THE IMPACT OF FOOD DESERTS ON FOOD INSUFFICIENCY AND SNAP PARTICIPATION AMONG THE ELDERLY

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Residents of neighborhoods with limited access to grocery stores may face barriers to obtaining adequate food for a healthy diet. Low-income elderly may be uniquely affected by these so-called "food deserts" due to limited transportation options, strong attachments to local neighborhoods, fixed incomes, and physical limitations for food shopping. Using 2006 and 2010 Health and Retirement Study data linked to census tract-level measures of food deserts, this study measures whether living in a food desert affects food and material hardship, participation in food assistance programs, and the food spending of elderly adults. In both cross-sectional and fixed effects regressions of elderly residents of urban counties, we find little evidence that living in a food desert affects these outcomes. We find, however, that individuals residing in a food desert without a vehicle are 12 percentage points more likely to report food insufficiency. Those SNAP recipients living in food deserts are 11 percentage points more likely to receive subsidized meals, while nonparticipants in food deserts and SNAP recipients outside of food deserts are less likely to receive subsidized meals. Our findings suggest that seniors without vehicles and SNAP recipients in food deserts may be the most vulnerable to limited food store access.

Key words: Food deserts, food environment, food sufficiency, elderly, Supplemental Nutrition Assistance Program.

JEL codes: I3, Q18, R12, R40.

The Economic Research Service (ERS) of the U.S. Department of Agriculture (USDA) estimates that in 2010, more than 18 million persons, including almost 5 million elderly, lived in a food desert; this is a low-income U.S. Census tract where a substantial number or share of residents had low levels of access to a grocery store (ERS 2013). A growing number of policies seek to reduce the population with limited food access because limited access to nutritious food choices is thought to be related to poor health and economic well-being.

The food choices made by food desert residents may be limited not only by proximity, but also by food prices and travel costs. Because supermarkets tend to have the lowest food prices (Hausman and Leibtag 2007; Kaufman et al. 1997), residents of neighborhoods without supermarkets may face greater difficulty affording adequate food due to higher food prices in the smaller stores nearby. Some food desert residents may overcome this by traveling farther to reach healthier options at lower average prices. Traveling to other neighborhoods, however, increases the travel and time costs of food acquisition. As a result, living in a food desert may not only affect diet quality, but also the risk of food hardship, household budget tradeoffs, and the need for food assistance programs.

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Amer. J. Agr. Econ. 98(1): 19–40; doi: 10.1093/ajae/aav044
Published online August 10, 2015

Elderly food desert residents may be particularly susceptible to these harmful effects. Strong neighborhood attachments may encourage the elderly to stay after food retailers leave a neighborhood. Moreover, limitations on driving, walking, and/or using public transit may make accessing stores outside the immediate area difficult.[1] Higher food prices and travel costs, in combination with fixed incomes, could lead to greater food hardship among the elderly in food deserts.

This food hardship may not be adequately addressed by the Supplemental Nutrition Assistance Program (SNAP), the primary nutritional assistance program addressing food insufficiency, because the additional income from SNAP benefits may be offset by higher food prices and/or greater travel costs. If true, limited access to food retailers may be one explanation for low SNAP take-up rates among the eligible elderly—35.1% of eligible elderly individuals participate in SNAP, compared to 75.6% of eligible non-elderly adults—and increased reliance on the Meals-on-Wheels program (Eslami, Leftin, and Strayer 2012).

Understanding the effects of food deserts on well-being is of substantial policy importance as policies to improve food access ranging from new supermarket development to mobile fruit and vegetable retailers are being implemented across all levels of government.[2] In FY2013, for example, the U.S. federal government devoted $314 million to improving food access and supporting healthy food retail development through existing community development programs.[3] The Agricultural Act of 2014 (the 2014 Farm Bill) formalized this effort as the Healthy Food Financing Initiative (HFFI) by authorizing $125 million to improve access to nutritious food. State and local governments also allocated resources toward improving food access in underserved communities. As these policies evolve, ensuring they are well-targeted and that they improve both the diet and food adequacy of low-income consumers is important.

A better understanding of food access and food assistance use among the large and growing elderly population is also important for understanding how SNAP affects hardship. Elderly individuals are less likely to participate in SNAP than other demographic groups, despite having fixed incomes and more generous program rules that should increase their SNAP use. In FY2012, only 9.0% of SNAP participants were elderly (age 60 or over), and 7.7% of benefits went to elderly adults (Gray and Eslami 2014). While the elderly have lower food insecurity rates than other groups, 11.4% of the elderly faced some type of food insecurity between 2001 and 2005 (Ziliak, Gundersen, and Haist 2008). Even more striking, however, the number of elderly people at-risk for hunger grew between 2001 and 2011 (Ziliak and Gundersen 2013).

With the recent Great Recession reducing the wealth and employment prospects of many people at or near retirement, food hardship and the need for food assistance will likely increase. If food access limitations are related to food insufficiency or encourage older Americans to shift from entitlement programs like SNAP to non-entitlement programs such as subsidized meals, those who are at-risk for hunger will be more vulnerable to both the Congressional budget process and the ability of non-profit food providers to meet their needs.

We utilize the 2006 and 2010 waves of restricted-use Health and Retirement Study (HRS) data to document the relationship between food deserts and food insufficiency, household budget tradeoffs, food assistance participation, and food spending for a sample of low-income elderly adults living in urban census tracts. We find little evidence that food deserts are associated with food or material hardship, or receipt of food assistance. However, for those that do not own a vehicle, we find a strong effect of living in a food desert on food insufficiency—elderly food desert residents that do not own a vehicle were 12 percentage points more likely to report food insufficiency than otherwise similar food desert residents who owned a vehicle. Our results suggest that elderly food desert residents without a personal vehicle may be particularly susceptible to poor food

[1] Households could choose to shop at a location not nearby their home, such as near a workplace or other location. Widener et al. (2013) show differences in access measures when commuting patterns are considered, and Hamrick and Hopkins (2012) provide evidence that shoppers combine work and other activities around grocery shopping. With less labor force attachment for the elderly, we believe this is less of a concern than for other demographic groups.

[2] Local efforts to boost access to healthy foods are growing. See the Healthy Food Access Portal for specific details about these and other examples (http://www.healthyfoodaccess.org/).

[3] The federal Healthy Food Financing Initiative is modeled after Pennsylvania's Fresh Food Financing Initiative, a public-private partnership to develop supermarkets in underserved areas.

access and reducing food hardship in areas with limited food access may require greater attention to transportation needs.

We also find that residents of food deserts are 4 percentage points less likely to receive subsidized meals, but SNAP recipients living in food deserts are nearly 11 percentage points more likely to receive subsidized meals. This suggests that for those who have limited access to food retailers, SNAP and subsidized meals are complementary programs in the nutritional safety net.

We make several contributions to the growing body of literature on the effects of food deserts. To our knowledge, we are the first to examine the effects of food deserts on the elderly, and among the first to address the relationship between food deserts and food sufficiency. We also provide the first examination of both 2006 and 2010 food desert data, which allows us to exploit longitudinal data on individuals and their food environments. In doing so, we examine changes in the food environment and overcome a notable shortcoming of prior work by controlling for a key individual-level (as opposed to a neighborhood-level) indicator of access—that is, whether the household faces transportation difficulties. This examination allows us to understand a key mechanism through which the elderly may be uniquely affected by living in a food desert.

Conceptual Framework and Previous Literature

The literature on food deserts and, more generally, the food environment primarily examines the purchase and consumption of "healthy food" such as fruits and vegetables, and diet-related health outcomes such as diet quality and body weight. The food environment is hypothesized to affect these outcomes because it affects the availability, prices, and nutritional composition of the food available to households.

The literature has paid little attention to other outcomes that could be related to the food environment, including food sufficiency and use of food assistance.[4] Food insufficiency and food insecurity, the official measures of food hardship in the United States, have negative consequences for individuals. For instance, inadequate food and the coping mechanisms individuals adopt when faced with food hardship, such as consumption of food with little nutritional value, reduce health (Gundersen and Ribar 2011). Among the elderly, food insecurity reduces nutrient intake (Bhattacharya et al. 2003; Lee and Frongillo 2001; Ziliak, Gundersen, and Haist 2008), lowers body mass index (BMI; Bhattacharya et al. 2003), results in fair or poor health (Lee and Frongillo 2001; Ziliak, Gundersen, and Haist 2008), and is associated with limitations in Activities of Daily Living (ADLs; Ziliak, Gundersen, and Haist 2008).[5]

Food insecurity is not solely due to low incomes (Demarco and Thornburn 2009; Gundersen and Ribar 2011; Mammen, Bauer, and Richards 2009; Ziliak, Gundersen, and Haist 2008; Ziliak and Gundersen 2009). Indeed, more than half of the elderly with incomes above the poverty line experienced some problem obtaining adequate resources for food, and these problems are correlated with age, race, living arrangements, education, and geography (Ziliak, Gundersen, and Haist 2008). The food assistance safety net, including SNAP, exists to reduce the prevalence of food insecurity and poor diet and nutrition. The best evidence that addresses the endogeneity of SNAP participation finds that SNAP reduces food insecurity (Caswell and Yaktine 2013; Gundersen and Oliveira 2001; Nord 2013; Nord and Prell 2011; Wilde and Nord 2005; Ratcliffe, McKernan, and Zhang 2011; Yen et al. 2008).[6] Still, SNAP's effectiveness likely depends on the accessibility of retailers where participants can redeem benefits.

Food prices are one channel through which the food environment could affect food hardship. Most research on how the food environment affects food prices focuses on the cost of food items, especially fruits and vegetables, or the cost of food in neighborhoods that differ by store access, store type, income, and race/ethnicity. For example, there is good evidence that supermarkets and

[4] One exception is Bonanno and Li (2012), who examine the relationship between adult food insecurity and type of food outlet (Walmart Supercenters, medium-to-large grocery stores, and small food stores).

[5] ADLs is a standard measure used to assess whether an individual can live independently, and includes eating, bathing, dressing, getting out of bed, and transferring.

[6] A vast body of literature exists on the effect of SNAP on food insecurity (for reviews, see Gundersen, Kreider, and Pepper 2011 and Caswell and Yaktine 2013).

supercenters offer more variety and lower prices than other types of stores, but mixed evidence on how food prices vary across different stores and neighborhoods and across subpopulations of interest (Broda, Leibtag, and Weinstein 2009; Cassady, Jetter, and Culp 2007; Chung and Myers 1999; Hayes 2000; Hausman and Leibtag 2007; Hendrickson, Smith, and Eikenberry 2006; Kaufman et al. 1997).[7] Thus, holding income constant, greater access to a supermarket may allow households to purchase a larger quantity of food, and therefore reduce the likelihood of food hardship.

Previous work on the relationship between food prices and food security has examined geographic areas much larger than the neighborhood. At the county level, Bonanno and Li (2012) find that food security is negatively correlated with the number of medium and large grocery stores per capita, as well as the number of smaller food stores per capita. Gregory and Coleman-Jensen (2013) find that food price variation across U.S. regions affects the prevalence of food security among SNAP recipients. Other costs, however, may also be important. For example, budget tradeoffs such as those faced by low-income households facing high heating or cooling costs result in reduced caloric intake and increased risk of food insecurity (Bhattacharya et al. 2003; Nord and Kantor 2006). If food prices are higher in food deserts, they could increase food insufficiency or crowd out expenditures on other household necessities.

Individuals also face time and travel costs to acquire food. If food prices are higher inside food deserts, consumers may travel to access lower prices outside their neighborhood and purchase greater quantities of food (or a greater variety or quality). The Community Development Financial Institutions Fund (CDFI Fund) estimates that residents of areas with limited supermarket access spend, on average, $1,120 annually on food products outside their neighborhood (CDFI Fund 2012). Broda, Leibtag, and Weinstein (2009) found that consumers with low incomes (between $8,000-$30,000 per year) pay the lowest prices, while consumers with very low incomes (less than $8,000) pay 0.5% to 1.3% more for the same grocery items. Those with the highest incomes pay the most. Thus, some lower-income consumers can shop at lower-price food retailers, but the poorest may not be able to access stores with the lowest prices.

One reason that some may not access stores with the lowest prices is that travel can be costly. Using 2007 data from New Orleans, Rose et al. (2009) estimate that, depending on the travel mode, the difference in the combined travel and time costs to the nearest supermarket for those in census tracts with poor supermarket access and those with good supermarket access range from over $5 to almost $60 per trip. These costs are not trivial and could force budget tradeoffs that increase food hardship. Feather (2003) calculates that improving store access for SNAP recipients would increase consumer welfare by $500 million to $1 billion.

One's food environment may also affect the decision to participate in food assistance programs, particularly SNAP and subsidized meals programs like Meals-on-Wheels. A lack of affordable retailers to redeem benefits makes the program less attractive and may encourage a reliance on subsidized meal programs.[8] High prices at neighborhood retailers also decrease the purchasing power of SNAP benefits, and possibly hinder its ability to reduce food insufficiency. On the other hand, SNAP benefits could be used to free up other household resources to make travel to stores that are farther away more feasible (Andrews, Bhatta, and Ver Ploeg 2013).

Studies of SNAP participation among the elderly indicate that their lower participation rates compared to all other eligible groups are due to a lack of awareness about eligibility (Daponte, Sanders, and Taylor 1999; Hollonbeck and Ohls 1984; Wolfe et al. 1996; Wu 2009), stigma (Gabor et al. 2002), low benefit levels (Gabor et al. 2002; Wu 2009), and crowd-out from other nutritional assistance programs like subsidized meals (Wu 2009). The elderly may also face higher costs in navigating the application process (Wilde and Dagata 2002; Heflin and Mueser 2010) or have less need for the program (Haider, Jacknowitz, and Schoeni 2003).[9]

[7] Most studies focus only on average prices within neighborhood stores rather than prices paid by shoppers, regardless of if they shop in their neighborhood or outside of their neighborhood.

[8] A wide variety of food retailers, from large supermarkets to convenience stores to farmers' markets, accept SNAP benefits. For details about retailer eligibility during our sample period and for changes in eligibility made in the 2014 Agricultural Act, see USDA (2014).

[9] Zedlewski and Issa (2010) note that long waiting lists exist for Meals on Wheels, suggesting that unmet nutrition needs do

Data and Methodology

We use restricted-use data from the 2006 and 2010 Health and Retirement Study (HRS), a longitudinal survey that began in 1992 and collects data on more than 20,000 Americans over the age of 50 every two years. The richness of the HRS data allows us to explore a number of outcomes that could be affected by food deserts, including food insufficiency, budget crowd-out, receipt of food assistance programs, and food spending.[10] The panel aspect of the data also allows us to examine how these outcomes relate to changes in the food desert status of our sample.

Measuring the Food Environment

Several national level measures of limited food access have been developed (The Reinvestment Fund 2012; Centers for Disease Control and Prevention 2009 and 2011; ERS 2013 and 2015).[11] We use the food desert measure developed in 2011 by the ERS in support of the proposed HFFI, and updated in 2013. The 2011 measure uses 2006 food retailer data and 2000 census income and tract boundaries to classify tracts as food deserts if they were both low-income and contained a significant number or share of residents who live far—one mile in urban areas and 10 miles in rural areas—from a supermarket (ERS 2013).[12]

Over 6,500 census tracts (9.6% of all tracts) containing 13.6 million individuals with limited access were classified as food deserts in 2006. The 2013 updated measure used 2010 food retailer data, 2010 census tract definitions, 2010 decennial census data, and 2006–2010 American Community Survey data. This updated measure estimated that 8,959 census tracts (12.3% of all census tracts) were food deserts in 2010, and contained more than 18 million individuals with limited access to supermarkets (ERS 2013).

Figures 1 and 2 are maps of food deserts in Dallas County, Texas in 2006 (figure 1) and 2010 (figure 2). Food desert census tracts are dark gray in each figure.[13] The number of food desert census tracts in Dallas County increased between 2006 and 2010, a trend consistent with national-level estimates. A large portion of this increase may be due to declines in income between 2000 and 2010 arising from the Great Recession. Comparing figures 1 and 2, some parts of the county were food deserts in both years, but other tracts experienced change, as supermarkets closed or opened.

In robustness checks, we include additional census tract measures of the respondent's food environment from Dun and Bradstreet Marketplace Data (D&B), namely the number of grocery stores, the number of restaurants, and the number of drug stores.[14] The number of grocery stores includes stores of all sizes, not only supermarkets but also smaller retailers such as bodegas and convenience stores that are not captured in the food desert measure. The number of restaurants includes both fast food restaurants and sit-down restaurants. The number of drug stores is included because many drug stores sell basic staple grocery items and may participate in SNAP. In specifications with the D&B data, we also control for the census tract population because the number of food retailers will be correlated with the population size.

The D&B data capture the respondent's food environment and provide a check to ensure that our estimates are not biased by the requirement that a food desert tract is low-income. We link the ZIP code-level D&B data to the respondent's census tract

exist. Like other groups, the elderly report "too many hassles" as a reason for not participating in SNAP (Daponte, Sanders, and Taylor 1999; Gabor et al. 2002). Yet, the elderly likely have more leisure time than other groups and should face lower opportunity costs than working households or households with children.

[10] The HRS does not include the Food Security Survey Module so we are unable to measure food security status, only self-reports of insufficient food due to lack of resources. Gundersen and Ribar (2011) conclude that self-reports of food insufficiency are significantly correlated with food security status.

[11] Measuring the food environment, particularly at the national level, is problematic because it is difficult to assess food availability and prices among retailers. Additionally, measuring access at the neighborhood level, rather than the individual level, may mask differences in resources across individuals that may be related to other characteristics such as vehicle availability, transportation modes, social networks, and food preferences.

[12] Low-income is based on the New Markets Tax Credit program definition: "Any population Census tract if: (a) the poverty rate for that tract is at least 20%, or (b) in the case of a tract not located within a metropolitan area, the median family income for the tract does not exceed 80% of statewide median family income, or in the case of a tract located within a metropolitan area, the median family income for the tract does not exceed 80% of the greater of statewide median family income or the metropolitan area median family income."

[13] Tract boundaries and shapes are not necessarily the same in these two figures: the 2006 food deserts are based on 2000 census tract boundaries, while the 2010 food deserts are based on 2010 tract boundaries.

[14] Specifically, the D&B data is from the fourth quarter of 2005 and the fourth quarter of 2009.

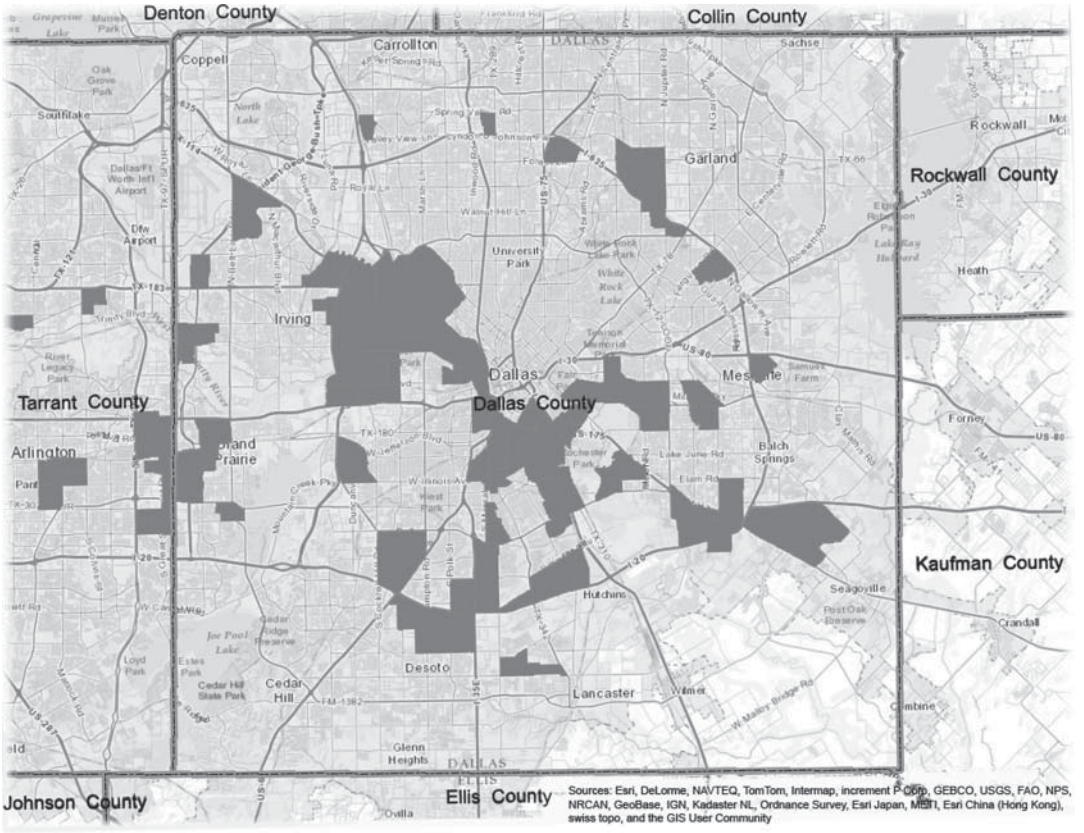

Figure 1. Food deserts in Dallas County, Texas, 2006

Note: Food desert census tracts are shown in dark gray. Food desert census tracts are based on ERS data that merges 2006 food retailer data and 2000 census income data to 2000 census tract definitions (ERS 2013).

based on the proportion of the ZIP code in each census tract. For example, if a ZIP code has 20 grocery stores and the respondent's census tract comprises 20% of the ZIP code, then that census tract would be assigned 4 grocery stores (20×0.20). While this method has been used extensively in the economics literature (e.g., see Rosenthal and Strange 2003 and Rohlin 2011), it can result in census tracts with fractional grocery stores, restaurants, or drug stores.

The D&B food environment data provide a useful supplement to our food desert measure, but do not capture the distance of food retailers from residential populations and include many smaller stores where few do the majority of their food shopping. In contrast, the food desert measure captures distance from residents to food retailers, even if the nearest food retailer is in an adjacent census tract. Additionally, the food desert measure captures SNAP retailers that are supermarkets, supercenters, and large grocery stores, which comprise almost 88% of SNAP benefit redemptions (Castner and Henke 2011).

Methods

The 2006 and 2010 waves of the HRS are matched to the 2006 and 2010 ERS food desert data. For each wave, we select respondents who are aged 60 and older, the definition of elderly in SNAP. We also limit our sample to respondents with household incomes at or below 200% of the federal poverty line in the wave prior to our sample period (2004 for the 2006 sample and 2008 for the 2010 sample). This sample selection ensures that we have individuals who are most likely to be both SNAP eligible and at-risk of food insufficiency. It also allows us to focus on those more likely to live in

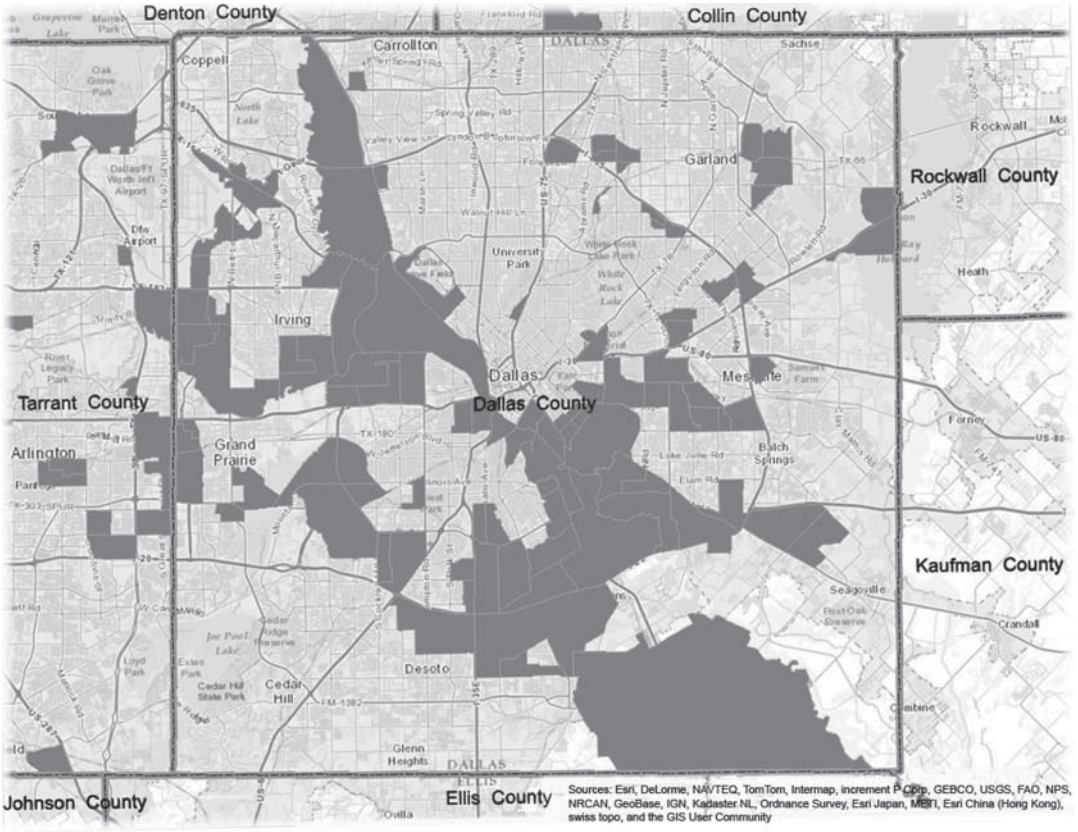

Figure 2. Food deserts in Dallas County, Texas, 2010

Note: Food desert census tracts are shown in dark gray. Food desert census tracts are based on ERS data that merges 2010 food retailer data and 2006–2010 ACS income data to 2000 census tract definitions (ERS 2013).

census tracts that meet the income criteria to be considered a food desert. We expect that these individuals face greater food access barriers than higher-income individuals.

We further restrict our samples to those living in urban areas to use a common definition of a food desert—populations living more than 1 mile from a supermarket. Almost 82% of 2006, and about 88% of 2010 food desert residents, lived in urban areas in 2010.

To measure how residing in a food desert affects the outcomes of interest, we estimate the following equation:

$$
\begin{aligned}
(1)\qquad Outcome_{icst} = {} & \alpha + \beta_1 FoodDesert_{ct} \\
& + \beta_2 NoVehicle_{it} \\
& + \boldsymbol{\beta_3 Indiv_{it}} \\
& + \boldsymbol{\beta_4 CensusTract_{ct}} \\
& + \delta_s + \varepsilon_{icst}
\end{aligned}
$$

where i, c, s, and t index household, census tract, state, and time, respectively. Further, *Outcome* is one of the outcomes of interest and *FoodDesert* is a dichotomous variable indicating that the household lived in an area designated as a food desert in the relevant year. The variable *NoVehicle* reflects that the household does not own a vehicle in the relevant year. While vehicle ownership may potentially be endogenous to household preferences and residential location, it best captures limitations that households face in accessing food due to lack of transportation.

The outcomes we consider relate to food and material hardship that the respondent reports experiencing at any time since the last interview (roughly two years): food insufficiency, skipped meals, and skipped prescription drugs. Each of these measures is based on the respondent reporting that the primary reason for their behavior was a lack of financial resources. Food insufficiency

is measured by the respondent reporting that anyone in the household was unable to purchase enough food due to lack of financial resources. Skipped meals and skipped prescription drugs each reflect that the respondent reports that anyone in the household skipped meals and skipped purchasing prescription drugs, respectively, due to a lack of financial resources.

We also measure receipt of two food assistance programs: SNAP and subsidized meals (commonly referred to as Meals-on-Wheels). We hypothesize that food deserts have an ambiguous effect on SNAP receipt, while subsidized meal receipt reflects both a lack of financial resources and a lack of access to food retailers. Finally, we examine the natural logarithm of the household's weekly food spending to determine if those in food deserts spend more to meet their food needs. For food spending, we total the weekly amount spent on food consumed at home, food delivered, and food eaten away from home. Food spending does not include SNAP benefits due to its endogeneity, so instead we include SNAP receipt as a control variable in that model.

We also control for other factors that may be related to either the food desert status of the census tract or the outcomes of interest, including the respondent's characteristics and the characteristics of the local economic environment. The vector ***Indiv*** contains the demographic and economic characteristics of the respondent and the household: the respondent's gender, marital status, age, age squared, race, number of children ever born, employment status; whether the employment requires physical exertion; whether the respondent has at least some college education; real household income (in thousands of dollars); and the size of the household. We also include a proxy for whether the respondent has a child living within 10 miles to control for the potential assistance that a family member may provide in accessing food and transportation.

The vector ***CensusTract*** controls for characteristics of the local economic environment, including county unemployment rate, portion of the census tract composed of non-whites, and census tract poverty rate for senior households (aged 65 and over). We include the housing price index of the metropolitan statistical area (MSA) from the Federal Housing Finance Agency to control for housing prices (and likely rents), as well as trends in housing prices related to the severity of the Great Recession in each MSA. Finally, state fixed effects, δ, control for time invariant characteristics of the state.

We estimate equation 1 in two ways. First, we use a cross-sectional approach by estimating the model separately in 2006 and 2010 for all households that meet our sample selection criteria in the relevant year (these results appear in a supplementary online appendix). We also create a balanced panel with individuals that meet our sample selection criteria in 2006 and are observed in the HRS in 2010. The balanced panel uses individual fixed effects to identify the effect of food deserts from changes in the food desert status of an individual's census tract over time. This is our preferred approach and the focus of the analysis. All estimates are weighted by the appropriate HRS weight. In all models, we utilize robust standard errors, and for the balanced panel models we cluster standard errors at the individual level.[15]

Our methodology is an improvement on previous work. Fixed effects control for key individual-level (as opposed to a neighborhood-level) indicators of food access. Our balanced panel model controls for time-invariant food preferences and food habits that play an important role in food choices and dietary outcomes, as well as residential location decisions that may depend on unobservable preferences for local amenities such as grocery stores.[16] Individual fixed effects also control for any time-invariant mobility or other limitations that create difficulties in food acquisition. Many previous studies fail to control for individual factors that may affect the level of food access, particularly car ownership, which increases the set of available stores (for exceptions see Inagami et al. 2009; Rose and Richards 2004).

[15] We experimented with clustering standard errors at the county level. The results are largely unchanged, save for a slight increase in the standard errors for the subsidized meal outcomes, which renders the point estimate statistically insignificant with p-values of 0.12. Because the county does not adequately capture the food environment faced by individuals, particularly in urban areas, we report standard errors clustered at the individual level.

[16] Two longitudinal studies in the United Kingdom suggest that when supermarkets open in underserved areas there is little to no change in the consumption of fruits and vegetables (Wrigley, Warm, and Margetts 2003; Cummins et al. 2005). Another study based on longitudinal data in the United States did not find a relationship between supermarket proximity and dietary intake (Boone-Heinonen et al. 2011). Harding and Lovenheim (2014) find that census-tract store density measures are not related to broad categories of foods purchased by consumers.

Results

Table 1 presents the summary statistics of our sample of low-income elderly urban residents in 2006 and 2010 by food desert status in columns 1 through 4. In each year, significant differences in the sample means by food desert status are denoted in table 1. The mean income of residents of food deserts is approximately $4,000 less than the income of residents in other census tracts in 2006 and $6,000 less in 2010, which are large differences considering that the sample is limited to households at or below 200% of the poverty level in the prior wave.[17] In both waves, elderly residents of food deserts live in census tracts with significantly greater elderly poverty rates and a greater proportion of minorities, counties with significantly higher unemployment rates, and MSAs with significantly lower housing prices.

Compared to those not living in a food desert, there were no differences in the percentage of food desert residents that were female, married, working, employed in jobs that require physical exertion, and did not own a vehicle in either 2006 or 2010. Slightly more than one-third of respondents did not own a vehicle. In each year, there is no difference in the functional and cognitive limitations by food desert status with respondents averaging less than one ADL and one Instrumental Activity of Daily Living (IADL) that s/he is unable to accomplish independently, indicating that the health and disability status of our sample is fairly stable over time.[18] Finally, in terms of geographic characteristics, no differences exist in the total number of grocery stores, restaurants, or drug stores by food desert status in either year. In each year, there are approximately three grocery stores, nine restaurants, and less than one drug store in the census tracts of respondents.

In table 1, we also use the balanced panel to compare the observable characteristics of elderly individuals whose food desert status changed between 2006 and 2010 in columns 5 and 6. The food desert status of a neighborhood could change for several reasons, including one or more stores opening and/or closing, changes in the location of where people live relative to existing stores, and changes in the income of neighborhood residents.[19]

Column 5 in table 1 presents the characteristics of those individuals experiencing improved food retailer access between 2006 and 2010—those who lived in food deserts in 2006 but not in 2010. Statistically significant differences in the sample means of all those in food deserts in 2006 (column 1) relative to those with improving food retailer access (column 5) are denoted in column 5 of table 1. These individuals are significantly more likely to be married and have significantly better cognitive and functional status (measured by the number of IADLs and ADLs). The census tracts these individuals live in have fewer minorities and lower senior poverty rates. As only 4.25% of our balanced sample moved between 2006 and 2010, these changes likely reflect changes in the characteristics of the respondent's census tract.

Column 6 in table 1 presents the characteristics of those experiencing declining access to food retailers, that is, respondents living in a census tract not classified as a food desert in 2006 but classified as a food desert by 2010. Statistically significant differences in sample means between food desert residents in 2010 (column 3) and residents experiencing declining access to food retailers (column 6) are denoted next to column 6 in table 1. Those experiencing declining access to food retailers are significantly more likely to be white and older, significantly less likely to be employed and work in a job that requires physical exertion, and live in census tracts with significantly fewer minorities and lower senior poverty rates. This suggests that, in general, these "new" food desert census tracts experienced a decline in socio-economic characteristics between 2006 and 2010, perhaps driven by the economic changes occurring from the Great Recession.

Descriptive statistics for the outcomes of interest are presented in table 2. Columns 1 through 4 provide these outcomes by food desert status in both 2006 and 2010. Statistically significant differences in sample

[17] Between 2006 and 2010, real household income increases. This is most likely from cost of living adjustments in Social Security that were greater than inflation.

[18] Instrumental Activities of Daily Living (IADLs) refer to activities that are not fundamental to living but are necessary for independently living in the community. These include taking prescribed medications, managing money, and shopping and preparing for meals.

[19] The ERS food desert status of a tract could change because people moved closer to or further from an existing store. See ERS (2013) for more detail on the food desert measure.

Table 1. Summary Statistics, by Food Desert Status in 2006 and 2010

	2006		2010		Change between 2006 and 2010	
	Food Desert	Not a Food Desert	Food Desert	Not a Food Desert	Food Desert 2006 Not a Food Desert 2010	Not a Food Desert 2006 Food Desert 2010
	(1)	(2)	(3)	(4)	(5)	(6)
Individual and Household Characteristics						
Married	0.317 (0.466)	0.370 (0.483)	0.400 (0.491)	0.384 (0.487)	0.424* (0.497)	0.402 (0.492)
Female Respondent	0.682 (0.467)	0.680 (0.467)	0.611 (0.488)	0.662 (0.473)	0.729 (0.447)	0.632 (0.484)
White	0.644 (0.480)	0.789*** (0.408)	0.683 (0.466)	0.746 (0.435)	0.634 (0.485)	0.798** (0.403)
Age	72.854 (9.004)	73.665 (9.472)	71.464 (9.153)	73.731*** (9.474)	73.317 (8.129)	75.877*** (9.115)
Number of Persons in Household	2.355 (1.530)	2.371*** (1.505)	2.414 (1.621)	2.405 (1.619)	2.496 (1.606)	2.396 (1.814)
Number of Kids Ever Born	3.872 (2.842)	3.389* (2.293)	3.718 (2.690)	3.378* (2.207)	3.995 (3.168)	3.378 (2.821)
Child lives within 10 miles	0.564 (0.497)	0.533* (0.499)	0.603 (0.490)	0.537** (0.499)	0.517 (0.503)	0.619 (0.488)
Respondent With Some College	0.188 (0.391)	0.241*** (0.428)	0.199 (0.400)	0.312*** (0.463)	0.239 (0.429)	0.159 (0.367)
Household Income, in $1,000s (2010)	18.767 (15.631)	22.480** (21.113)	21.083 (19.091)	27.269*** (33.647)	20.283 (17.650)	19.384 (13.541)
Respondent Works	0.145 (0.353)	0.133 (0.340)	0.148 (0.355)	0.146 (0.353)	0.215 (0.414)	0.090* (0.287)
Respondent does Physical Work	0.089 (0.286)	0.083 (0.276)	0.123 (0.329)	0.103 (0.305)	0.102 (0.304)	0.064** (0.246)
Respondent Does Not Own a Car	0.360 (0.481)	0.367 (0.482)	0.363 (0.482)	0.348 (0.477)	0.352 (0.480)	0.410 (0.494)
Respondent IADLs	0.595 (1.164)	0.576 (1.164)	0.641 (1.230)	0.657 (1.268)	0.216*** (0.709)	0.831 (1.503)
Respondent ADLs	0.790 (1.274)	0.643 (1.193)	0.673 (1.235)	0.643 (1.236)	0.380*** (0.814)	0.844 (1.406)
Geographic Characteristics						
Number of Grocery Stores	3.159 (2.619)	3.025 (5.563)	3.523 (4.028)	3.438 (7.264)	2.917 (2.830)	3.306 (4.807)
Number of Restaurants	7.261 (7.828)	8.683 (13.741)	9.360 (10.912)	11.339 (21.039)	8.681 (13.022)	9.198 (11.133)
Number of Drug Stores	0.670 (0.644)	0.859 (1.438)	0.743 (0.899)	0.930 (1.849)	0.676 (0.807)	0.721 (0.972)
County Unemployment Rate	5.299 (1.335)	5.107*** (1.316)	10.752 (2.261)	10.450*** (2.538)	5.110 (1.168)	10.496 (2.245)
Percent Minority in Census Tract	0.648 (0.323)	0.374*** (0.353)	0.376 (0.317)	0.330 (0.288)	0.554** (0.338)	0.284*** (0.282)
Percent Senior Poverty in Census Tract	0.195 (0.107)	0.116*** (0.107)	0.174 (0.124)	0.114*** (0.113)	0.155*** (0.106)	0.150** (0.112)
MSA Housing Price Index	203.188 (61.929)	219.229*** (63.087)	165.823 (23.202)	181.918*** (33.580)	220.426** (69.094)	168.911 (24.887)
Observations	247	1,460	326	1,553	82	129

Note: Authors' calculations using 2006 and 2010 Health and Retirement Survey (HRS) data for households living in an urban area and at or below 200% of the federal poverty line in 2004. Standard deviations provided in parentheses. Columns 1 through 4 include a cross-sectional sample of households in the relevant year. Columns 5 and 6 include a sample of households from 2006 that were also in the HRS in 2010. See text for further description of the samples.

Table 2. Outcomes, by Food Desert Status in 2006 and 2010

	2006		2010		Change between 2006 and 2010	
	Food Desert	Not a Food Desert	Food Desert	Not a Food Desert	Food Desert 2006 Not a Food Desert 2010	Not a Food Desert 2006 Food Desert 2010
	(1)	(2)	(3)	(4)	(5)	(6)
Food and Material Hardship						
Food Insufficient	0.129 (0.335)	0.092*** (0.290)	0.126 (0.332)	0.136 (0.343)	0.102 (0.305)	0.068** (0.252)
Observations	247	1,458	326	1,545	82	129
Skipped Meals due to Financial Resources	0.051 (0.220)	0.046 (0.209)	0.080 (0.272)	0.084 (0.278)	0.059 (0.237)	0.036** (0.186)
Observations	247	1,459	325	1,545	82	129
Skipped Prescriptions due to Financial Resources	0.127 (0.333)	0.128 (0.335)	0.126 (0.333)	0.127 (0.333)	0.110 (0.315)	0.112 (0.317)
Observations	247	1,456	324	1,551	82	129
Receipt of Food Assistance						
Received SNAP	0.166 (0.373)	0.113*** (0.317)	0.214 (0.411)	0.144*** (0.351)	0.121 (0.328)	0.206 (0.406)
Observations	247	1,460	326	1,553	82	129
Received Subsidized Meals	0.055 (0.228)	0.048* (0.214)	0.061 (0.239)	0.048 (0.215)	0.059 (0.238)	0.030 (0.172)
Observations	247	1,458	325	1,550	82	129
Food Spending						
Ln(Weekly Food Spending)	4.047 (0.607)	4.134 (0.714)	4.233 (0.693)	4.243 (0.689)	4.066 (0.497)	4.224 (0.615)
Observations	197	1,162	282	1,280	68	104

Note: Authors' calculations using 2006 and 2010 Health and Retirement Survey (HRS) data for households living in an urban area and at or below 200% of the federal poverty line in 2004. Standard deviations provided in parentheses. Columns 1 through 4 include a cross-sectional sample of households in the relevant year. Columns 5 and 6 include a sample of households from 2006 that were also in the HRS in 2010. See text for further description of the samples.

means, by food desert status, are denoted in the table. Residents of food deserts in 2006 report significantly higher rates of food insufficiency over the previous 2 years (almost 13% of food desert residents but only 9% of those not in a food desert), but do not report a difference in skipping meals (roughly 5%). In 2010, however, those in food deserts were almost equally likely to report food-related distress as those not in a food desert. This may reflect the poor economy in 2010 compared to 2006. Among all respondents, food insufficiency rates in 2010 were higher than the rates in 2006. For the two other food and material hardship outcomes, there were no differences by food desert status in either year.

In both 2006 and 2010, elderly food desert residents are significantly more likely to receive SNAP over the previous two years than those not living in food deserts. Subsidized meal receipt is less common overall—only roughly 5% of households in each year—and those in food deserts are slightly more likely to report receiving subsidized meals than those outside of food deserts in both years, but this difference is only significant in 2006.

In columns 5 and 6 of table 2, we compare these outcomes for those experiencing a change in the food environment between 2006 and 2010. Those in improving food environments (column 5) appear more similar in these outcomes than all those in food deserts in 2006. In contrast, those in worsening food environments (column 6) were better off, on average, than all those in food deserts in 2010 in terms of food insufficiency and skipping meals.

Cross-sectional Estimates

We begin with cross-sectional estimates for the sample of households in 2006 and 2010, respectively, to provide a benchmark for our balanced panel results (these are included in the supplemental online appendix). In both 2006 and 2010, residing in a food desert is uncorrelated with our measures of hardship: food insufficiency, skipping meals due to financial resources, or skipping prescription drugs due to financial resources. For each of these outcomes, point estimates are negative, which is contrary to our hypotheses, but economically small and statistically insignificant. Likewise, there is no significant relationship between residing in a food desert and receiving food assistance from either SNAP or subsidized meals programs, although with the exception of receiving SNAP in 2006, the point estimate is positive. We find no relationship between living in a food desert and weekly food spending.

Based on the cross-sectional results alone, we would conclude that food deserts are unrelated to food and material hardship, use of food assistance, or food spending. However, because these estimates may be biased by unobservable individual characteristics, we focus on fixed effect specifications that control for unobservable time-invariant characteristics with our balanced sample of respondents.

Fixed-effects Estimates for Food and Material Hardship

Table 3 presents the results from estimating equation 1 with the balanced sample of respondents that exploits the variation in food deserts over time and controls for individual, time-invariant characteristics that lead to bias in cross-sectional regressions (full results are included in the online appendix). Panel A presents estimates for food and material hardship outcomes. We find that living in a food desert is uncorrelated with self-reported food insufficiency (column 1), skipping meals (column 3), or skipping prescription drugs (column 5) due to a lack of resources. Point estimates for each outcome are negative and statistically insignificant, suggesting that living in a food desert does not increase food or material hardship.

To test the sensitivity of these results, we conduct two specification checks. First, we re-estimate equation 1 excluding time-varying control variables (household income, respondent employment status and physical exertion in employment, an indicator of a child residing within 10 miles of the respondent, and vehicle ownership) that are potentially endogenous and which would bias our fixed-effects estimates.[20,21] We find no impact on our point estimates.

[20] While household income may be potentially endogenous, for our balanced panel of elderly households, it is less endogenous than the working age population due the contribution of Social Security to the household income of the elderly. In 2006, 96% of the sample received Social Security; in 2010, 99% of the sample received Social Security.

[21] This sensitivity test is conducted for each outcome and each specification. Results are not reported.

Table 3. Fixed-effects Regression Estimates for the Relationship of Food Desert Status on Food and Material Hardship, Receipt of Food Assistance, and Food Acquisition

Panel A. Food and Material Hardship

	Food Insufficient		*Skipped Meals due to Financial Resources*		*Skipped Prescriptions due to Financial Resources*	
	(1)	(2)	(3)	(4)	(5)	(6)
Food Desert	−0.037 (0.031)	−0.039 (0.031)	−0.023 (0.024)	−0.024 (0.024)	−0.024 (0.030)	−0.025 (0.029)
Number of Grocery Stores	–	−0.001 (0.007)	–	−0.005 (0.004)	–	−0.003 (0.005)
Number of Restaurants	–	−0.002 (0.004)	–	−0.001 (0.003)	–	0.005 (0.003)
Number of Drug Stores	–	−0.044 (0.035)	–	0.003 (0.020)	–	−0.041 (0.027)
Observations	2,393	2,393	2,393	2,393	2,393	2,393

Panel B. Receipt of Food Assistance Programs and Food Spending

	Received SNAP		*Received Subsidized Meals*		*Ln(Weekly Food Spending)*	
	(1)	(2)	(3)	(4)	(5)	(6)
Food Desert	0.037 (0.029)	0.038 (0.029)	−0.041* (0.024)	−0.040* (0.024)	−0.019 (0.050)	−0.019 (0.051)
Number of Grocery Stores	–	−0.001 (0.004)	–	−0.0002 (0.003)	–	0.044*** (0.013)
Number of Restaurants	–	0.001 (0.003)	–	−0.003 (0.002)	–	−0.003 (0.007)
Number of Drug Stores	–	0.005 (0.020)	–	0.041** (0.016)	–	−0.154** (0.066)
Observations	2,393	2,393	2,393	2,393	1,900	1,900

Note: Author's calculations based on Health and Retirement Study data. See text for details on the sample selection and covariates. Standard errors, clustered at the individual level, are provided in parentheses. Asterisks indicate that the coefficient is statistically different from zero at the 10% (*), 5%, (**), and 1% (***) levels.

Our second check includes using the following additional food environment variables: the number of grocery stores, restaurants, and drug stores in the respondent's census tract. These results are included in panel A of table 3 for food insufficiency (column 2), skipped meals (column 4), and skipped prescription drugs (column 6). Adding these controls does little to change the food desert estimate. Point estimates for the food environment variables are statistically insignificant and, in general, negative and small in magnitude.

Fixed Effects—Food Assistance Receipt and Food Spending

Panel B of table 3 shows estimates of the relationship between living in a food desert and receipt of food assistance and food spending. The point estimate for SNAP receipt (column 1) is positive but statistically insignificant. This result suggests that either the lack of easy access to a food retailer is not an impediment to SNAP take-up, or the lack of purchasing power of SNAP benefits exactly offsets the additional need for the program due to higher food prices.

Living in a food desert is associated with a statistically significant 4.1 percentage point decrease in the likelihood of subsidized meal receipt (panel B, column 3). Because food desert residents by definition live in areas with less access to full-service grocery retailers, this relationship is somewhat surprising. One possible explanation is that food desert residents also have less access to non-profit meal providers. This could be particularly true for those experiencing a worsening food environment between 2006 and 2010 who may be unfamiliar with social service agencies providing subsidized meals. Further, social service agencies may have had difficulty in reaching all those who could potentially benefit from assistance due to both increased demand and declining financial support during the Great Recession.

Another explanation could be that many food desert residents do not experience difficulties in traveling to nearby food retailers because they own a vehicle, but those without a vehicle face difficulties with food shopping. The coefficient on not owning a vehicle—our proxy for transportation difficulties—indicated a statistically significant 7.7 percentage point increase in subsidized meal receipt. We will explore the relationship between vehicle ownership and food assistance receipt in more detail with additional specifications.

The coefficient estimate on the relationship between the natural log of weekly food spending and food deserts is negative (column 5) but insignificant. Thus, we find little evidence that any increase in food prices in food deserts relates to greater food spending. Estimates from models of food spending where the indicator for SNAP receipt was excluded did not differ.

As before, we conduct the same specification checks. Eliminating potentially endogenous regressors results in little change in the point estimate of the food desert variable, although the estimate for subsidized meal receipt loses statistical significance ($p = 0.103$) due to a slight decrease in the coefficient estimate and a slight increase in the standard error. Again, we conclude that potentially endogenous control variables do not bias our estimates.

Using additional food environment controls for SNAP receipt (Column 2), receipt of subsidized meals (Column 4), and weekly food spending (Column 6) has little effect on the estimate of the food desert coefficient. Coefficient estimates on the food environment variables are small and, for the most part, statistically insignificant. For subsidized meals, an additional drug store in the census tract is significantly related to a 4.1 percentage point increase in receipt. To place this estimate in context, in our data there are 0.78 drug stores and 0.50 drug stores per census tract at the mean and median, respectively. Thus, an additional drug store is a large change. Although the mechanisms behind this result are unclear, it could be that census tracts with greater numbers of drug stores may be correlated with spending on health care, particularly prescription medication, and use of social support services.

The number of grocery stores is positively related to food spending. An additional grocery store is related to a 4.4% increase in food spending. When included in the model with the food desert measure, this grocery store variable reflects the presence of the small grocery and convenience stores that typically have higher prices than full-service supermarkets.

We find that each additional drug store in a respondent's census tract significantly reduces food spending by 15.2%. The reasons for this large effect are not clear, but it is

possible that drug stores, which often sell a diverse mix of products, food items with long shelf-lives and perhaps higher profit margins, and pharmacy products that may at least partially be paid by insurance, all encourage price competition with smaller food retailers that drives down food prices.

The Effects of Food Deserts for Those without a Vehicle

Food deserts are only one indicator of the food access limitations that individuals within a neighborhood face. Two food desert residents may have very different levels of access if one is able to drive to a supermarket outside of the neighborhood and the other is not because they do not have a car or cannot drive. We hypothesize that elderly food desert residents without a vehicle are more adversely affected by the lack of a nearby supermarket than those who own a vehicle. This is especially true if those who do not own a vehicle face physical limitations in walking or taking public transit to the nearest food retailer.

Many of the estimates reported in table 3 showed large and significant estimates on the coefficient for lack of vehicle ownership (results reported in the online appendix). To explore further, we modify equation 1 to interact food desert status with vehicle ownership to estimate if there is an additional effect of living in a food desert without a vehicle (tables 4a and 4b). Full results for all covariates are included in the supplemental appendix online.

Respondents without a vehicle may face greater hardship, more need for food assistance, and spend less on food. Focusing on vehicle ownership could potentially bias our estimates if the unobservable characteristics related to vehicle ownership are time-varying. For example, those facing declining income or health are less likely to own vehicles but more likely to experience hardship. This bias is reduced by controlling for employment and household income. Further, for many in our sample, Social Security benefits are a significant source of income that they have little ability to change. To the extent that health changes affect a respondent's ability to operate a vehicle, those in better health will be more likely to report owning a vehicle. Upon investigation, however, we find that neither residing in a food desert nor vehicle ownership is significantly

Table 4a. Fixed-effects Estimates for the Interaction of Lack of Vehicle Ownership and Food Desert Status on Food and Material Hardship

	Food Insufficient		*Skipped Meals due to Financial Resources*		*Skipped Prescriptions due to Financial Resources*	
	(1)	(2)	(3)	(4)	(5)	(6)
Food Desert Status	−0.085** (0.037)	−0.084** (0.037)	−0.060* (0.032)	−0.058* (0.033)	−0.011 (0.038)	−0.012 (0.037)
No Vehicle	0.002 (0.035)	0.0003 (0.035)	−0.035 (0.029)	−0.034 (0.029)	−0.034 (0.046)	−0.036 (0.045)
*Food Desert * No Vehicle*	0.122* (0.070)	0.118* (0.071)	0.096 (0.064)	0.091 (0.065)	−0.034 (0.056)	−0.033 (0.056)
Number of Grocery Stores		0.0003 (0.007)		−0.004 (0.004)		−0.003 (0.005)
Number of Restaurants		−0.002 (0.004)		−0.001 (0.003)		0.005 (0.003)
Number of Drug Stores		−0.047 (0.036)		0.001 (0.020)		−0.040 (0.027)
F-statistic on Total Effect of Food Desert status	0.42	0.34	0.56	0.46	1.06	1.04
P-value on F-statistic	0.52	0.56	0.46	0.50	0.30	0.31
Observations	2,393	2,393	2,393	2,393	2,393	2,393

Note: Author's calculations based on Health and Retirement Study (HRS) data. Coefficient estimates presented are the interaction between food desert status and lack of vehicle ownership. See text for details on the sample selection and covariates. Standard errors, clustered at the individual level, are provided in parentheses. Asterisks indicate that the coefficient is statistically different from zero at the 10% (*), 5%, (**), and 1% (***) levels.

Table 4b. Fixed-effects Estimates for the Interaction of Lack of Vehicle Ownership and Food Desert Status on Receipt of Food Assistance and Food Spending

	Received SNAP		*Received Subsidized Meals*		*Ln(Weekly Food Spending)*	
	(1)	(2)	(3)	(4)	(5)	(6)
Food Desert Status	0.043 (0.036)	0.043 (0.034)	−0.018 (0.022)	−0.017 (0.022)	−0.009 (0.054)	−0.018 (0.055)
No Vehicle	0.058 (0.037)	0.056 (0.037)	0.088*** (0.029)	0.090*** (0.029)	−0.091 (0.082)	−0.108 (0.080)
*Food Desert * No Vehicle*	−0.015 (0.053)	−0.016 (0.052)	−0.058 (0.048)	−0.061 (0.049)	−0.033 (0.099)	−0.001 (0.099)
Number of Grocery Stores		−0.001 (0.004)		−0.001 (0.003)		0.044*** (0.013)
Number of Restaurants		0.001 (0.003)		−0.003* (0.002)		−0.003 (0.007)
Number of Drug Stores		0.005 (0.020)		0.043*** (0.016)		−0.154** (0.066)
F-statistic on Total Effect of Food Desert Status	0.41	0.40	2.78	2.89	0.21	0.05
P-value on F-statistic	0.52	0.53	0.10	0.09	0.64	0.83
Observations	2,393	2,393	2,393	2,393	1,900	1,900

Note: Author's calculations based on Health and Retirement Study data. Coefficient estimates presented are the interaction between food desert status and lack of vehicle ownership. See text for details on the sample selection and covariates. Standard errors, clustered at the individual level, are provided in parentheses. Asterisks indicate that the coefficient is statistically different from zero at the 10% (*), 5%, (**), and 1% (***) levels.

associated with the number of ADLs or IADLs.[22]

Table 4a shows that respondents in food deserts who also do not own a vehicle experience a 12 percentage-point increased probability in food insufficiency (column 1). The total effect of living in a food desert on the probability of food insufficiency is positive but not statistically significant (p-value = 0.52). Thus, only food desert residents without a vehicle are more likely to be food insufficient.

We turn next to skipping meals due to financial resources, presented in column 3 of table 4a. Although the economic magnitude is large, with a 9.6 percentage point increase in the likelihood of skipping meals due to financial resources for food desert residents without a vehicle, the point estimate (column 3) is insignificant. The total effect of living in a food desert is also not statistically significant (p-value = 0.46). We interpret this as suggestive but inconclusive evidence that living in a food desert without a vehicle may be related to an increased likelihood of skipping meals.

There is little evidence that living in a food desert, with or without a vehicle, is related to skipping prescription drugs due to financial resources (column 5). Neither the negative point estimate on the interaction of living in a food desert without owning a vehicle, nor the total effect of living in a food desert on the probability of skipping prescriptions are statistically significant. Prescription drug coverage may explain the lack of relationship. Much of our sample is eligible for Medicare Part D, introduced in 2006, and approximately one-quarter of the sample receives Medicaid, which provides prescription drug coverage.

Our specification check of dropping potentially endogenous variables, except the vehicle ownership variable, does not affect the estimates. Further, adding the food environment controls does little to change the estimated effect of food deserts for food insufficiency (column 2), skipping meals (column 4), or skipping prescription drugs (column 6). None of the food environment variables are statistically different from zero.

Finally, we examine the use of food assistance and food spending. We find that the likelihood of SNAP receipt is not

[22] Results are not reported.

differentially affected by vehicle ownership for residents of food deserts (table 4b, column 1), and the total effect of living in a food desert on SNAP receipt is insignificant (p-value=0.53). Similarly, for subsidized meal receipt, we find no statistically significant effect of living in a food desert without a vehicle, and the total effect of living in a food desert is not significant. However, regardless of food desert status, not owning a vehicle is associated with a 9 percentage point increase in the likelihood of receiving subsidized meals. Thus, subsidized meal receipt appears more related to transportation difficulties than to limited geographic access to food retailers. Estimates for weekly food spending (column 5) show little evidence that living in a food desert, with or without a vehicle, affects food spending.

We again conduct our two robustness checks. Omitting potentially endogenous covariates, except for vehicle ownership, has no effect on the estimates. Including food environment variables does not change the relationship between living in a food desert and SNAP or subsidized meal receipt (columns 2 and 4), or weekly food spending (column 6).

The food environment estimates, however, reveal some interesting relationships. An additional drug store in the census tract increases the likelihood of subsidized meal receipt by 4.3 percentage points, while an additional restaurant decreases receipt by 0.3 percentage points. With 8.7 restaurants per tract at the sample mean and 5.6 restaurants per tract at the median, the number of restaurants in the typical census tract has a large effect on subsidized meal receipt. It may be that take-out and delivery from local restaurants allow those with transportation or cooking difficulties to substitute purchasing meals at local restaurants for subsidized meals. For food spending, an additional grocery store increases weekly food spending by 4.4%, while an additional drug store decreases it by 15%. Price and competition factors are one possible explanation for these findings. Future research may further explore the relationships between these measures and the number of food store outlets.

The Effects of Food Deserts and SNAP Participation

SNAP recipients are likely to have the lowest incomes and greatest food needs and may

Table 5a. Fixed-effects Regression Estimates for the Interaction of SNAP Receipt and Food Desert Status on Food and Material Hardship

	Food Insufficient		*Skipped Meals due to Financial Resources*		*Skipped Prescriptions due to Financial Resources*	
	(1)	(2)	(3)	(4)	(5)	(6)
Food Desert Status	−0.027 (0.032)	−0.030 (0.033)	−0.014 (0.026)	−0.015 (0.026)	−0.031 (0.028)	−0.031 (0.028)
SNAP Recipient	0.066 (0.054)	0.068 (0.054)	0.042 (0.050)	0.043 (0.050)	0.119** (0.047)	0.117** (0.047)
*Food Desert * SNAP Recipient*	−0.073 (0.098)	−0.065 (0.099)	−0.059 (0.079)	−0.056 (0.078)	0.012 (0.085)	0.008 (0.083)
Number of Grocery Stores		−0.0004 (0.007)		−0.005 (0.004)		−0.003 (0.005)
Number of Restaurants		−0.0002 (0.004)		−0.001 (0.003)		0.005 (0.003)
Number of Drug Stores		−0.045 (0.035)		0.003 (0.020)		−0.042 (0.027)
F-statistic on Total Effect of Food Desert Status	1.16	1.03	1.01	0.98	0.05	0.07
P-value on F-statistic	0.28	0.31	0.32	0.32	0.83	0.79
Observations	2,393	2,393	2,393	2,393	2,393	2,393

Note: Author's calculations based on Health and Retirement Study data. Coefficient estimates presented are the interaction between SNAP participation status and food desert status. See text for details on the sample selection and covariates. Standard errors, clustered at the individual level, are provided in parentheses. Asterisks indicate that the coefficient is statistically different from zero at the 10% (*), 5%, (**), and 1% (***) levels.

Table 5b. Fixed-effects Regression Estimates for the Interaction of SNAP Receipt and Food Desert Status on Receipt of Subsidized Meals and Food Spending

	Received Subsidized Meals		*Ln(Weekly Food Spending)*	
	(1)	(2)	(3)	(4)
Food Desert Status	−0.058** (0.024)	−0.058** (0.024)	−0.011 (0.054)	−0.012 (0.055)
SNAP Recipient	−0.047* (0.026)	−0.047* (0.026)	−0.122* (0.071)	−0.121* (0.071)
*Food Desert * SNAP Recipient*	0.109* (0.065)	0.110* (0.065)	−0.042 (0.128)	−0.036 (0.128)
Number of Grocery Stores		−0.0002 (0.003)		0.044*** (0.013)
Number of Restaurants		−0.003* (0.002)		−0.003 (0.007)
Number of Drug Stores		0.042** (0.016)		−0.154** (0.066)
F-statistic on Total Effect of Food Desert Status	0.67	0.69	0.20	0.17
P-value on F-statistic	0.41	0.42	0.65	0.68
Observations	2,393	2,393	1,900	1,900

Note: Author's calculations based on Health and Retirement Study data. Coefficient estimates presented are the interaction between SNAP participation status and food desert status. See text for details on the sample selection and covariates. Standard errors, clustered at the individual level, are provided in parentheses. Asterisks indicate that the coefficient is statistically different from zero at the 10% (*), 5%, (**), and 1% (***) levels

be more vulnerable to food access barriers. Tables 5a and 5b explore the extent to which SNAP recipients in food deserts experience unique difficulties by interacting the food desert indicator with a SNAP receipt indicator. SNAP receipt is endogenous, but as long as the unobservable characteristics related to SNAP participation do not vary over time, our fixed-effects approach addresses this endogeneity. If unobservable time-varying characteristics are present, however, our estimates will be biased upwards because SNAP recipients are both more likely to experience food and material hardship and more likely to enroll in other means-tested programs than similar nonparticipants. Our estimate for food spending, however, may be biased downwards because weekly food spending does not include SNAP benefits, and SNAP participants may be less able to spend money on food than similar nonparticipants.

We estimate that SNAP participants in food deserts are not more likely to be food insufficient (table 5a, column 1) or skip meals due to financial resources (column 3) than SNAP participants outside of food deserts. For both outcomes, the total effect of residing in a food desert is statistically insignificant. We find no difference in the likelihood of skipping a prescription for financial reasons for SNAP participants in food deserts (column 5), but SNAP receipt is related to a nearly 12 percentage point increase in skipping prescription drugs due to a lack of financial resources.

Our specification check excluding the potentially endogenous regressors, except for SNAP receipt, has no effect on the variables of interest. Adding the food environment variables for food insufficiency (column 2), skipping meals (column 4), or skipping prescriptions (column 6) results in no meaningful changes in our key variables. None of the food environment variables are statistically significant.

SNAP receipt is related to a significant 11 percentage point increase in subsidized meal receipt for food desert residents (table 5b, column 1). Subsidized meal receipt complements their SNAP benefits, while food desert residents who do not receive SNAP and SNAP recipients outside of food deserts are significantly less likely to receive subsidized meals. We find no differential effect on food spending for SNAP recipients living in food deserts (column 3). SNAP receipt, however, significantly decreases weekly food spending by 12 percentage points. As weekly food spending does not include SNAP benefits, this likely reflects that SNAP recipients are able to reduce some of their out-of-pocket spending on food.

We perform the same robustness checks as above and find that the estimates are essentially unchanged when excluding potentially endogenous regressors, although the interaction between residing in a food desert and SNAP receipt for the subsidized meal receipt outcome loses statistical significance by a small margin (p=0.103). Many of the food environment variables, however, are statistically significant. We find a similar pattern of results for the relationship between subsidized meal receipt, restaurants, and

drug stores. An additional restaurant in the census tract slightly reduces subsidized meal receipt by 0.3 percentage points, while an additional drug store increases subsidized meal receipt by 4.2 percentage points. As in earlier results, an additional grocery store increases food spending by 4.4%, while an additional drug store has the opposite effect, that is, decreasing food spending by 15.4%.

Conclusions

Our results indicate that transportation burdens among the elderly may be more important in determining food and material hardship than whether a senior lives in a food desert. Elderly individuals living in food deserts without a vehicle are 12 percentage points more likely to be food insufficient than those with vehicles in food deserts. Policies that target elderly food desert residents with transportation limitations by providing transportation to food stores or food delivery to those unable to access food retailers may improve their food sufficiency.

We find subsidized meal participation is 9 percentage points more likely among those who have transportation difficulties than those who do not, regardless of whether they live in a food desert. Among SNAP recipients in food deserts, subsidized meal receipt is 11 percentage points greater. Subsidized meal programs may be closing the gap in food needs among elderly who either lack an independent means of transportation or who receive SNAP but lack access to supermarkets. This relatively overlooked food safety net program may require additional attention and support given the growth in the elderly population.

Our fixed-effects estimates are an improvement upon previous work but we cannot rule out that unobservable and time-varying factors are correlated with the food environment, vehicle ownership, SNAP receipt, and the outcomes of interest. If the lack of a vehicle is associated with unobservable time-varying factors, our estimates for living in a food desert without a vehicle on food and material hardship and food assistance use are biased upward. Similarly, if SNAP receipt is associated with unobservable time-varying factors, estimates of the effect of SNAP participation for food desert residents are also upwardly biased. However, these estimates are economically large, so substantial bias would be needed to negate these estimated effects.

More work is needed to understand the causal links between food deserts, the food environment, transportation options, and food hardship. It is important to know how food deserts may affect other indicators of the well-being of the elderly, especially given the HFFI and state and local resources allocated to improve food access in low-income communities. Future work will explore whether food deserts affect the measured health of elderly individuals.

Supplementary Material

Supplementary material is available at http://oxfordjournals.org/our_journals/ajae/online.

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