biases**

|  |  |
| --- | --- |
| Variable | Standardized Bias |
| Hispanic |  |
| Black |
| Asian |
| Female |
| Poverty Level |
| Physical Activity |
| Age |
| Years of Education |
| Marital Status |
| Insurance Status |
|  |

The standardized bias results show a clear advantage to PSM, with eight of the nine variables having lower bias with the PSM procedure than with the MDM procedure. In addition, the mean and median bias is lower with PSM (0.9 and 0.9 respectively) than with MDM (2.6 and 3.1 respectively). Although it was predicted that MDM would provide a better match, PSM has shown to be a better fit with this data, so I will present results from the PSM matched population. However, I will also conduct all analyses with the MDM population and discuss them as sensitivity analyses.

### Means comparisons

Table 6 below shows the differences in the means on the food desert variable for the four DRD variables for the entire population. Table 7 shows the mean differences for the elderly population.

**Table 6: Matched DRD Means Comparisons**

|  |  |  |  |
| --- | --- | --- | --- |
| Variable | Mean Difference | | |
| Unmatched | PSM | MDM |
| Hypertension | 4.38% | 3.92% | 4.46% |
| Diabetes | 3.09% | 2.33% | 2.55% |
| BMI | 1.18 | 0.808 | 0.702 |
| Obese | 6.87% | 4.84% | 4.81% |

Note: all differences are statistically significant at the 1% level.

**Table 7: Matched DRD Means Comparisons (Elderly)**

|  |  |  |  |
| --- | --- | --- | --- |
| Variable | Mean Difference (Elderly) | | |
| Unmatched | PSM | MDM |
| High BP | 4.77%\*\*\* | 3.27% | 2.71% |
| Diabetes | 6.04%\*\*\* | 3.53% | 4.86%\* |
| BMI | 0.001\* | 0 | -0.001 |
| Obese | 1.49% | -1.07% | -1.89% |
| Underweight | 5.05% | 4.23% | 1.04% |

\*\*\* - P<0.01 \*\* - P<0.05 \*-P<0.10

For the general population, the matching procedures reduced the effect size of living in a food desert for all four DRDs, but did not reduce their statistical significance. Just comparing means, living in a food desert was correlated with a 4% higher chance of hypertension, a 2.3% higher chance of diabetes, and a 5% higher chance of obesity for all participants. For the elderly population, effects of living in a food desert on DRD prevalence were significant before matching, but the matching procedures removed all statistical significance, indicating that the mean differences were largely a result of covariate differences rather than a result of food desert residency. Regressions are needed to control for any remaining bias in the results, and the next section will present those results.

### Regression Results

Results from the three different regression models (OLS, Logit, and Log-binomial) for the matched (PSM) sample on the three DRDs without the elderly interaction variable are presented in tables 7, 9, and 11. Regression results with the elderly interaction variable are presented in tables 8, 10, and 12. Additional results are presented in the appendix, including regressions using MDM instead of PSM, using an alternative definition of food desert [low income and low access at 1 mile (urban) and 10 miles (rural)], regressions on an underweight variable, and regressions including interaction terms for other covariates besides elderly.

**Table 7: BMI and Obesity Regression Results**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variable | BMI | Obesity | | |
| Linear | Linear | Logit | Log-binomial |
| Food desert | 0.734\*\*\* | 0.042\*\*\* | 0.042\*\*\* | 0.039\*\*\* |
| Hispanic | 0.291\* | -0.002 | -0.001 | -0.003 |
| Black | 0.807\*\*\* | 0.057\*\*\* | 0.055\*\*\* | 0.054\*\*\* |
| Asian | -0.660\*\*\* | -0.043\*\*\* | -0.045\*\*\* | -0.042\*\*\* |
| Female | 0.242\*\* | 0.047\*\*\* | 0.047\*\*\* | 0.053\*\*\* |
| Poverty level | -0.002\*\*\* | -0.000\*\*\* | -0.000\*\*\* | -0.000\*\*\* |
| Physical Activity | -1.391\*\*\* | -0.087\*\*\* | -0.086\*\*\* | -0.087\*\*\* |
| Age | 0.074\*\*\* | 0.004\*\*\* | 0.004\*\*\* | 0.004\*\*\* |
| Years of Education | -0.011 | -0.003\* | -0.002\* | -0.002\* |
| Elderly | -3.562\*\*\* | -0.191\*\*\* | -0.188\*\*\* | -0.191\*\*\* |
| Married | -0.064\* | -0.003 | -0.003 | -0.003 |
| Uninsured | -0.524\*\*\* | -0.031\*\*\* | -0.031\*\*\* | -0.034\*\*\* |
| Size of Household | <0.001 | <0.001 | <0.001 | 0.001 |
| constant | 26.500\*\*\* | 0.256\*\*\* |  |  |
| r2 | 0.051 | 0.038 |  |  |
| bic | 143181.602 | 28408.975 | 27074.177 | 28383.617 |
| chi2 |  |  | 840.121 | 876.826 |

\*\*\* - P<0.01 \*\* - P<0.05 \* - P<0.10

**Table 8: BMI and Obesity Regression Results (Elderly)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variable | BMI | Obesity | | |
| Linear | Linear | Logit | Log-binomial |
| Food desert | 0.839\*\*\* | 0.049\*\*\* | 0.048\*\*\* | 0.044\*\*\* |
| Elderly\*Food Desert | -0.704\*\* | -0.048\*\* | -0.046\* | -0.035 |
| Hispanic | 0.293\* | -0.001 | -0.001 | -0.004 |
| Black | 0.811\*\*\* | 0.057\*\*\* | 0.056\*\*\* | 0.054\*\*\* |
| Asian | -0.656\*\*\* | -0.042\*\*\* | -0.045\*\*\* | -0.042\*\*\* |
| Female | 0.240\*\* | 0.047\*\*\* | 0.047\*\*\* | 0.053\*\*\* |
| Poverty level | -0.002\*\*\* | -0.000\*\*\* | -0.000\*\*\* | -0.000\*\*\* |
| Physical Activity | -1.394\*\*\* | -0.087\*\*\* | -0.086\*\*\* | -0.087\*\*\* |
| Age | 0.074\*\*\* | 0.004\*\*\* | 0.004\*\*\* | 0.004\*\*\* |
| Years of Education | -0.011 | -0.003\* | -0.002\* | -0.002\* |
| Elderly | -3.323\*\*\* | -0.175\*\*\* | -0.172\*\*\* | -0.177\*\*\* |
| Married | -0.064\* | -0.003 | -0.003 | -0.003 |
| Uninsured | -0.526\*\*\* | -0.031\*\*\* | -0.031\*\*\* | -0.034\*\*\* |
| Size of Household | -0.001 | <0.001 | <0.001 | 0.001 |
| constant | 26.476\*\*\* | 0.254\*\*\* |  |  |
| r2 | 0.051 | 0.038 |  |  |
| bic | 143184.068 | 28412.223 | 27077.948 | 28390.126 |
| chi2 |  |  | 846.341 | 883.245 |

\*\*\* - P<0.01 \*\* - P<0.05 \* - P<0.10

In the entire population, living in a food desert is correlated with a 0.73 point increase in the respondents BMI (12% of one standard deviation), and elderly living in a food desert had a 0.13 point higher BMI (2% of one standard deviation) after controlling for the covariates. Living in a food desert also increased the probability that the respondent was obese by between 3.9% and 4.2% in the general population across the three models. This difference disappears for elderly living in a food desert, whose rate of obesity was not different than the rest of population. The results for the entire population were consistent across all three models, when using MDM instead of PSM, and when using an alternative definition of food desert. Results for elderly living in a food desert were not consistent during sensitivity analysis. I also tested if living in a food desert had an effect on elderly being underweight (BMI < 18.5) and found no significant effect. There were also no significant effects on food desert interactions with any other covariates including race/ethnicity, gender, physical activity, years of education, poverty level, and insurance status.

**Table 9: Diabetes Regression Results**

|  |  |  |  |
| --- | --- | --- | --- |
| Variable | Diabetes | | |
| Linear | Logit | Log-binomial |
| Food desert | 0.021\*\*\* | 0.022\*\*\* | 0.020\*\*\* |
| Hispanic | 0.019\*\* | 0.025\*\*\* | 0.026\*\*\* |
| Black | 0.019\*\*\* | 0.020\*\*\* | 0.019\*\*\* |
| Asian | 0.018\* | 0.018\* | 0.017\*\* |
| Female | -0.007 | -0.006 | -0.010\*\* |
| Poverty level | -0.000\*\*\* | -0.000\*\*\* | -0.000\*\*\* |
| Physical Activity | -0.034\*\*\* | -0.032\*\*\* | -0.035\*\*\* |
| Age | 0.005\*\*\* | 0.005\*\*\* | 0.004\*\*\* |
| Years of Education | -0.004\*\*\* | -0.002\*\* | -0.002\*\*\* |
| Elderly | 0.009 | -0.061\*\*\* | -0.038\*\*\* |
| Married | -0.001 | -0.004\*\* | -0.007\*\*\* |
| Uninsured | -0.034\*\*\* | -0.038\*\*\* | -0.040\*\*\* |
| Size of Household | -0.004\*\* | -0.003\* | -0.005\*\*\* |
| constant | -0.009 |  |  |
| r2 | 0.103 |  |  |
| bic | 8616.163 | 12829.103 | 8834.631 |
| chi2 |  | 2229.43 | 2224.933 |

\*\*\* - P<0.01 \*\* - P<0.05 \* - P<0.10

**Table 10: Diabetes Regression Results (Elderly)**

|  |  |  |  |
| --- | --- | --- | --- |
| Variable | Diabetes | | |
| Linear | Logit | Log-binomial |
| Food desert | 0.017\*\*\* | 0.022\*\*\* | 0.024\*\*\* |
| Elderly\*Food Desert | 0.029\* | -0.001 | -0.007 |
| Hispanic | 0.019\*\* | 0.025\*\*\* | 0.026\*\*\* |
| Black | 0.019\*\*\* | 0.020\*\*\* | 0.020\*\*\* |
| Asian | 0.018\* | 0.018\* | 0.017\*\* |
| Female | -0.007 | -0.006 | -0.009\*\* |
| Poverty level | -0.000\*\*\* | -0.000\*\*\* | -0.000\*\*\* |
| Physical Activity | -0.034\*\*\* | -0.032\*\*\* | -0.035\*\*\* |
| Age | 0.005\*\*\* | 0.005\*\*\* | 0.004\*\*\* |
| Years of Education | -0.004\*\*\* | -0.002\*\* | -0.002\*\*\* |
| Elderly | <0.001 | -0.060\*\*\* | -0.035\*\*\* |
| Married | -0.001 | -0.004\*\* | -0.007\*\*\* |
| Uninsured | -0.034\*\*\* | -0.038\*\*\* | -0.040\*\*\* |
| Size of Household | -0.004\*\* | -0.003\* | -0.005\*\*\* |
| constant | -0.008 |  |  |
| r2 | 0.103 |  |  |
| bic | 8620.207 | 12839.09 | 8843.433 |
| chi2 |  | 2229.434 | 2211.325 |

\*\*\* - P<0.01 \*\* - P<0.05 \* - P<0.10

Living in a food desert also increased the probability that the respondent had diabetes by between 2.0% and 2.2% in the entire population across the three models. There was no significant effect of elderly living in food desert on rates of diabetes. The results for the entire population were consistent across three models and when using MDM instead of PSM, but not when the alternative definition of food desert was used. There were also no significant effects on food desert interactions with any other covariates including race/ethnicity, gender, physical activity, years of education, poverty level, and insurance status.

**Table 11: Hypertension Regression Results**

|  |  |  |  |
| --- | --- | --- | --- |
| Variable | **Hypertension** | | |
| Linear | Logit | Log-binomial |
| Food desert | 0.036\*\*\* | 0.034\*\*\* | 0.034\*\*\* |
| Hispanic | -0.025\*\* | -0.028\*\* | -0.019\* |
| Black | 0.057\*\*\* | 0.056\*\*\* | 0.052\*\*\* |
| Asian | 0.033\*\*\* | 0.032\*\*\* | 0.043\*\*\* |
| Female | -0.009 | -0.007 | 0.001 |
| Poverty level | -0.000\*\*\* | -0.000\*\*\* | -0.000\*\*\* |
| Physical Activity | -0.047\*\*\* | -0.046\*\*\* | -0.041\*\*\* |
| Age | 0.013\*\*\* | 0.012\*\*\* | 0.012\*\*\* |
| Years of Education | -0.004\*\*\* | -0.003\*\*\* | -0.002\*\* |
| Elderly | -0.031\*\* | -0.084\*\*\* | -0.142\*\*\* |
| Married | 0.007\*\*\* | 0.002 | <0.001 |
| Uninsured | -0.057\*\*\* | -0.054\*\*\* | -0.074\*\*\* |
| Size of Household | -0.011\*\*\* | -0.011\*\*\* | -0.012\*\*\* |
| constant | -0.143\*\*\* |  |  |
| r2 | 0.283 |  |  |
| bic | 21885.961 | 21110.218 | 22596.533 |
| chi2 |  | 6701.82 | 6895.991 |

\*\*\* - P<0.01 \*\* - P<0.05 \* - P<0.10

**Table 12: Hypertension Regression Results (Elderly)**

|  |  |  |  |
| --- | --- | --- | --- |
| Variable | Hypertension | | |
| Linear | Logit | Log-binomial |
| Food desert | 0.035\*\*\* | 0.035\*\*\* | 0.044\*\*\* |
| Elderly\*Food Desert | 0.004 | -0.001 | -0.021\* |
| Hispanic | -0.025\*\* | -0.028\*\* | -0.019\* |
| Black | 0.057\*\*\* | 0.056\*\*\* | 0.052\*\*\* |
| Asian | 0.032\*\*\* | 0.032\*\*\* | 0.043\*\*\* |
| Female | -0.009 | -0.007 | 0.001 |
| Poverty level | -0.000\*\*\* | -0.000\*\*\* | -0.000\*\*\* |
| Physical Activity | -0.047\*\*\* | -0.046\*\*\* | -0.040\*\*\* |
| Age | 0.013\*\*\* | 0.012\*\*\* | 0.012\*\*\* |
| Years of Education | -0.004\*\*\* | -0.003\*\*\* | -0.002\*\*\* |
| Elderly | -0.032\*\* | -0.084\*\*\* | -0.134\*\*\* |
| Married | 0.007\*\*\* | 0.002 | <0.001 |
| Uninsured | -0.057\*\*\* | -0.054\*\*\* | -0.074\*\*\* |
| Size of Household | -0.011\*\*\* | -0.011\*\*\* | -0.012\*\*\* |
| constant | -0.143\*\*\* |  |  |
| r2 | 0.283 |  |  |
| bic | 21895.898 | 21120.206 | 22601.651 |
| chi2 |  | 6701.823 | 6876.057 |

\*\*\* - P<0.01 \*\* - P<0.05 \* - P<0.10

Finally, living in a food desert increased the probability that the respondent had hypertension by between 3.4% and 3.6% in the general population across the three models. Similar to the diabetes results, there was no significant effect of elderly living in a food desert on rates of hypertension. The results for the entire population were consistent across the three PSM models, when using MDM instead of PSM, and when using an alternative definition of food desert. There were also no significant effects on food desert interactions with any other covariates including race/ethnicity, gender, physical activity, years of education, poverty level, and insurance status.

## Discussion

The results presented above suggest that living in a food desert does significantly increase the chances of respondents in the general population having obesity or hypertension. However, the effect size on both was relatively small (about 4% for both), in comparison to the smallest effect from similar studies of 7.2%. Effect size for diabetes was even smaller (2%) and did not stay significant during sensitivity testing. For elderly people, results are not significantly different for any of the three DRDs, as well as underweight, compared to the non-elderly.

These results add to the existing literature that living in a food desert does have a significant effect on rates of obesity and hypertension, though the effect sizes are smaller than other studies. In addition, these results are the first to show that living in a food desert does not have a different effect on elderly people in the United States. This study improved methodologically on previous studies by using a large national sample, matching, and extensively testing sensitivity; therefore, these results better reflect the effect of food deserts on people in the entire United States than previous studies.

However, this study does have a few limitations.[[89]](#footnote-89) First, the cross-sectional design of this study does not allow the establishment of a causal relationship between the local food environment and DRD prevalence. Second, misclassification may have occurred if the census tract does not represent the area relevant to the food shopping habits of a particular individual, or if the definition of food desert does not accurately reflect the difficulty to obtain healthy food (i.e. the definition is too inclusive). While I believe the definition used is theoretically better than previous definitions, its inclusiveness may have led to the smaller effect sizes. Third, the possibility that individuals select neighborhoods with certain types of stores cannot be eliminated, nor can the possibility that market research locates supermarkets in areas where individuals have lower rates of DRDs. Fourth, other unobserved variables associated with the presence of different types of stores or the prevalence of DRDs could also account for the findings. Finally, the availability of a supermarket is a crude estimate for availability and cost of healthy foods because every individual food store offers a different array of food options.[[90]](#footnote-90)

Ways to address limitations in future work are to track the DRD status of participants who have switched between living in a food desert and not, by using the participant’s address, and surveying them about their shopping habits. Adding access to unhealthy food sources as a covariate will also be an improvement.

## Implications and Conclusions

There are other justifications for government intervention to combat food deserts in addition to effects on DRDs, including that minorities are disproportionately affected by low access and that all Americans have the right to choose healthy food. But in terms of effects on diet-related diseases, these results give some support to public investment in food deserts. However, the effects of living in a food desert on diet-related diseases may not be as large as previous studies have found. More research on the effects of living in a food desert is needed in order to establish long-term impacts of living in a food desert. The methodology in this paper improves upon prior research, and research should continue to examine the causal effect of living in a food desert on diet-related diseases. Finally, we need more research on the impact of food deserts on vulnerable populations such as children and the elderly.

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## Appendix: Additional Data/Results

|  |  |  |  |
| --- | --- | --- | --- |
| Diabetes (Mahalanobis Distance Matching) | | | |
|  | Linear | Logit | Log-binomial |
| Food desert | 0.022\*\*\* | 0.021\*\*\* | 0.022\*\*\* |
| Hispanic | 0.015\* | 0.021\*\* | 0.026\*\*\* |
| Black | 0.015\*\* | 0.017\*\* | 0.017\*\*\* |
| Asian | 0.013 | 0.015\* | 0.018\*\* |
| Female | 0 | 0.001 | 0 |
| Poverty level | -0.000\*\*\* | -0.000\*\*\* | -0.000\*\*\* |
| Activity | -0.026\*\*\* | -0.024\*\*\* | -0.025\*\*\* |
| Age | 0.005\*\*\* | 0.005\*\*\* | 0.004\*\*\* |
| Years of Education | -0.005\*\*\* | -0.003\*\*\* | -0.002\*\*\* |
| Elderly | 0.014 | -0.056\*\*\* | -0.041\*\*\* |
| Married | -0.009 | 0.003 | 0.008\* |
| Uninsured | -0.029\*\*\* | -0.031\*\*\* | -0.038\*\*\* |
| Size of Household | -0.003\* | -0.003 | -0.004\*\* |
| constant | -0.009 |  |  |
| r2 | 0.101 |  |  |
| bic | 7317.318 | 11433.011 | 7553.255 |
| chi2 |  | 1946.661 | 2011.427 |

|  |  |  |  |
| --- | --- | --- | --- |
| Diabetes (Mahalanobis Distance Matching) | | | |
|  | Linear | Logit | Log-binomial |
| Food desert | 0.019\*\*\* | 0.025\*\*\* | 0.029\*\*\* |
| Elderly\*Food Desert | 0.016 | -0.01 | -0.015\* |
| Hispanic | 0.015\* | 0.021\*\* | 0.026\*\*\* |
| Black | 0.015\*\* | 0.017\*\* | 0.017\*\*\* |
| Asian | 0.013 | 0.015\* | 0.018\*\* |
| Female | 0 | 0.001 | 0.001 |
| Poverty level | -0.000\*\*\* | -0.000\*\*\* | -0.000\*\*\* |
| Activity | -0.026\*\*\* | -0.024\*\*\* | -0.025\*\*\* |
| Age | 0.005\*\*\* | 0.005\*\*\* | 0.004\*\*\* |
| Years of Education | -0.005\*\*\* | -0.003\*\*\* | -0.002\*\*\* |
| Elderly | 0.008 | -0.052\*\*\* | -0.033\*\*\* |
| Married | -0.009 | 0.003 | 0.009\* |
| Uninsured | -0.029\*\*\* | -0.031\*\*\* | -0.037\*\*\* |
| Size of Household | -0.003\* | -0.003 | -0.004\*\* |
| constant | -0.008 |  |  |
| r2 | 0.101 |  |  |
| bic | 7325.507 | 11441.598 | 7558.429 |
| chi2 |  | 1947.968 | 1987.092 |

|  |  |  |  |
| --- | --- | --- | --- |
| Diabetes (Alternative Food Desert Definition) | | | |
|  | Linear | Logit | Log-binomial |
| Food desert | 0.007 | 0.007 | 0.011\*\* |
| Hispanic | 0.015\* | 0.022\*\*\* | 0.027\*\*\* |
| Black | 0.017\*\* | 0.019\*\*\* | 0.019\*\*\* |
| Asian | 0.015\* | 0.017\* | 0.020\*\* |
| Female | 0.001 | 0.001 | 0.001 |
| Poverty level | -0.000\*\*\* | -0.000\*\*\* | -0.000\*\*\* |
| Activity | -0.026\*\*\* | -0.024\*\*\* | -0.026\*\*\* |
| Age | 0.005\*\*\* | 0.005\*\*\* | 0.004\*\*\* |
| Years of Education | -0.005\*\*\* | -0.003\*\*\* | -0.003\*\*\* |
| Elderly | 0.015 | -0.056\*\*\* | -0.038\*\*\* |
| Married | 0.001 | -0.002 | -0.005\*\*\* |
| Uninsured | -0.029\*\*\* | -0.031\*\*\* | -0.038\*\*\* |
| Size of Household | -0.004\*\* | -0.003\* | -0.005\*\*\* |
| constant | -0.004 |  |  |
| r2 | 0.1 |  |  |
| bic | 7342.944 | 11455 | 7575.376 |
| chi2 |  | 1924.673 | 1966.168 |

|  |  |  |  |
| --- | --- | --- | --- |
| Diabetes (Alternative Food Desert Definition) | | | |
|  | Linear | Logit | Log-binomial |
| Food desert | 0.005 | 0.006 | 0.009\* |
| Elderly\*Food Desert | 0.034\*\* | 0.012 | 0.009 |
| Hispanic | 0.015\* | 0.022\*\*\* | 0.027\*\*\* |
| Black | 0.016\*\* | 0.018\*\*\* | 0.019\*\*\* |
| Asian | 0.014 | 0.017\* | 0.019\*\* |
| Female | 0.001 | 0.001 | 0 |
| Poverty level | -0.000\*\*\* | -0.000\*\*\* | -0.000\*\*\* |
| Activity | -0.026\*\*\* | -0.024\*\*\* | -0.026\*\*\* |
| Age | 0.005\*\*\* | 0.005\*\*\* | 0.004\*\*\* |
| Years of Education | -0.005\*\*\* | -0.003\*\*\* | -0.003\*\*\* |
| Elderly | 0.003 | -0.060\*\*\* | -0.042\*\*\* |
| Married | 0.001 | -0.002 | -0.005\*\*\* |
| Uninsured | -0.028\*\*\* | -0.031\*\*\* | -0.038\*\*\* |
| Size of Household | -0.004\*\* | -0.003\* | -0.005\*\*\* |
| constant | -0.004 |  |  |
| r2 | 0.1 |  |  |
| bic | 7344.613 | 11462.613 | 7582.056 |
| chi2 |  | 1926.952 | 1979.45 |

|  |  |  |  |
| --- | --- | --- | --- |
| Variable | Diabetes (MDM with interactions) | | |
| Linear | Logit | Log- Binomial |
| Food Desert | -0.045 | -0.014 | -0.005 |
| Elderly\*Food Desert | -0.044\* | -0.030\* | -0.035\*\* |
| Uninsured\*Food Desert | 0.008 | 0.017 | 0.025 |
| Age \*Food Desert | 0.002\*\*\* | 0.001 | 0.001\* |
| Female\* Food Desert | -0.014 | -0.014 | -0.020\*\* |
| Years of Ed\*Food Desert | 0.001 | 0.001 | 0.001 |
| Active\*Food Desert | -0.007 | -0.003 | -0.005 |
| Hispanic\* Food Desert | -0.014 | -0.021 | -0.021\* |
| Black\* Food Desert | 0.012 | 0.006 | 0.002 |
| Hispanic | 0.020\*\* | 0.029\*\*\* | 0.033\*\*\* |
| Black | 0.011 | 0.015\* | 0.017\*\* |
| Asian | 0.014 | 0.015\* | 0.018\*\* |
| Female | 0.006 | 0.007 | 0.009 |
| Poverty level | -0.000\*\*\* | -0.000\*\*\* | -0.000\*\*\* |
| Physical Activity | -0.023\*\*\* | -0.023\*\*\* | -0.023\*\*\* |
| Age | 0.004\*\*\* | 0.005\*\*\* | 0.003\*\*\* |
| Years of Education | -0.005\*\*\* | -0.003\*\* | -0.003\*\*\* |
| Elderly | 0.031\*\* | -0.044\*\*\* | -0.021\* |
| Married | 0.001 | -0.002 | -0.006\*\*\* |
| Uninsured | -0.032\*\*\* | -0.038\*\*\* | -0.049\*\*\* |
| Size of Household | -0.004\*\* | -0.003\* | -0.005\*\*\* |
| constant | 0.013 |  |  |
| r2 | 0.103 |  |  |
| bic | 7361.449 | 11494.256 | 7591.619 |
| chi2 |  | 1964.555 | 2040.429 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Obesity (Mahalanobis Distance Matching) | | | | |
|  | BMI Linear | Linear | Logit | Log-binomial |
| Food desert | 0.626\*\*\* | 0.042\*\*\* | 0.042\*\*\* | 0.041\*\*\* |
| Hispanic | 0.193 | -0.011 | -0.011 | -0.012 |
| Black | 0.901\*\*\* | 0.059\*\*\* | 0.058\*\*\* | 0.056\*\*\* |
| Asian | -0.357\* | -0.030\* | -0.031\* | -0.027\* |
| Female | 0.238\* | 0.041\*\*\* | 0.041\*\*\* | 0.046\*\*\* |
| Poverty level | -0.002\*\*\* | -0.000\*\*\* | -0.000\*\*\* | -0.000\*\*\* |
| Activity | -1.491\*\*\* | -0.087\*\*\* | -0.086\*\*\* | -0.085\*\*\* |
| Age | 0.071\*\*\* | 0.004\*\*\* | 0.004\*\*\* | 0.003\*\*\* |
| Years of Education | -0.054\*\* | -0.006\*\*\* | -0.005\*\*\* | -0.005\*\*\* |
| Elderly | -3.348\*\*\* | -0.177\*\*\* | -0.174\*\*\* | -0.173\*\*\* |
| Married | 0.19 | 0.007 | 0.009 | 0.006 |
| Uninsured | -0.644\*\*\* | -0.039\*\*\* | -0.039\*\*\* | -0.041\*\*\* |
| Size of Household | -0.013 | 0.001 | 0.001 | 0.002 |
| constant | 27.092\*\*\* | 0.287\*\*\* |  |  |
| r2 | 0.048 | 0.037 |  |  |
| bic | 130447.809 | 25872.87 | 24656.603 | 25863.914 |
| chi2 |  |  | 744.444 | 766.347 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Obesity (Mahalanobis Distance Matching) | | | | |
|  | BMI Linear | Linear | Logit | Log-binomial |
| Food desert | 0.760\*\*\* | 0.051\*\*\* | 0.050\*\*\* | 0.049\*\*\* |
| Elderly\*Food Desert | -0.961\*\*\* | -0.065\*\* | -0.064\*\* | -0.060\*\* |
| Hispanic | 0.198 | -0.011 | -0.01 | -0.012 |
| Black | 0.907\*\*\* | 0.059\*\*\* | 0.058\*\*\* | 0.056\*\*\* |
| Asian | -0.351\* | -0.030\* | -0.030\* | -0.027\* |
| Female | 0.237\* | 0.041\*\*\* | 0.041\*\*\* | 0.046\*\*\* |
| Poverty level | -0.002\*\*\* | -0.000\*\*\* | -0.000\*\*\* | -0.000\*\*\* |
| Activity | -1.492\*\*\* | -0.087\*\*\* | -0.086\*\*\* | -0.086\*\*\* |
| Age | 0.071\*\*\* | 0.004\*\*\* | 0.004\*\*\* | 0.003\*\*\* |
| Years of Education | -0.055\*\* | -0.006\*\*\* | -0.005\*\*\* | -0.005\*\*\* |
| Elderly | -2.999\*\*\* | -0.153\*\*\* | -0.150\*\*\* | -0.148\*\*\* |
| Married | 0.191 | 0.007 | 0.009 | 0.006 |
| Uninsured | -0.647\*\*\* | -0.039\*\*\* | -0.039\*\*\* | -0.041\*\*\* |
| Size of Household | -0.013 | 0.001 | 0.001 | 0.002 |
| constant | 27.050\*\*\* | 0.284\*\*\* |  |  |
| r2 | 0.049 | 0.038 |  |  |
| bic | 130445.857 | 25872.001 | 24656.037 | 25864.69 |
| chi2 |  |  | 754.901 | 778.354 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Obesity (Alternative Food Desert Definition) | | | | |
|  | BMI Linear | Linear | Logit | Log-binomial |
| Food desert | 0.543\*\*\* | 0.035\*\*\* | 0.034\*\*\* | 0.032\*\*\* |
| Hispanic | 0.232 | -0.009 | -0.008 | -0.008 |
| Black | 0.932\*\*\* | 0.061\*\*\* | 0.060\*\*\* | 0.059\*\*\* |
| Asian | -0.31 | -0.027\* | -0.027\* | -0.024 |
| Female | 0.230\* | 0.041\*\*\* | 0.041\*\*\* | 0.046\*\*\* |
| Poverty level | -0.002\*\*\* | -0.000\*\*\* | -0.000\*\*\* | -0.000\*\*\* |
| Activity | -1.500\*\*\* | -0.088\*\*\* | -0.087\*\*\* | -0.085\*\*\* |
| Age | 0.069\*\*\* | 0.004\*\*\* | 0.004\*\*\* | 0.003\*\*\* |
| Years of Education | -0.056\*\* | -0.006\*\*\* | -0.005\*\*\* | -0.005\*\*\* |
| Elderly | -3.340\*\*\* | -0.175\*\*\* | -0.173\*\*\* | -0.171\*\*\* |
| Married | -0.058 | -0.003 | -0.004 | -0.003 |
| Uninsured | -0.642\*\*\* | -0.039\*\*\* | -0.039\*\*\* | -0.041\*\*\* |
| Size of Household | -0.022 | 0.001 | 0.001 | 0.001 |
| constant | 27.538\*\*\* | 0.315\*\*\* |  |  |
| r2 | 0.048 | 0.036 |  |  |
| bic | 130463.801 | 25888.868 | 24672.131 | 25883.016 |
| chi2 |  |  | 728.915 | 742.987 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Obesity (Alternative Food Desert Definition) | | | | |
|  | BMI Linear | Linear | Logit | Log-binomial |
| Food desert | 0.573\*\*\* | 0.037\*\*\* | 0.036\*\*\* | 0.034\*\*\* |
| Elderly\*Food Desert | -0.434 | -0.029 | -0.028 | -0.025 |
| Hispanic | 0.237 | -0.008 | -0.008 | -0.008 |
| Black | 0.938\*\*\* | 0.061\*\*\* | 0.060\*\*\* | 0.059\*\*\* |
| Asian | -0.304 | -0.026\* | -0.027\* | -0.024 |
| Female | 0.230\* | 0.041\*\*\* | 0.041\*\*\* | 0.046\*\*\* |
| Poverty level | -0.002\*\*\* | -0.000\*\*\* | -0.000\*\*\* | -0.000\*\*\* |
| Activity | -1.501\*\*\* | -0.088\*\*\* | -0.087\*\*\* | -0.085\*\*\* |
| Age | 0.069\*\*\* | 0.004\*\*\* | 0.004\*\*\* | 0.003\*\*\* |
| Years of Education | -0.057\*\* | -0.006\*\*\* | -0.006\*\*\* | -0.005\*\*\* |
| Elderly | -3.182\*\*\* | -0.165\*\*\* | -0.162\*\*\* | -0.161\*\*\* |
| Married | -0.057 | -0.003 | -0.004 | -0.003 |
| Uninsured | -0.643\*\*\* | -0.039\*\*\* | -0.039\*\*\* | -0.041\*\*\* |
| Size of Household | -0.022 | 0 | 0.001 | 0.001 |
| constant | 27.537\*\*\* | 0.315\*\*\* |  |  |
| r2 | 0.048 | 0.036 |  |  |
| bic | 130470.977 | 25896.399 | 24679.734 | 25891.187 |
| chi2 |  |  | 731.205 | 745.159 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Obesity (MDM with interactions) | | | | |
|  | BMI Linear | Linear | Logit | Log-binomial |
| Food Desert | -0.582 | 0.044 | 0.05 | 0.059 |
| Elderly\*Food Desert | -1.544\*\*\* | -0.078\*\* | -0.066\* | -0.05 |
| Uninsured\*Food Desert | 0.218 | 0.001 | 0.003 | 0.01 |
| Age \*Food Desert | 0.016\* | 0 | 0 | 0 |
| Female\* Food Desert | 0.544\*\* | 0.029\* | 0.026 | 0.023 |
| Years of Ed\*Food Desert | 0.059 | 0.001 | 0.001 | 0.001 |
| Active\*Food Desert | 0.029 | -0.012 | -0.006 | -0.003 |
| Hispanic\* Food Desert | -0.810\*\* | -0.052\*\* | -0.053\*\* | -0.056\*\* |
| Black\* Food Desert | -0.381 | -0.018 | -0.022 | -0.023 |
| Hispanic | 0.471\*\* | 0.007 | 0.009 | 0.01 |
| Black | 1.035\*\*\* | 0.065\*\*\* | 0.066\*\*\* | 0.066\*\*\* |
| Asian | -0.361\* | -0.030\* | -0.031\* | -0.027\* |
| Female | 0.034 | 0.030\*\*\* | 0.031\*\*\* | 0.036\*\*\* |
| Poverty level | -0.002\*\*\* | -0.000\*\*\* | -0.000\*\*\* | -0.000\*\*\* |
| Physical Activity | -1.504\*\*\* | -0.083\*\*\* | -0.084\*\*\* | -0.084\*\*\* |
| Age | 0.063\*\*\* | 0.004\*\*\* | 0.004\*\*\* | 0.003\*\*\* |
| Years of Education | -0.077\*\* | -0.006\*\*\* | -0.006\*\*\* | -0.005\*\* |
| Elderly | -2.785\*\*\* | -0.148\*\*\* | -0.148\*\*\* | -0.152\*\*\* |
| Married | -0.067\* | -0.004 | -0.004 | -0.003 |
| Uninsured | -0.730\*\*\* | -0.039\*\*\* | -0.040\*\*\* | -0.045\*\*\* |
| Size of Household | -0.012 | 0.001 | 0.001 | 0.002 |
| constant | 27.908\*\*\* | 0.308\*\*\* |  |  |
| r2 | 0.05 | 0.038 |  |  |
| bic | 130484.701 | 25924.414 | 24709.6 | 25918.767 |
| chi2 |  |  | 770.586 | 791.399 |

|  |  |  |  |
| --- | --- | --- | --- |
| Underweight (MDM) | | | |
|  | Linear | Logit | Log-binomial |
| Food desert | -0.003 | -0.003 | -0.004\* |
| Elderly\*Food Desert | 0.003 | 0.003 | 0.004 |
| Hispanic | -0.012\*\*\* | -0.013\*\*\* | -0.013\*\*\* |
| Black | -0.004 | -0.004 | -0.004 |
| Asian | 0.004 | 0.003 | 0.003 |
| Female | 0.011\*\*\* | 0.012\*\*\* | 0.010\*\*\* |
| Poverty level | 0 | 0 | 0 |
| Activity | -0.003 | -0.003 | -0.002 |
| Age | -0.000\*\*\* | -0.001\*\*\* | -0.001\*\*\* |
| Years of Education | -0.001 | -0.001 | -0.001\* |
| Elderly | 0.020\*\*\* | 0.022\*\*\* | 0.028\*\*\* |
| Married | 0.002\* | 0.002\* | 0.001\* |
| Uninsured | 0.002 | 0.003 | 0.004\* |
| Size of Household | 0 | 0 | 0 |
| constant | 0.045\*\*\* |  |  |
| r2 | 0.007 |  |  |
| bic | -15566.068 | 2663.091 | -14571.005 |
| chi2 |  | 94.6 | 131.813 |

|  |  |  |  |
| --- | --- | --- | --- |
| Underweight (PSM) | | | |
|  | Linear | Logit | Log-binomial |
| Food desert | -0.004\* | -0.004\* | -0.005\*\* |
| Elderly\*Food Desert | 0.009 | 0.008 | 0.008 |
| Hispanic | -0.011\*\*\* | -0.012\*\*\* | -0.009\*\*\* |
| Black | -0.004\*\* | -0.005\*\* | -0.003\* |
| Asian | 0.006\*\* | 0.004\* | 0.004\*\* |
| Female | 0.014\*\*\* | 0.016\*\*\* | 0.014\*\*\* |
| Poverty level | 0 | 0 | 0 |
| Activity | -0.003\*\* | -0.003\*\* | -0.002 |
| Age | -0.000\*\*\* | -0.000\*\*\* | -0.001\*\*\* |
| Years of Education | -0.001\*\*\* | -0.001\*\*\* | -0.001\*\*\* |
| Elderly | 0.014\*\*\* | 0.016\*\*\* | 0.019\*\*\* |
| Married | 0.002\*\*\* | 0.002\*\*\* | 0.002\*\*\* |
| Uninsured | 0 | 0.001 | 0.001 |
| Size of Household | -0.001 | -0.001 | 0 |
| constant | 0.045\*\*\* |  |  |
| r2 | 0.009 |  |  |
| bic | -50789.954 | 7643.56 | -50849.438 |
| chi2 |  | 385.179 | 431.356 |

|  |  |  |  |
| --- | --- | --- | --- |
| Underweight (Alternative Definition of Food Desert) | | | |
|  | Linear | Logit | Log-binomial |
| Food desert | -0.006\*\* | -0.006\*\* | -0.005\*\* |
| Elderly\*Food Desert | 0.007 | 0.006 | 0.003 |
| Hispanic | -0.011\*\*\* | -0.012\*\*\* | -0.009\*\*\* |
| Black | -0.004\*\* | -0.005\*\* | -0.004\* |
| Asian | 0.006\*\* | 0.004\* | 0.004\*\* |
| Female | 0.014\*\*\* | 0.016\*\*\* | 0.014\*\*\* |
| Poverty level | 0 | 0 | 0 |
| Activity | -0.003\* | -0.003\*\* | -0.002 |
| Age | -0.000\*\*\* | -0.000\*\*\* | -0.001\*\*\* |
| Years of Education | -0.001\*\*\* | -0.001\*\*\* | -0.001\*\*\* |
| Elderly | 0.015\*\*\* | 0.017\*\*\* | 0.020\*\*\* |
| Married | 0.002\*\*\* | 0.002\*\*\* | 0.002\*\*\* |
| Uninsured | 0 | 0.001 | 0.001 |
| Size of Household | -0.001 | -0.001 | 0 |
| constant | 0.046\*\*\* |  |  |
| r2 | 0.009 |  |  |
| bic | -50795.646 | 7637.609 | -50846.871 |
| chi2 |  | 391.13 | 431.29 |

|  |  |  |  |
| --- | --- | --- | --- |
| Hypertension (MDM) | | | |
|  | Linear | Logit | Log-binomial |
| Food desert | 0.037\*\*\* | 0.037\*\*\* | 0.032\*\*\* |
| Hispanic | -0.037\*\*\* | -0.039\*\*\* | -0.026\*\* |
| Black | 0.054\*\*\* | 0.054\*\*\* | 0.053\*\*\* |
| Asian | 0.031\*\* | 0.032\*\* | 0.049\*\*\* |
| Female | -0.014\* | -0.012\* | -0.002 |
| Poverty level | -0.000\*\*\* | -0.000\*\*\* | -0.000\*\*\* |
| Activity | -0.043\*\*\* | -0.041\*\*\* | -0.037\*\*\* |
| Age | 0.013\*\*\* | 0.012\*\*\* | 0.012\*\*\* |
| Years of Education | -0.006\*\*\* | -0.005\*\*\* | -0.003\*\*\* |
| Elderly | -0.013 | -0.066\*\*\* | -0.131\*\*\* |
| Married | -0.032\*\*\* | -0.016\* | -0.002 |
| Uninsured | -0.060\*\*\* | -0.056\*\*\* | -0.080\*\*\* |
| Size of Household | -0.009\*\*\* | -0.008\*\*\* | -0.012\*\*\* |
| constant | -0.080\*\*\* |  |  |
| r2 | 0.284 |  |  |
| bic | 19606.868 | 18957.099 | 20225.625 |
| chi2 |  | 6067.278 | 6426.119 |

|  |  |  |  |
| --- | --- | --- | --- |
| Hypertension (PSM) | | | |
|  | Linear | Logit | Log-binomial |
| Food desert | 0.041\*\*\* | 0.041\*\*\* | 0.052\*\*\* |
| Elderly\*Food Desert | -0.025 | -0.028 | -0.045\*\*\* |
| Hispanic | -0.036\*\*\* | -0.039\*\*\* | -0.026\*\* |
| Black | 0.054\*\*\* | 0.054\*\*\* | 0.053\*\*\* |
| Asian | 0.031\*\* | 0.033\*\* | 0.049\*\*\* |
| Female | -0.014\* | -0.012\* | -0.003 |
| Poverty level | -0.000\*\*\* | -0.000\*\*\* | -0.000\*\*\* |
| Activity | -0.043\*\*\* | -0.041\*\*\* | -0.036\*\*\* |
| Age | 0.013\*\*\* | 0.012\*\*\* | 0.012\*\*\* |
| Years of Education | -0.006\*\*\* | -0.005\*\*\* | -0.003\*\*\* |
| Elderly | -0.004 | -0.057\*\*\* | -0.112\*\*\* |
| Married | -0.032\*\*\* | -0.016\* | -0.001 |
| Uninsured | -0.060\*\*\* | -0.057\*\*\* | -0.080\*\*\* |
| Size of Household | -0.009\*\*\* | -0.008\*\*\* | -0.012\*\*\* |
| constant | -0.081\*\*\* |  |  |
| r2 | 0.284 |  |  |
| bic | 19614.633 | 18963.991 | 20213.968 |
| chi2 |  | 6070.278 | 6397.473 |

|  |  |  |  |
| --- | --- | --- | --- |
| Hypertension (Alternative Definition of Food Desert) | | | |
|  | Linear | Logit | Log-binomial |
| Food desert | 0.027\*\*\* | 0.025\*\*\* | 0.022\*\*\* |
| Hispanic | -0.036\*\*\* | -0.038\*\*\* | -0.023\* |
| Black | 0.056\*\*\* | 0.056\*\*\* | 0.054\*\*\* |
| Asian | 0.033\*\* | 0.035\*\*\* | 0.051\*\*\* |
| Female | -0.012\* | -0.01 | -0.002 |
| Poverty level | -0.000\*\*\* | -0.000\*\*\* | -0.000\*\*\* |
| Activity | -0.043\*\*\* | -0.042\*\*\* | -0.037\*\*\* |
| Age | 0.013\*\*\* | 0.012\*\*\* | 0.012\*\*\* |
| Years of Education | -0.006\*\*\* | -0.005\*\*\* | -0.003\*\*\* |
| Elderly | -0.01 | -0.065\*\*\* | -0.129\*\*\* |
| Married | 0.007\*\*\* | 0.003 | 0.001 |
| Uninsured | -0.059\*\*\* | -0.056\*\*\* | -0.080\*\*\* |
| Size of Household | -0.011\*\*\* | -0.010\*\*\* | -0.012\*\*\* |
| constant | -0.107\*\*\* |  |  |
| r2 | 0.283 |  |  |
| bic | 19640.986 | 18987.94 | 20250.854 |
| chi2 |  | 6036.437 | 6394.157 |

|  |  |  |  |
| --- | --- | --- | --- |
| Hypertension (Alternative Definition of Food Desert) | | | |
|  | Linear | Logit | Log-binomial |
| Food desert | 0.026\*\*\* | 0.024\*\*\* | 0.023\*\*\* |
| Elderly\*Food Desert | 0.005 | 0.003 | -0.003 |
| Hispanic | -0.036\*\*\* | -0.038\*\*\* | -0.023\* |
| Black | 0.056\*\*\* | 0.056\*\*\* | 0.055\*\*\* |
| Asian | 0.033\*\* | 0.034\*\*\* | 0.051\*\*\* |
| Female | -0.012\* | -0.01 | -0.002 |
| Poverty level | -0.000\*\*\* | -0.000\*\*\* | -0.000\*\*\* |
| Activity | -0.043\*\*\* | -0.042\*\*\* | -0.037\*\*\* |
| Age | 0.013\*\*\* | 0.012\*\*\* | 0.012\*\*\* |
| Years of Education | -0.006\*\*\* | -0.005\*\*\* | -0.003\*\*\* |
| Elderly | -0.012 | -0.066\*\*\* | -0.128\*\*\* |
| Married | 0.007\*\*\* | 0.003 | 0.001 |
| Uninsured | -0.059\*\*\* | -0.056\*\*\* | -0.080\*\*\* |
| Size of Household | -0.011\*\*\* | -0.010\*\*\* | -0.012\*\*\* |
| constant | -0.107\*\*\* |  |  |
| r2 | 0.283 |  |  |
| bic | 19650.76 | 18997.779 | 20260.636 |
| chi2 |  | 6036.49 | 6393.196 |

|  |  |  |  |
| --- | --- | --- | --- |
| Variable | Hypertension (MDM with interactions) | | |
| Linear | Logit | Log- Binomial |
| Food Desert | -0.035 | 0.015 | 0.024 |
| Elderly\*Food Desert | -0.085\*\*\* | -0.038 | -0.059\*\*\* |
| Uninsured\*Food Desert | 0.01 | 0.015 | 0 |
| Age \*Food Desert | 0.002\*\*\* | 0 | 0 |
| Female\* Food Desert | 0.019 | 0.02 | 0.016 |
| Years of Ed\*Food Desert | 0.001 | 0 | 0 |
| Active\*Food Desert | 0.009 | 0.011 | 0.005 |
| Hispanic\* Food Desert | -0.039\* | -0.041\* | -0.044\* |
| Black\* Food Desert | -0.002 | -0.005 | 0.003 |
| Hispanic | -0.024\* | -0.025\* | -0.008 |
| Black | 0.054\*\*\* | 0.056\*\*\* | 0.051\*\*\* |
| Asian | 0.030\*\* | 0.032\*\* | 0.049\*\*\* |
| Female | -0.019\*\* | -0.018\* | -0.009 |
| Poverty level | -0.000\*\*\* | -0.000\*\*\* | -0.000\*\*\* |
| Physical Activity | -0.046\*\*\* | -0.045\*\*\* | -0.038\*\*\* |
| Age | 0.013\*\*\* | 0.012\*\*\* | 0.012\*\*\* |
| Years of Education | -0.006\*\*\* | -0.005\*\*\* | -0.003\*\* |
| Elderly | 0.02 | -0.052\*\*\* | -0.106\*\*\* |
| Married | 0.007\*\*\* | 0.002 | 0.001 |
| Uninsured | -0.063\*\*\* | -0.062\*\*\* | -0.081\*\*\* |
| Size of Household | -0.010\*\*\* | -0.009\*\*\* | -0.011\*\*\* |
| constant | -0.087\*\* |  |  |
| r2 | 0.285 |  |  |
| bic | 19668.744 | 19025.882 | 20268.717 |
| chi2 |  | 6077.634 | 6430.265 |

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