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Cost of living, healthy food acquisition, and the Supplemental Nutrition Assistance Program

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Abstract

We tested the hypothesis that high costs of living, such as from high housing rents, reduce the healthfulness of food acquisitions. Using the National Household Food Acquisition and Purchase Survey (2012-13), we examined the relationships between cost of living and food acquisition patterns among both SNAP participants and non-participants (*N* = 5,414 individuals from households participating in SNAP, 3,863 individuals from non-participating households <185% of the federal poverty threshold, and 5,036 individuals from non-participating households ≥185% of the federal poverty threshold). Indices for cost of living included county-level Regional Price Parities for major classes of expenditures and the geographic adjustment to the Supplemental Poverty Measure, which is based on rent prices. We regressed the cost of living indices against measures of food acquisitions per person per day in each of several standard food categories, controlling for individual-, household-, and county-level characteristics. Using endogenous treatment effects models to potentially address unmeasured confounders influencing both the propensity to live in high-cost areas and patterns of food acquisition, we observed that higher area-level costs of living were associated with less healthy food acquisitions, including significantly fewer acquisitions of vegetables, fruits, and whole grains, and significantly greater acquisitions of refined grains, fats and oils, and added sugars. Overall, living in a high-cost area was associated with an 11% reduction in the Healthy Eating Index—a composite nutritional index previously associated with obesity, type II diabetes, and all-cause mortality. Additionally, we found that SNAP participation was associated with a significantly improvement in the healthfulness of food acquisitions among persons living in high-cost counties.

Executive Summary

A recent Institute of Medicine report raised the question of whether Supplemental Nutrition Assistance Program (SNAP) benefits should be adjusted for geographic variations in the cost of living, including variations in the cost of food, to promote nutrition among low-income Americans (1). Substantial existing literature in the fields of sociology, economics, and epidemiology has highlighted the trade-offs that low-income Americans face when attempting to pay for foods, such as having to sacrifice food budgets to pay for heating bills or medical care costs (2, 3).

Here, we sought to test the following three key hypotheses relating the cost of living to the healthfulness of food acquisitions: (i) first, a higher area-level cost of living is associated with less healthy food acquisitions (which we define as lower Healthy Eating Index [HEI] scores, particularly from lower acquisition of fruits and vegetables and higher acquisition of refined grains and added sugars); (ii) second, SNAP participation is associated with living in a lower-cost area after accounting for other observed and unobserved covariates related to both SNAP and area of living (because the value of a SNAP dollar would be more in a lower-cost area, thus incentivizing enrollment); and (iii) third, any association between SNAP participation and the healthfulness of food acquisitions (i.e., HEI scores) is moderated by area-level cost of living (i.e., SNAP would have differential benefits to nutrition among areas with different costs of living).

To test these hypotheses, we utilized data from the National Household Food Acquisition and Purchase Survey (2012-13; *N* = 5,414 SNAP participants, 3,863 SNAP-eligible non-participants <185% of the federal poverty threshold, and 5,036 ineligible non-participants $\geq$185% of the federal poverty threshold), which we linked to data on the cost of living computed by the Bureau of Economic Analysis (Regional Price Parities for major classes of expenditures) and by the U.S. Census Bureau (geographic

adjustments to the Supplemental Poverty Measure). These indices of cost of living were chosen because they are routinely updated and therefore theoretically available to agencies that wish to regularly adjust benefit allotments from safety net programs for area cost of living; we studied these cost indices at the county-level, as the county area typically includes the primary food store of purchasing for most FoodAPS participants (4), unlike smaller areas of analysis, and has readily available social and economic covariate statistics that capture important area-level variations in food availability, unlike larger areas of analysis.

Because there are potentially several unobserved or unmeasured confounders that may relate to SNAP participation, the propensity to live in a higher- or lower-cost area, and the healthfulness of food acquisitions, we used endogenous treatment effects models to test our hypotheses. These models utilize a control function approach to minimize the influence of endogeneity on estimates of the effects of an exposure on an outcome, such as the effect of living in a high-cost area on the HEI score.

We found evidence consistent with our first hypothesis—that higher area-level cost of living was associated with less healthy food acquisitions. We defined a high cost of living area as being more than one standard deviation above the mean cost measured by either a regional price parity or the geographic adjustment to the Supplemental Poverty Measure. We found that living in a high-cost of living area was associated with significantly fewer acquisitions of vegetables, fruits, and whole grains, and was associated with significantly greater acquisitions of refined grains, dairy products, protein, fats and oils, and added sugars. This finding was observed no matter which metric we chose for the area-level cost of living: overall regional price parity, rent/housing cost regional price parity, food regional price parity, regional price parities for goods or for services, or the geographic adjustment to the Supplemental Poverty Measure. Having controlled for individual-level factors such as education level,

household-level factors such as income, and county-level factors such as food availability, the estimated effect of living in a high-cost county reduced the overall HEI score by approximately 11%. Clinically-speaking, this observed decrease in HEI is larger than those associated with a significantly increased risk of cardiovascular disease, type II diabetes, and all-cause mortality. Hence, we would expect such effects to be meaningful to public health.

Importantly, we observed that the cost of living metric for food was not necessarily the most predictive of changes in the healthfulness of food acquisitions, perhaps because significant expenditures in other domains of life greatly influence the food budget. For the overall nutritional metric of HEI score, higher rent costs were more strongly associated with reduced healthiness of food acquisitions than higher food indices. This is an important result for policymakers who may need to choose metric of overall cost of living rather than only food costs when considering whether SNAP benefits should be adjusted for local-area cost of living.

Our further subgroup analyses examining the relationships between area-level cost of living and food acquisitions revealed that low-income (<185% of the federal poverty threshold) SNAP non-participants were more sensitive to overall cost of living metrics than SNAP participants net of other individual-, household- and county-level covariates, consistent with the idea that SNAP participation itself buffers the negative impact of high living costs on nutrition. In our analytical sample, low-income non-participants had lower income than SNAP participants, contrary to the idea that eligible non-participants are those who would typically receive the least SNAP benefits. This indicates that encouraging SNAP participation among eligible non-participants may be particularly beneficial to buffering low-income populations from negative nutritional effects of living in high-cost areas.

We rejected our second hypothesis that SNAP would be associated with living in a lower-cost

area. Rather, receiving SNAP was associated with a significantly increased probability of living in a high-cost area. One theory is that SNAP participation, by increasing economic mobility, may permit low-income households to live in environments where they would otherwise be "priced out". Alternatively, the association may be indicative of reverse causality: that living in a high-cost area induces eligible populations to enroll in SNAP because the additional SNAP dollars are vital to survival.

In testing our third hypotheses, we found that SNAP was associated with no significant on the healthfulness of food acquisitions in lower-cost areas, because increased fruit and vegetable acquisitions and lower refined grain acquisitions attributable to SNAP participation were counterbalanced by increased acquisitions of fats and oils as well as added sugars. Overall, SNAP increased calories but did not disproportionately increase "unhealthy" calories; hence, SNAP had a statistically-neutral impact on HEI scores in lower-cost areas. By contrast, while individuals had a worse dietary profile in higher-cost areas, as discussed above, SNAP was associated with improved nutrition in such areas—permitting greater acquisitions of vegetables and fewer refined grains, with fewer adverse compensation from increased fat and oil or added sugar acquisitions. One theory to explain these findings may be that in a higher-cost environment, SNAP dollars are used disproportionately to assist households in acquiring those foods that are most out of reach due to high perceived or real prices. This finding may also be a commentary on the nature of the food acquisition environment in lower-cost counties; if lower-cost counties indeed have environments saturated with less-healthy foods, as suggested in the public health literature, SNAP participation may have limited effects on the healthfulness of food acquisitions because the unhealthy food environment overwhelms any potentially beneficial effects of SNAP.

Our findings do not necessarily imply that a cost of living adjustment using currently available county-level cost of living metrics would improve the healthfulness of food acquisitions among SNAP

participants currently living in lower-cost areas. However, our findings imply that SNAP participation is associated with living in a higher-cost area, and that SNAP participation is associated with improved nutrition in those areas. If SNAP participation is associated with living in higher-cost areas because SNAP increases economic mobility, then additional benefits might accrue to low-income populations given a cost-of-living adjustment. The existing sociology literature suggests that higher-cost areas that are typically lower in poverty may have substantial health benefits for low-income individuals who move to such areas. However, if SNAP benefits are reduced by cost of living adjustments among those populations living in lower-cost areas, it is possible that SNAP participation would be discouraged, or that SNAP would no longer have a neutral association with nutrition, but have rather a negative association, especially, if such benefits become disproportionately used on fats and oils or added sugars. A direct experiment or pilot study involving cost-adjusted SNAP benefits would help shed light on the effects of benefit modification on living costs and healthy food acquisitions.

Introduction

Food insecurity among low-income Americans has been associated with poor nutrition, an increased risk of major nutrition-related chronic diseases, and poor clinical outcomes for patients with chronic diseases such as hypertension and type II diabetes (5–8). It is believed that low-income Americans faced with food insecurity often engage in economic trade-offs—sacrificing their food budgets to pay for major living expenditures, such as rent or other housing costs, or medical bills (2,3). Potentially as a result of such trade-offs, foods purchased by low-income Americans tend to be of lower nutrition value, in part because perceived or real prices of healthier food items such as fruits and vegetables are often higher than those of calorie-dense, nutrient-poor food items, which primarily contain refined grains and added sugars (9). Furthermore, in the context of rising economic inequality,

many low-income Americans live in areas where neighborhood living costs are driven higher by inflated housing and food prices, even as real wages have lagged behind (10). As a result, neighborhood-level cost of living has increased for many low-income American households (particularly as housing costs have increased as a proportion of income (11)) potentially putting further pressure on food budgets among the lowest-income households (12).

Extensive prior studies have associated local-area food availability and food costs with poor nutrition and nutrition-related health outcomes (for recent systematic reviews of this very large literature, see (13,14)). To assist in improving nutrition among the food insecure, the nation's largest nutritional assistance program—the Supplemental Nutrition Assistance Program (SNAP)—currently provides assistance to nearly 1 in 7 Americans (15). SNAP has been extensively studied for its effects on nutritional purchasing and nutrition-related health outcomes, with variable results. Some highly publicized prior research studies have associated SNAP participation with obesity and poor nutritional metrics (16,17), although these findings have not been consistently robust to alternative statistical specifications—particularly when unmeasured confounders (i.e., unobserved factors that may be correlated to both SNAP participation and poor nutrition) are considered (18,19). Area-level cost of living is among one of the key correlates of food insecurity for which data have been previously very limited, and to our knowledge the relationships between overall area-level cost of living, SNAP participation, and the healthfulness of food acquisitions have not been studied.

The relationships between these factors are of particular interest because SNAP benefits are currently set based on a national estimate of the cost of living (rather than local-area costs). SNAP benefits are calculated by subtracting from a maximum monthly benefit, which is based on household size and fixed across the contiguous 48 states and the District of Columbia (while set to slightly higher

levels in Alaska and Hawaii), from which 30% of net income is subtracted to determine an individual participant's benefit (20). The maximum monthly benefit is given by the cost of the Thrifty Food Plan (TFP), which is a model-based estimate of the average national cost of a market basket of low-cost foods that would permit participants to achieve some components of national dietary guidelines on a limited budget. Net income is based on gross income (most private income and some transfer income) minus deductions based on national thresholds for major living costs including official child support payments, a standard deduction based on household size, a high-cost shelter deduction, and an out-of-pocket medical cost deduction for the elderly and disabled. Some prior adjustments to SNAP benefits have occurred, as legislation in 1988 increased the TFP by 3% to reflect time-lags in how quickly the national cost of living adjustment was implemented between its calculation and its reflection in actual payments to beneficiaries; the 3% increase was later eliminated (21). More recently, as part of the post-recession American Recovery and Reinvestment Act of 2009, a 13.6% increase was added to the TFP for most households, which expired in 2013 (22). To our knowledge, studies of the 1988 adjustment on food security or nutritional outcomes are unavailable, but a study of the more recent 2009 increase reported that "the food security of low-income households (those with incomes in the eligible range for SNAP) improved from 2008 to 2009, and a substantial share of that improvement may be due to the increase in SNAP benefits implemented under ARRA" (23). Early studies of this change suggest that Medicaid costs in Massachusetts reduced during the ARRA stimulus (24), potentially as fewer low-income households experienced the complications of chronic disease associated with food insecurity (e.g., hypoglycemia among people with diabetes (25)).

In considering the relationships between cost of living and SNAP benefits, it is noteworthy to understand prior assumptions and data availability concerning living costs. The maximum SNAP benefit

is adjusted each year in October based on Consumer Price Indices (CPIs) for 29 food categories included in the TFP that have a CPI for each age- and sex-group in the country (26). To disaggregate costs of living or food to local areas would require further sub-national data. Yet, the Bureau of Labor Statistics that produces CPIs does not provide an official CPI measure or measures for the TFP for different areas of the country at a sufficient scale. Monthly CPIs are available for only three large metro areas, bimonthly CPIs for 14 metro areas, semiannual CPIs for 26 metro areas, and CPIs for 362 metropolitan statistical areas have annual data (27). Hence large areas of the contiguous U.S. states may substantially differ in their costs of living, or at least in food costs, to warrant a nationally-based cost input to the TFP, but CPI data area unavailable for them. This dilemma was addressed when the U.S. Department of Agriculture produced the Quarterly Food-at-home Price Database in 2011, which provided retrospective estimates of prices in 26 metropolitan and 9 nonmetropolitan areas from 1999. The Quarterly Food-at-home Price Database required extensive matching and reconstruction of variables from corporate databases obtained from consumer purchasers (e.g., the Nielsen Homescan Data) to translate prices into standard comparable quantities, forbidding the effort from becoming a routine annual exercise from which to adjust the TFP (28). We discuss this limitation and a potential strategy to overcome it below, where we discuss the recent availability of Regional Price Parity (RPP) statistics from the Bureau of Economic Analysis.

Nevertheless, the Quarterly Food-at-home Price Database and its underlying Nielsen Homescan Data do reveal substantial geographic variations in food prices across the nation, as detailed in several papers from the USDA's Economic Research Service (29–31). One study by Todd and colleagues found that although healthy foods were not universally more expensive than less healthy foods, there was great variation in healthy food prices across the country (30). For example, whole grains were almost

always more expensive than refined grains across the country; but the price variation ranged from 23% higher in San Francisco to >60% higher in nonmetropolitan Pennsylvania and New York. Similarly, fresh and frozen dark green vegetables were more expensive than starchy vegetables across the country, but prices varied from 20% higher to 80% higher. Furthermore, Gregory and Coleman-Jensen observed that the variations in food price related to variations in food security, such that one standard deviation increase in food prices was associated with a 5.0% increase in the prevalence of adult food insecurity (32).

These variations are unlikely to be sufficiently accounted for by the existing TFP formula. Prior studies in Boston and Philadelphia suggest that the TFP is unlikely to provide sufficient benefits to meet the intended nutritional standards in some urban areas. For example, a study in 2008 based on surveys of TFP-based food lists reported that a family of four receiving its maximum SNAP benefit would require an additional $2,520 in metropolitan Boston and $3,165 in metropolitan Philadelphia each year to purchase foods that meet the TFP's nutrition goals; these quantities are approximately 40% to 50% greater than the maximum annual benefit as of 2008 (33). Notably, many of the TFP food items (16-38%) were also unavailable at surveyed stores.

Despite the fact that the national standard for cost of living adjustment may not account for such food price differences and food availability differences, there are some implicit area-level adjustments in the SNAP benefit formula. Two major deductions available to working SNAP participants include a 20% deduction of earnings from gross income, which implicitly accounts for wage variation across local labor markets (34), and a dependent care deduction which permits direct costs of dependent care including transportation and copayments for fees to be deducted, implicitly accounting for childcare cost variations across geographic areas (35). For the elderly and disabled, out-of-pocket

medical cost deductions may additionally alter the impact of regional medical spending variations (36). The deduction for child support payments may account for state differences in child support awards (37). Finally, the inclusion of income from other safety net programs (such as Temporary Assistance for Needy Families, or TANF) may adjust benefits in the opposite direction, by reducing the size of the SNAP benefit. Because TANF is larger in higher-cost states (e.g., California, New York), adjustment for TANF benefits may effectively "tax" SNAP benefits for those living in high-cost states.

In reviewing this information, an Institute of Medicine Panel assembled in 2013 to assess the adequacy of SNAP benefits concluded: "Because most of the geographic differences in cost of living in the SNAP benefit formula are implicit rather than explicit, the question arises of whether making the adjustment more direct would facilitate definition of the benefit's adequacy…The challenge of implementing geographic cost-of-living adjustments is that at present, BLS [the Bureau of Labor Statistics] does not produce a regional price index…adjusting the maximum benefit geographically for differences in cost of living (or even food) is likely to be infeasible until further progress is made on regional price indices" (1).

Since the publication of the Institute of Medicine panel report, regional price indices have been produced and disseminated by the Bureau of Economic Analysis (BEA) and the U.S. Census, to assist in meeting the challenge of defining small area-level cost of living indices that can be routinely updated to adjust benefit formulas such as the TFP. The BEA has constructed regional price parities (RPPs), which are price indices measuring the price level differences across regions for a given time period by dividing the average price of goods or services in an area (typically a metropolitan statistical area, county, or state) by the national average price across all areas (38,39). The national average is set to a value of 100 such that an area's RPP can be interpreted as a percent of the national average, e.g., all goods and

services in New York State are 14.1% higher than the national average, so New York State has an RPP of 114.1. To derive the RPP index, the BEA obtained price and expenditure levels of individual goods and services in 16 expenditure classes (apparel, rents, and a goods class and a services class in each of the categories of: education, food, housing excluding rents, medical, recreation, transportation, and other), which are further subdivided into strata (e.g., "major appliances", under "goods") and elementary level items (e.g., "refrigerators and freezers", under "major appliances"), and clusters (e.g., "refrigerators", under "refrigerators and freezers"). The prices for rents are obtained from the American Community Survey, while the prices for other goods and services are estimated from expanded BLS data obtained from product sellers, as is done to construct CPIs. The individual price observations (~1 million observations per year) include hundreds of consumer goods and services, often including multiple quotes for the same product from multiple sellers. The geometric average of the prices for each type of good, specific to outlet type and unique product, is then taken and linked to expenditure weights designed to reflect the distribution of personal consumption expenditures in a geographic area (40). Expenditures for rents account for the largest weighted share of expenditures (~43% of total expenditures), and variation in rents are greater than that of any other expenditure class nationally. The data are then allocated to counties, such that the RPP methodology implicitly ignores within-county variations in price; for goods and services other than rents, the methodology effectively ignores variations across counties within a BLS index area from which BLS consumer purchasing datasets are not further disaggregated (e.g., RPPs in Jefferson county (WV), in Prince George's county (MD), and in Alexandria City (VA), are effectively assumed to be the same as the average in the entire Washington-DC-MD-VA-WV area, because this region is a single BLS area). Finally, the data are subjected to hedonic regressions, which attempt to account for variations in characteristics of goods and services provided, including differences in packaging, unit size, and type of outlet from which they are sold, to assemble an

aggregate index of cost in each item stratum. Hedonic regressions take into account consumer preference variations by area (e.g., apples may be a preferred fruit in one county, and oranges in another, so food regional price parities will account for variations in fruit preferences by location, rather than only comparing apple prices across all areas). An outlier analysis is performed to exclude extreme values, and missing data are imputed in some locations with limited input data. Estimation details have been extensively catalogued previously (38,39).

While the RPPs produced by the BEA have been newly constructed, the U.S. Census Bureau had previously assembled another metric of area cost of living: the geographic adjustment to the Supplemental Poverty Measure (41). In 1990, Congress appropriated a budget for an independent scientific study of the measurement and data for a poverty measure, with which the National Academy of Sciences established the Panel on Poverty and Family Assistance (42). Though the Panel released a report in 1995 discussing the need for a new measure to supplement the official poverty measure and account for a broad array of challenges faced by households in poverty, it was not until 2010 that the Interagency Technical Working Group on Developing a Supplemental Poverty Measure provided further details sufficient to incorporate a new measure into the Current Population Survey (CPS) to both produce a Supplemental Poverty Measure that captures a broad array of improvements to the poverty measure, including geographic adjustment of poverty thresholds for cost of living (43). The latter improvements are based on geographic differences in rental costs in the American Community Survey (ACS). The ACS now provides sufficient information on differences in rental prices across geographic areas, based on 5-year estimates of median gross rents for two-bedroom apartments with complete kitchen and plumbing facilities. Hence, this “geographic adjustment to the Supplemental Poverty Measure” is less comprehensive than the BEA’s RPPs and is primarily reliant on housing costs, which are

generally the largest expenditure for low-income households (11). Separate medians are estimated for each of 271 metropolitan statistical areas large enough to be identified on the public-use version of the CPS data file. For each state, a median is estimated for all nonmetropolitan areas and for a combination of all smaller metropolitan areas, producing 385 adjustment factors (41).

Given the availability of both RPPs and the geographic adjustment to the Supplemental Poverty Measure, we sought to test three key hypotheses relating the cost of living to the healthfulness of food acquisitions. Our *first hypothesis* was that a higher area-level cost of living would be associated with less healthy food acquisitions (which we define as lower Healthy Eating Index-2010 [HEI] scores, particularly from lower acquisition of fruits and vegetables and higher acquisition of refined grains and added sugars). The rationale for this first hypothesis was that higher cost of living would induce individuals to sacrifice food budgets for other costs such as rent, and that in many areas the perceived or real costs of healthier food items would be higher than those of less healthy items, such that lower overall food budgets would induce less healthy food acquisitions. Our *second hypothesis* was that SNAP participation would be associated with living in a lower-cost area after accounting for other observed and unobserved covariates related to both SNAP and area of living. The rationale for this second hypothesis was that SNAP benefits are adjusted based on national average cost of living indices, not local data, so the purchasing power of a SNAP dollar would be higher in lower food-cost areas, where overall cost of living is typically lower as well. Our *third hypothesis* was that any association between SNAP participation and the healthfulness of food acquisitions (i.e., HEI scores) would be partially moderated by area-level cost of living. The rationale for this third hypothesis is that SNAP participation itself may lead to changes in the healthfulness of food acquisitions (e.g., SNAP benefits may lead to the ability to purchase more fruits and vegetables, which are generally thought to be more expensive products), but the degree to which

SNAP dollars affect the healthfulness of food acquisitions may be influenced both by food costs in the area, and by costs of living including expenditures that compete with the food budget (e.g., rent) and affect how much SNAP users are able to supplement their SNAP allotments with other sources of income.

All three of our hypotheses have genuine scientific equipoise, as reasonable alternative hypotheses are available for each. Specifically, an arguable alternative to our first hypothesis is that a higher area-level cost of living will be associated with more healthy food acquisitions, due to self-selection of highly health-conscious persons to live in more costly areas that have real or perceived increased availability of healthier foods, and real or perceived social norms favoring healthier food consumption. Similarly, an alternative to our second hypothesis is that higher-cost areas would be associated with greater SNAP participation because people in such areas would be more desperate for funds to supplement their budgets. Finally, an alternative to our third hypothesis is that any association between SNAP participation and the healthfulness of food acquisitions is not significantly moderated by area-level cost of living, as the latter may be irrelevant or have only a weak effect if SNAP participants compartmentalize their food budget from other budgets.

Methods

We tested our hypotheses using newly-available data from the National Household Food Acquisition and Purchase Survey (2012-13) made available by the U.S. Department of Agriculture, which is the first nationally representative survey of American households to collect comprehensive data about household food purchases and acquisitions (44).

Details on the data source

The National Household Food Acquisition and Purchase Survey, or FoodAPS, is a unique household-level food survey that details food-at-home (FAH) and food-away-from-home (FAFH) purchases and acquisitions among a national sample of households, each surveyed for one week during the period April 2012 to January 2013. Households were defined as all persons who live together and share food and who expect to be present at the sampled address during at least part of the data collection week. The survey design attempts to be representative of non-institutionalized households nationally, as well as representative of four subgroups: SNAP participants, and nonparticipant households in three income groups (income below the federal poverty threshold for household size; incomes equal to or greater than 100 percent of the federal poverty threshold but less than 185 percent; and income greater than or equal to 185 percent of the federal poverty threshold). The sample of households was selected through a multi-stage sample design limited to the contiguous United States, with oversampling of SNAP-participating and other low-income households. Within a stratified sample of 50 counties or groups of contiguous counties selected as Primary Sampling Units through probability proportional to size selection, eight secondary sampling units of a census block group or group of contiguous block groups were selected. Among these secondary sampling units, households were screened for eligibility, and a total of 4,826 households containing 14,317 individuals participated in the survey.

During screening for participation, a primary respondent in each household was identified as the main food shopper or meal planner, and was asked to complete two in-person interviews and to call the study's telephone center for three brief telephone interviews regarding food acquisition events over the course of one week. In addition, each household member 11 years or older was asked to track and

report all food acquisitions during the week in specially-prepared booklets distinguishing between food and drink brought home and used to prepare meals for consumption at home or elsewhere (e.g., sandwich made at home and brought to work), which constituted FAH, and food and drink obtained and consumed away from home, and prepared foods brought home or delivered (e.g., pizza), which constituted FAFH. The booklets also enabled participants to enter detailed information about food acquisition "events", including location, date, and payment types. Households scanned barcodes on packaged foods and submitted receipts from stores and restaurants, which enabled independent confirmation of reports. Variable-weight items (e.g., a head of lettuce or individual apples) and other items without a barcode were also included by enabling respondents to scan barcodes from a standardized food barcode book or write item details of foods not coded. Post-collection processing included resolution of inconsistencies through receipts and imputation where possible, as detailed elsewhere (45). To enable nutritional analyses, individual food items were matched to items in the USDA Food and Nutrient Database for Dietary Studies or the USDA National Nutrient Database for Standard Reference (46,47).

Additional data collection in FoodAPS included detailed demographic, socioeconomic and nutrition-related information about each household. This information included SNAP participation status in the prior 30 days, determined by both participant self-report and matches to USDA administrative records for confirmation of SNAP participation or non-participation among the 97.5% of respondents who consented to the administrative match. When administrative match was not consented to or no match was found, participant self-report of SNAP participation status was taken at face value. Of note, FoodAPS identified households in which anyone received SNAP, but did not try to identify who within each household received SNAP, under the premise that household members would typically share SNAP

benefits.

In addition to SNAP participation, FoodAPS data collection included self-reported information about the primary store at which the household did most of its food shopping, the typical mode of transportation used to get to that store, and type of store (e.g., supercenter, grocery store, convenience store). Locations of SNAP-authorized stores were geocoded and distances from the households to the nearest SNAP supermarket or supercenter, as well as distances to the primary food store were recorded. Euclidean distance (straight line) estimates were our primary distance metric, as these are more standardized than driving and walking route estimates. Additional self-reported WIC participation by any member of the household and food security status based on the 10 questions used to assess household food security status in USDA's 30-day Adult Food Security Scale were also asked, as were standard Census-type questions regarding participant demographics and socioeconomic characteristics including education and employment (48).

Each household was given a sampling weight, based on reported SNAP participation status revised per the administrative data match, to make the sample nationally representative of all non-institutionalized households in the contiguous United States and account for differential probability of selection and nonresponse. Weights were stratified to replicate 2013 Current Population Survey Annual Social and Economic Supplement estimates of the number of households in the United States and the distribution by demographic and economic characteristics using iterative proportional fitting for Hispanic status, race, annual income, receipt of SNAP, poverty status, household size, number of children in the household, and presence of least one person age 60 or older in the household. Weights were trimmed to reduce design effect.

Data organization, variable construction, and choice of outcome metrics.

To perform our assessment, we first constructed estimates of household-level food acquisition, expressed in both kilocalories (kcals) and in food pattern equivalents units (ounce-equivalents, oz-eq, or cup-equivalents, cup-eq) per household per day. Specifically, we used estimates of the kilocalories per 100 grams and food pattern equivalents per 100 grams contained in each food product, provided in the FoodAPS, which were estimated by the USDA by matching individual food items to records in the Food Patterns Equivalents Database (2011-2012) and Food Patterns Ingredients Database, supplemented by the School Nutrition Dietary Assessment Study for foods obtained from reimbursable school lunch and breakfast meals (49,50). We multiplied kilocalories per 100 grams or food pattern equivalents per 100 grams by the estimated volume (in 100-grams, unrounded to include exact decimals) of each product, also estimated by the USDA and provided in FoodAPS for both at-home and away-from-home food acquisition events based on participant-reported descriptions of food and/or product database estimates of the edible portion of each scanned food item. We summed the total kilocalories and total food pattern equivalents acquired per household across all events over the entire 7-day survey period, then computed the average total kilocalories as well as the food pattern equivalents per household member per day in the eight food categories assembled from the classification system in the National Food and Nutrient Database for Dietary Studies, version 5.0 (2012): (i) vegetables (total dark green, red and orange, starchy vegetables, and legumes counted as vegetables); (ii) whole fruits and 100% fruit juices; (iii) whole grains; (iv) refined grains; (v) dairy products (milk, yogurt, cheese, and whey); (vi) proteins (meat, poultry, seafood, eggs, soy, nuts, seeds, and legumes counted as protein); (vii) solid fats and oils; and (viii) added sugars. Individual-level estimates accounted for the number of household members and non-household guests among whom the food item was reported to be shared; however,

the FoodAPS survey only contained information on acquisitions, not on consumption (i.e., the data are not dietary recalls), hence we cannot account for intra-household variations in consumption, food preparation, or food waste.

As an overall dietary quality metric, we computed a Healthy Eating Index (HEI, version 2010) for each individual. The HEI is a widely-used metric of overall dietary quality, which has been correlated to cardiovascular disease and cancer risk in longitudinal cohort studies of diet and health. A key advantage of HEI is that it is constructed to assess dietary quality through universal standards and a density approach (e.g., nutrients per 1000 calories) that can be applied and compared at all levels of the food system—from farm to supermarket to individual—and at all levels of production or consumption—from manufacturer to neighborhood availability to food acquisition to dietary intake. Hence, the Index has been applied, for example, to assess the dietary quality of neighborhood food environments, individual restaurant menus, supermarket sales circulars, and food purchases among food assistance program participants (51–57). At the time of this writing, the HEI-2010 was the most recently-available year of the Index, corresponding to the Dietary Guidelines for Americans, 2010 (58). The more recent Guidelines (released 2016, but recommended for years 2015-2020) are mostly concordant with the 2010 Guidelines, but additionally recommend reducing meat intake among adult males, and limiting intake of added sugars (59). The HEI-2010 is a composite score from 0 to 100 indicating the concordance of, in our case, food acquisitions per person per day, to the 2010 Dietary Guidelines for Americans; a score of 50 would indicate that the quality of an individual's food acquisitions are only half as high as recommended. The score is constructed from 12 food categories and nutrient components by adding points for foods considered health-promoting per the 2010 Guidelines (total fruit, whole fruit, total vegetables, greens and beans, whole grains, dairy, total protein foods, seafood and plant proteins, and

poly- and mono-unsaturated fatty acids), and for low intake of foods considered potentially harmful to health (refined grains, sodium, and empty calories, referring to calories from solid fats, added sugars and alcohol). Macro- and micro-nutrient components such as sodium and fatty acids were available per food item in FoodAPS, calculated by the USDA by matching foods to the Food and Nutrient Database for Dietary Studies (2011-2012), and its underlying National Nutrient Database for Standard Reference (46,47), as well as to the School Nutrition Dietary Assessment Study (50) for foods obtained from reimbursable school lunch and breakfast meals. The HEI-2010 for each individual was then calculated from the density ratios of each food category and nutrient component, using standardized software code assembled by the National Cancer Institute, available online (60). For reference, a recent assessment of the 2010 U.S. food supply based on national food availability data estimated an overall HEI-2010 score of 55 for the nation (54); a recent assessment of U.S. national food consumption patterns based on dietary recall data in the National Health and Nutrition Examination Survey (2009-2010, *N* = 9,522) also reported a mean HEI-2010 score of 55 (51).

Hypothesis 1: Relationships between cost of living and healthy food acquisition

To test hypothesis (i), that a higher area-level cost of living is associated with less healthy food acquisition, we regressed daily per person food acquisition in each food category and, separately, the HEI measure of food acquisition quality, against metrics of the cost of living (regional price parities or the geographic adjustment to the supplemental poverty measure). We performed separate regressions for each food category and for the HEI score, and separate regressions for each metric of living cost (overall regional price parity; regional price parities for rent, food, all goods and all services; and the geographic adjustment to the supplemental poverty measure). Among the regional price parities, we specifically focused on the rent regional price parity (generally the largest share of overall household

expenditure among low-income consumers) and food regional price parity (39). The regional price parities and geographic adjustments to the supplemental poverty measures were available at the Metropolitan Statistical Area (MSA) level, and included an average for non-MSA areas in each state. The BEA lacks regularly-updated data for geocoded areas smaller than the MSA level, hence it is likely that if SNAP were to be adjusted for local area-level cost of living, the MSA level would be the smallest local area for which such costs would be routinely available from the BEA. By comparison, the USDA's Quarterly Food-at-home Price Database, the previously most-comprehensive public source for food price data nationally, was aggregated to much larger food purchasing metropolitan market groups, which are more aggregate than the level of MSA (i.e., there are 99 food purchasing market groups, instead of the 388 MSAs). We linked the MSA-level data to county geocodes in the FoodAPS dataset, as MSAs are defined by one or more counties, and county geocodes were available in the FoodAPS.

In our regressions, we included individual-, household-, and area-level covariates that we theorized to be potentially of pertinence to the relationship between area-level cost of living and food acquisitions. We chose the county as the area level of interest, as significant data were available at the county level to describe pertinent aspects of the food environment and living environment that were unavailable at smaller geocoded units, as detailed further below. Additionally, recent studies including those conducted on FoodAPS have revealed that SNAP participant households as well as non-participant households tend to travel outside of their immediate census block or census tract when acquiring food, but the primary food store remains typically within their county of residence (61–64). Hence, too small of a geographical area may not capture pertinent covariates of interest. At the individual level, covariates in our regressions included age (in years), age-squared, sex, race (White, Black, or other), ethnicity (Hispanic or not), education (high school or less, or more than high school), and employment

status (currently employed or not). At the household level, covariates in our regressions included household size (number of non-guest residents in the home), income (annual, as a percent of the federal poverty threshold adjusted for household size), distance to primary food store (Euclidean distance, which per a prior USDA assessment was thought to provide more standardized estimates than distances based on driving or walking routes (4) (65), rural residence, food security status (low or very low food security of the primary adult respondent on the USDA 30-day adult food security scale) (48), WIC participation (current self-reported participation of any household member), and SNAP participation (current SNAP participation of any household member, either administratively-confirmed or based on self-report for participants not consenting to administrative confirmation or for whom administrative data were not available for confirmation). At the county level, covariates in our regressions included density of supermarkets (stores per 1,000 population), density of non-supermarket food-selling stores (per 1,000), density of full-service restaurants ("sit down" restaurants, per 1,000), density of limited-service restaurants ("order at the counter" restaurants, often referred to as "fast food" establishments, per 1,000), poverty rate (% of population below federal poverty threshold), area-level household income (median annual in 2012 inflation-adjusted U.S. Dollars), education (% of population 25 years or older with at least high school education), access to kitchens (% of occupied housing units with complete kitchen facilities available), and vehicle density (% of occupied housing units with at least one vehicle available).

Despite the extensive data available on pertinent covariates at multiple levels, additional unobserved factors could influence individuals to both live in a high-cost or a low-cost area, and affect the healthfulness of their food acquisition patterns (e.g., preferences for organic foods might influence individuals towards living in higher-cost areas and towards having higher HEI scores). Hence, our

regressions were performed using an endogenous treatment effects model, which attempts to control for the endogeneity of treatment assignment (whether one lives in a high-cost or lower-cost area) by including residuals from a model of treatment assignment as a regressor in the models for the potential outcomes (i.e., a control function approach) (66) . The endogenous treatment effects approach has the following functional form:

[1] $y_{i0} = E(y_{i0}|\boldsymbol{x}_i) + \epsilon_{i0}$

[2] $y_{i1} = E(y_{i1}|\boldsymbol{x}_i) + \epsilon_{i1}$

[3] $t_i = E(t_i|\boldsymbol{z}_i) + v_i$

[4] $y_i = t_i y_{i1} + (1 - t_i) y_{i0}$

[5] $E(\epsilon_{ij}|\boldsymbol{x}_i \boldsymbol{z}_i) = E(\epsilon_{ij}|\boldsymbol{z}_i) = E(\epsilon_{ij}|\boldsymbol{x}_i) = 0$ for $j \in \{0, 1\}$

[6] $E(\epsilon_{ij}|t) \neq 0$ for $j \in \{0, 1\}$

where individuals *i* experience potential outcomes (food pattern equivalents, or HEI scores) y_{i1} when living in a high-cost area, or y_{i0} when living in a lower-cost area. The variable t_i designates the observed treatment and y_i the observed outcome. Each of the potential outcomes *y* is estimated from its expected value conditional on observed covariates $\boldsymbol{x}_i$ and an unobserved random component ϵ_{ij} for $j \in \{0, 1\}$. The treatment *t* (whether one lives in a high- or lower-cost area) is also estimated from its expected value conditional on regressors $\boldsymbol{z}_i$ (which, importantly, do not need to differ from $\boldsymbol{x}_i$), and from an unobserved component v_i. While equations 1 through 4 specify the treatment effects model, equation 5 specifies that unobserved factors in the potential outcome are independent from the observed regressors $\boldsymbol{z}_i$, and equation 6 specifies the endogeneous nature of treatment, indicating that

unobserved factors in the outcomes equations are potentially correlated to the treatment. Equation 5 restricts the correlation between t_i and unobserved factors to be equivalent to the correlation between ϵ_{ij} and v_i, which means that:

[7] $$E(\epsilon_{ij}|t) = E(\epsilon_{ij}|E(t|\boldsymbol{z}_i) + v_i) = E(\epsilon_{ij}|v_i) = v_i\beta_{2j}$$

To estimate the model, equation 3 is fit using a probit estimator, which produces the statistic $\widehat{v_i}$ for the difference between the treatment and the estimated $E(t_i|\boldsymbol{z}_i)$; this statistic, given equation 7, allows us to compute an estimate of $E(y_{ij}|\boldsymbol{x}_i, v_i, t_i)$:

[8] $$E(y_{ij}|\boldsymbol{x}_i, v_i, t_i = j) = \boldsymbol{x}_i'\beta_{1j} + v_i\beta_{2j} \text{ for } j \in \{0, 1\}.$$

We estimate the effect of living in a high- versus lower-cost area (the treatment) on the outcome of food pattern equivalents acquired in each food category and, separately, on the outcome of HEI score. The average treatment effect of living in a high- versus lost-cost area, $[E(y_{ij}|\boldsymbol{x}_i, v_i, t_i = 1) - E(y_{ij}|\boldsymbol{x}_i, v_i, t_i = 0)]$, is estimated by the generalized methods of moments using the Stata module eteffects (67). We included all individual-, household-, and county-level covariates as both regressors $\boldsymbol{x}_i$ and $\boldsymbol{z}_i$. As the endogenous treatment effects estimation approach requires a binary treatment, we constructed a cut-point for values of each regional price parity and for the geographic adjustment to the supplemental poverty measure, above which area cost of living was defined as "high" (and, conversely, below which cost of living was defined as "lower"). The cut-point for each regional price parity (overall, and for each good or service regional price parity) and for the geographic adjustment to the supplemental poverty measure was defined as one standard deviation above the mean. For comparison, we performed ordinarily least squares (OLS) regressions of the food pattern equivalents acquired and of HEI score against the metrics of cost of living and the above-noted covariates, although the effect size

estimates from such regressions would be expected to be biased by failing to account for potential unobserved factors influencing both the area of living and healthfulness of food acquisitions. Our rationale for performing OLS regressions was to explore whether older studies using OLS estimates (e.g., correlating SNAP participation to worse nutrition (17)) would be consistent with the endogenous treatment effects model. The Stata survey (svy) module was utilized to adjust regression estimates for stratification and clustering, and to apply survey sample weights to account for differential sampling and nonresponse. Missing data was not imputed, as food acquisition data cannot be determined to be missing (i.e., a failure to scan or report a food cannot be identified), and minimal data were missing for HEI score calculations or for covariates in the regressions (<7% missing for any single variable).

Hypothesis 2: SNAP participation and cost of living

To test hypothesis (ii), that SNAP participation is associated with living in a lower-cost area, we repeated the above endogenous treatment effects model, but labeled SNAP participation as the treatment *t* and the probability of living in an area with higher cost of living as the outcome *y* estimated using a probit model. The relationship between SNAP participation and cost of living can be conceived of as endogenous both because of the potential for reverse causality (e.g., living in a higher-cost area may induce a person to sign up for SNAP benefits to afford more or better quality foods, or alternatively receiving SNAP may lead a person to select a low-cost area in which to live, to make dollars go further), and because of unobserved factors (e.g., persistent economic deprivation may lead to both SNAP participation for poverty relief and selecting a lower cost of living area to reduce housing costs).

In regressing cost of living against SNAP participation, we included all of the individual-, household-, and county-level covariates as in our test of hypothesis (i), but we additionally included more regressors among $\boldsymbol{z}_i$—specifically, state variations in SNAP administration policy that may serve as

instrumental variables potentially inducing or discouraging SNAP administration. We tested several available instrumental variables describing state-level SNAP administrative policies that were included in FoodAPS, imported from the SNAP Policy Database: (i) whether the state uses broad-based categorical eligibility to increase or eliminate the asset test and/or to increase the gross income limit for virtually all SNAP applicants (true for 73% of the unweighted FoodAPS participant sample); (ii) whether the state operates call centers, and whether or not call centers service the entire State or select regions within the State (74%); (iii) whether the state operates a Combined Application Project for recipients of Supplemental Security Income (SSI), so that SSI recipients are able to use a streamlined SNAP application process (66%); (iv) whether the state disqualifies SNAP applicants or recipients who fail to perform actions required by other means-tested programs, primarily Temporary Assistance for Needy Families (TANF) (41%); (v) whether the state has been granted a waiver to use a telephone interview in lieu of a face-to-face interview at initial certification, without having to document household hardship (77%); (vi) whether the state has been granted a waiver to use a telephone interview in lieu of a face-to- face interview at recertification, without having to document household hardship (90%); (vii) whether the state requires fingerprinting of SNAP applicants (34%); (viii) whether all legal noncitizen adults (age 18-64) who satisfy other SNAP eligibility requirements such as income and asset limits are eligible for Federal SNAP benefits or State-funded food assistance (22%); (ix) whether the state allows households to submit a SNAP application online (74%); (x) the sum of Federal, State, and grant outreach spending in nominal dollars ($1,000s) (83% non-zero); (xi) for households with earnings, whether the state uses the simplified reporting option that reduces requirements for reporting changes in household circumstances (88%); (xii) whether the state excludes all vehicles in the household from the SNAP asset test (83%); (xiii) whether the state exempts an amount higher than the SNAP standard auto exemption from the fair market value to determine the countable resource value of a vehicle (14%); and (xiv) whether the state

excludes at least one, but not all, vehicles in the household from the SNAP asset test (3%). Other policies listed in the SNAP Policy Database had no variation (i.e., all states had the same policy), for example in eligibility towards noncitizen children, or had complete overlap with one of the above instruments in terms of which states implemented the policy. To select the strongest instruments for inclusion among regressors $\boldsymbol{z}_i$ in the endogenous treatment effects model, we performed a two-stage least-squares regression of overall cost of living against the individual-, household-, and county-level covariates and SNAP participation, where the latter was instrumented by each eligible instrument in turn; we then included the subset of instruments with a significant (p<0.05) first-stage F-test>10, which were instruments (ii) call centers (F=76.0), (iii) combined application project for SSSI recipients (F =699.2), (iv) disqualification for failing to perform TANF requirements (F =279.3), (vi) waiver for telephone interview (F =204.9), (vii) fingerprinting (F =526.8), (viii) eligibility for noncitizen adults (F =259.7), (ix) online application (F =160.7), (x) outreach spending (F =14.4), and (xi) simplified reporting (F =249.8) in the above list.

We isolated our test of hypothesis (ii) to only the subset of participants in SNAP and non-participants with household income less than 185% of the federal poverty threshold level, because our question was applicable only to the subset of the population theoretically eligible for SNAP participation and 185% of the federal poverty threshold is used as a cut-point for eligibility. We estimated both the average treatment effect (ATE, or the generalizable effect of participating in SNAP on whether a person lives in a low- or higher-cost area), and the average treatment effect on the treated (ATET, or the specific effect of participating in SNAP among those observed to be participants), using the Stata eteffects module (67). As in our testing of hypothesis (i), missing data were not imputed prior to estimation of the treatment effects in our regressions testing hypothesis (ii).

Hypothesis 3: Whether SNAP effects on healthy food acquisition are moderated by cost of living

Finally, we tested hypothesis (iii) that any association between SNAP participation and the healthfulness of food acquisitions (i.e., HEI scores) is partially moderated by area-level cost of living. To test this hypothesis, we repeated the endogenous treatment effects model, first labeling SNAP participation as the treatment *t* and food pattern equivalents acquired and, separately, overall HEI score as the outcome *y*, to assess the association between SNAP and the healthfulness of food acquisitions, then repeating the analysis with the interaction between SNAP participation and the area cost of living as the treatment, to determine the significance of the interaction term defining how the SNAP-food acquisition relationship was moderated by cost of living.

As with hypothesis (ii), we isolated our test of hypothesis (iii) to only the subset of participants in SNAP and non-participants with household income less than 185% of the federal poverty threshold level, because our question was applicable only to the subset of the population theoretically eligible for SNAP participation. We estimated both the average treatment effect (ATE, or the generalizable effect of participating in SNAP on whether a person lives in a low- or higher-cost area), and the average treatment effect on the treated (ATET, or the specific effect of participating in SNAP among those observed to be participants), using the Stata eteffects module. As in our testing of the other two hypotheses, missing data were not imputed prior to estimation of the treatment effects in our regressions testing hypothesis (ii).

All estimates were performed using Stata version MP/14 (StataCorp, College Station, Texas).

Results

Descriptive statistics on the analytical sample

Table 1 provides summary statistics on the analytical sample. The sample included 1,581 SNAP participant households (*N*=5,414 individuals), 1,391 non-participant households <185% of the federal poverty threshold (*N*=3,863 individuals), and 1,852 non-participant households >=185% of the federal poverty threshold (*N*=5,036 individuals). As shown in the Table, the average age of the SNAP participants in the sample (30 years of age) was eight to nine years younger than non-participants; only 6% of the SNAP participant sample were above the age of 65, as compared to 16% of non-participants <185% of the federal poverty threshold and 13% of non-participants >=185% of the federal poverty threshold. The SNAP participants in the sample had a similar proportion of females (54%), as compared to 54% and 51% of non-participants below and at/above 185% of the federal poverty threshold, respectively. Fewer SNAP participants in the sample were White (63%, versus 75% and 83% of non-participants below and at/above 185% of the federal poverty threshold, respectively), and more were Black (27% versus 15% and 10%, respectively) and Hispanic (31%, versus 28% and 12%, respectively). Fewer SNAP participants in the sample had completed high school (48%, versus 59% and 73% of non-participants below and at/above 185% of the federal poverty threshold, respectively) and fewer were employed (29%, versus 34% and 56%, respectively).

At a household level, the SNAP participant sample had larger household sizes (4.2 members, versus 3.6 and 3.1 among non-participants below and above 185% of the federal poverty threshold, respectively). SNAP participant households in the sample also had higher mean income than non-participants less than 185% of the federal poverty threshold, with SNAP households having an income of 138.6% of the federal poverty threshold for household size, versus 100.8% for non-participants less than

185% of the federal poverty threshold. This finding is contradictory to the perception that non-participants are those who are likely to get smaller SNAP benefits and therefore fail to enroll. SNAP participants in the sample also faced lower housing costs ($577 of monthly rent or mortgage expenses, versus $721 and $1,014 among non-participants below and at/above 185% of the federal poverty threshold, respectively), and were closer to their primary food store in Euclidean miles (3.1, versus 3.6 and 3.9, respectively), though both housing costs and distances to stores varied widely among all sample subgroups, as shown in **Table 1**. SNAP participants in the sample tended to be less rural than the other groups (23% in a rural residence, versus 28% and 35% among non-participants below and at/above 185% of the federal poverty threshold, respectively). SNAP participants in the sample were also more likely to have low or very low food security (43%, versus 32% and 7% among non-participants below and at/above 185% of the federal poverty threshold, respectively) and to participate in WIC (22%, versus 14% and 3%, respectively).

At the county level, SNAP participants in the sample had a similar density of supermarkets as non-participants (12 per 1,000 people), and slightly more non-supermarket food retailers (28 per 1,000, versus 26 and 23 among non-participants below and at/above 185% of the federal poverty threshold, respectively). SNAP participants in the sample also had fewer full-service restaurants (74 per 1,000 versus 79 and 82 among non-participants below and at/above 185% of the federal poverty threshold, respectively), but a similar density of limited-service “fast food” restaurants (at 69 per 1,000 among all subgroups). The poverty rate in the counties in which the SNAP participant sample lived was equivalent to that of the non-participant sample less than 185% of the federal poverty threshold (at 16%), and only slightly lower than among the non-participant sample ≥185% of the federal poverty threshold (at 14%). County-level median household incomes were more graded, with the SNAP participant sample living in

counties with an area median income of $50,400, versus $52,800 and $55,400 among non-participants below and at/above 185% of the federal poverty threshold, respectively. County-level high school educational attainment among persons at least 25 years old was similar across subgroups (85% among the SNAP participant sample, versus 84% and 87% among non-participants below and at/above 185% of the federal poverty threshold, respectively). Vehicle density and kitchen availability was high and did not differ among the subgroup samples of SNAP participants and non-participants below and at/above 185% of the federal poverty threshold.

The cost of living metrics were generally only minimally lower among the SNAP participant sample, on average, than among the non-participant samples—but the distributions of the cost of living metrics were largely overlapping among all three subgroup samples. The overall regional price parity averaged 98% among the SNAP participant sample versus 100% and 99% among non-participants below and above 185% of the federal poverty threshold, respectively. The rent regional price parity was more substantially lower on average for the SNAP participant sample, at 96%, versus 104% and 102% among non-participants below and at/above 185% of the federal poverty threshold, respectively. The food regional price parity was minimally lower on average for the SNAP participant sample, at 99%, versus 100% and 100% among non-participants below and at/above 185% of the federal poverty threshold, respectively. The regional price parity for goods was at 99% for all subgroup samples, and for services was slightly lower at 98% for the SNAP participant sample, versus 100% and 99% among non-participants below and at/above 185% of the federal poverty threshold, respectively. The geographic adjustment to the Supplemental Poverty Measure differed more between SNAP participants and non-participants, at 99% for the SNAP participant sample, versus 105% and 104%, respectively, among non-participants below and at/above 185% of the federal poverty threshold.

To further characterize overall cost of living among the studied populations, we plotted the distribution of the overall regional price parity among each subgroup sample (**Figure 1**). As shown in the Figure, all three population subgroups largely spanned the same spectrum of possible cost of living levels, and the overall regional price parity was multi-modal, with a larger population living below the national average cost (more common for SNAP participants than non-participants), a second group living near the national average (also more common for SNAP participants than non-participants), a third group living around 7% above the national average cost (more common for the non-participants at/above 185% of the federal poverty threshold) and a fourth group living around 25% above the national average cost (interestingly, most common for the non-participants below 185% of the federal poverty threshold).

Food acquisition patterns in the analytical sample

Table 2 summarizes the food acquisition patterns, at the household and at the individual level, among SNAP participants and non-participants below and at/above 185% of the federal poverty threshold in our analytical sample. As shown in **Table 2**, food acquisition patterns did not differ significantly among the three subgroup samples, except in the food category of added sugars. Among all groups, added sugars constituted the most acquired food category by grams, with SNAP participants having significantly (at the $p<0.05$ level) higher acquisition (941 grams/person/day, SE: 48) than non-participants below 185% of the federal poverty threshold (749, SE: 35), though not significantly differing from non-participants at/above 185% of the federal poverty threshold (884, SE: 45). Fats and oils constituted the second largest group of acquisitions by grams, followed by dairy products, refined grains, then vegetables and fruits, and last whole grains. The subgroups did not significantly differ in their acquisitions in these categories, and overall kilocalories acquired did not significantly differ among

the groups (ranging from a low of 2,336 kcals/person/day on average the SNAP non-participant sample below 185% of the federal poverty threshold, SE: 114, to a high of 2,588 kcals/person/day on average among the SNAP participant sample, SE: 122).

To provide reference ranges and context to the food acquisition values, **Table 3** compares the estimated food acquisitions per person per day in our analytical sample to the reported food consumption (estimated via 24-hour dietary recalls) among participants in the National Health and Nutrition Examination Survey (NHANES) (68), and to current National Dietary Guidelines (69). As shown in the Table, the food acquired among all three subgroup samples was generally consistent with the food consumed by nationally-representative participants in the NHANES survey, although the standard errors around the food acquired estimates were larger than the standard errors around consumption in NHANES. The notable exceptions were in added sugars, fats and soils, and refined grains, where estimates of food acquired were 86%, 27%, and 29% higher, respectively, in our FoodAPS food acquisition estimates than in the NHANES food consumption estimates. This may be because acquisition (FoodAPS) differs profoundly from consumption (NHANES) for these items, particularly because these products have longer shelf-lives and potentially are more commonly wasted or shelved rather than consumed; alternatively, it may suggest population sampling differences, as the most acquisition in all three categories was among the SNAP participant sample, whereas NHANES is a nationally-representative sample. Alternatively, the stigma associated with consuming these foods may mean that their consumption is underreported in NHANES dietary recalls. Consistent with the average HEI-2010 score of 55.4 (SE: 0.7) among NHANES participants, the average HEI-2010 score among all subgroup samples in FoodAPS was 54.4 and 54.7 (among SNAP participants and non-participants below 185% of the federal poverty threshold, respectively, SE 0.2) or 55.0 (among non-participants at/above 185% of

the federal poverty threshold, SE 0.1). Also consistent with NHANES, the food acquisition patterns in FoodAPS were highly discordant from federal nutrition guidelines, with all groups acquiring or consuming few fewer vegetables, fruits, whole grains or dairy products than recommended, and far more refined grains, fats and oils, and added sugars than recommended.

Hypothesis 1: is a higher area-level cost of living associated with less healthy food acquisition?

Table 4 summarizes the estimated average relationship between living in a high-cost county and patterns of food acquisition in the overall FoodAPS analytical sample. The coefficients and standard errors displayed in the Table are estimates from the endogenous treatment effects model in which county-level cost of living is regressed against food acquisitions in each food category, after controlling for the individual-, household-, and county-level covariates listed in **Table 1**. In **Table 4**, the rows display the metric of cost of living being used as an independent variable (e.g., overall regional price parity, regional price parity for rent, etc.); the columns display the outcome measure of foods acquired in each food category (e.g., vegetables, fruits, etc.) in food pattern equivalents (e.g., cup-equivalents, ounce-equivalents) specific to that food category, per person per day. For reference, the mean levels of food acquired in food pattern equivalent units, per person per day, is provided in **Table 2**.

As shown in **Table 4**, no matter which metric we used as a measure of cost of living (overall regional price parity, category-specific regional price parity, or the geographic adjustment to the Supplemental Poverty Measure), living in a higher cost of living county was associated with significantly fewer acquisitions of vegetables, fruits, and whole grains, and was associated with significantly greater acquisitions of refined grains, dairy products, protein, fats and oils, and added sugars. Having controlled for individual-level factors such as education level, household-level factors such as income, and county-level factors such as food availability, living in a high-cost county, as measured by the overall regional

price parity, was associated with a decline in vegetable acquisition by about 0.65 cup-equivalents per person per day (SE: 0.04, $p<0.001$), which is approximately a 37% decline relative to estimated mean acquisition for that food category among equivalent persons living in a low-cost county. Living in a higher-cost county (measured by the overall regional price parity) was also associated with 0.14 cup-equivalents lower fruit acquisitions (16%), and 0.11 ounce-equivalents lower whole grain acquisitions (11%). By contrast, living in a high-cost county, as measured by the overall regional price parity, was associated with an increase in refined grain acquisition by about 2.35 ounce-equivalents per person per day (SE: 0.12, $p<0.001$), which is approximately a 34% increase relative to mean acquisitions for that food category among equivalent persons living in a low-cost county. Living in a higher-cost county (measured by the overall regional price parity) was also associated with increased fat and oil acquisitions of 36.63 grams (52%), and increased added sugar acquisitions of 9.40 teaspoon-equivalents (35%). Living in a high-cost county was associated with a higher caloric intake by approximately 550 kcals/person/day when using the overall regional price parity as the metric of cost of living. Overall, living in a high-cost county, as measured by the overall regional price parity, was associated with a 6.0 point lower HEI-2010 score (SE: 0.09, $p<0.001$), a 11% decrease relative to the mean among equivalent persons living in a low-cost county.

Different subcategories of costs of living (rent, food, all goods, or all services) were most strongly associated with changes in different food categories. As shown in **Table 4**, reduced acquisition of vegetables was more strongly associated with an increase in rent regional price parity than with an increase in the food regional price parity. Acquisitions in the food categories of whole grains, protein, and fats and oils, as well as the overall HEI score, were also most sensitive to the rent regional price parity as compared to any other subcategory of cost of living. The food regional price parity was more

strongly correlated to acquisitions of fruits, refined grains, dairy products and added sugars than any other regional price parity. The geographic adjustment to the Supplemental Poverty Measure was, however, more strongly related to acquisitions of food in all of those categories, and to overall HEI-2010 score, than was the food regional price parity (**Table 4**). Overall, living in a high cost of living area as defined by the geographic adjustment to the Supplemental Poverty Measure was associated with a 2.1 point decline in HEI-2010 score, SE 0.9, $p<0.05$), whereas living in a high cost of living area as defined by the food regional price parity was associated with a 1.4 point decline (SE 1.0, $p>0.05$), and living in a high cost of living area as defined by the rent regional price parity was associated with 6.0 point decline (SE 0.9, $p<0.001$).

Figure 2 provides a subgroup analysis of the relationship between living in a high-cost county and patterns of food acquisition, stratified by the three subgroup samples of SNAP participants, non-participants below 185% of the federal poverty threshold, and non-participants at/above 185% of the federal poverty threshold. The Figure displays the coefficients and 95% confidence intervals around the coefficients from endogenous treatment effects models regressing county-level cost of living against HEI-2010 scores, after controlling for the individual-, household-, and county-level covariates listed in **Table 1**. Changes in individual food categories were consistent across all sample subgroups. As shown in **Figure 2**, however, SNAP non-participants below 185% of the federal poverty threshold were most sensitive to changes in the cost of living as measured by the regional price parity, while the non-participants at/above 185% of the federal poverty threshold were the least sensitive. Living in a high cost of living area, as measured by the overall regional price parity, was associated with 5.8 points lower HEI-2010 scores among SNAP participants (SE: 0.9, $p<0.001$), 7.0 points lower HEI-2010 scores among SNAP non-participants below 185% of the federal poverty threshold (SE: 1.0, $p<0.001$), and 4.0 points

lower HEI-2010 scores among SNAP non-participants at/above 185% of the federal poverty threshold (SE: 0.6, $p<0.001$). Consistent with the overall results, the subcategory of cost of living that was associated with the greatest decline in the HEI-2010 score among all subgroup populations was the rent regional price parity; by contrast, the food regional price parity was not significantly associated with changes in HEI scores due to large standard errors around the treatment effects model coefficient.

Hypothesis 2: is SNAP participation associated with living in a lower-cost area?

Table 5 summarizes the estimated average relationship between SNAP participation and the probability of living in a higher-cost area in the overall FoodAPS analytical sample. The coefficients and standard errors displayed in the Table are estimates from the endogenous treatment effects model in which county-level cost of living is regressed against food acquisitions in each food category, after controlling for the individual-, household-, and county-level covariates listed in **Table 1**, and additionally including instrumental variables that capture differences between states in how they execute SNAP enrollment (see **Methods**). In **Table 5**, the two columns display the change in the probability of living in a higher-cost county given SNAP participation, either among the overall eligible population (average treatment effect) or among those who are observed to be SNAP participants (average treatment effect on the treated). Each row lists a different metric for the cost of living, ranging from the overall regional price parity to various subcategories of regional price parities (rent, food, all goods, all services) to the geographic adjustment to the Supplemental Poverty Measure.

As shown in **Table 5**, SNAP participation was associated with a higher probability of living in a high-cost county, no matter which metric we chose to define cost of living, after controlling for relevant individual-, household-, and county-level confounding variables. In addition, as shown in the Table, the estimated association between SNAP and the probability of living in a high-cost county was smaller for a

theoretically eligible person (the average treatment effect) than for a person observed to participate in SNAP (average treatment effect on the treated). The average treatment effect was that SNAP participation was associated with a higher probability of living in a high-cost area, as measured by the overall regional price parity, from 0.20 to 0.64 (an increase of 0.44, SE: 0.01, $p<0.001$); the average treatment effect on the treated was that SNAP participation was associated with a higher probability of living in a high-cost area from <0.01 to 0.22 (an increase of 0.22, SE: <0.01, $p<0.001$). Notably, the biggest treatment effect on the treated was observed for the food regional price parity (SNAP participation was associated with a higher probability of living in a high-food-cost area by 0.24, SE 0.01, $p<0.001$). Since the directionality of the treatment-effects model is uncertain, this implies either that living in a high-cost county induces SNAP participation, or that SNAP participation induces living in a higher-cost area (e.g., SNAP permits individuals or their households to afford living in an area with more expensive food costs).

Hypothesis 3: does cost of living moderate the SNAP-food acquisition relationship?

Figure 3 displays the interactions between SNAP participation and cost of living when the outcome of interest is HEI-2010 score. As shown in the Figure, living in a high-cost area is associated with a lower HEI score, consistent with our results summarized above, but SNAP participation improved the low HEI score among those persons who lived in high-cost areas (from a score of 41 to a score of 61, based on the average treatment effect from the model). Yet the benefits of SNAP in changing the HEI-2010 score were not significant in lower-cost areas.

Table 6 provides a breakdown of how much SNAP participation and its interaction with cost of living is associated with food acquisitions in each of the studied food categories, based on endogenous treatment effects models. As shown in the Table, in both low- and high-cost areas SNAP participation

was associated with increased fruit and vegetable acquisition. In lower cost areas, SNAP was also associated with increased acquisition of fats and oils and sugars, which offset the HEI improvements, which would have been observed from the increased fruit and vegetable acquisition. Hence, SNAP participation was associated with an insignificant change in HEI score in low-cost areas, but a significantly improved HEI score in high-cost areas.

OLS results

In addition to testing the endogenous treatment effects model, we performed tests of endogeneity (estimating the significance of the correlation between unobservables that affect treatment and outcome in the control function equations specified above, which should be zero if there is no endogeneity). All of these tests rejected the null hypothesis of no endogeneity for all of our regressions—justifying our use of the endogenous treatment effects modeling approach. As a result, we would expect that ordinary least squares (OLS) regressions would be biased in their estimates due for example to omitted variables. We nevertheless present them here to understand how the endogenous treatment effects model differs from what would be observed in OLS regressions, and to understand how key covariates included as control variables in the regressions also relate to the outcomes of interest. We also show these OLS regressions because they are the classical strategy for relating SNAP to food acquisition outcomes, and we wish to understand how much this classical inference method differs from our endogenous treatment effects model.

Table 7 presents the OLS regressions revealing the associations between cost of living metrics and food acquisition in each food category, as well as the overall HEI score. A higher cost of living was associated with less acquisition of vegetables and more acquisition of refined grains, dairy products, fats and oils, and added sugars. The associations between cost of living metrics and acquisitions in the other

food categories were generally insignificant due to large standard errors around the estimates, or inconsistent in having some positive associations but not a robust association across all metrics of cost of living, as shown in the Table. A lower cost of living was generally associated with a lower HEI score, although this was not true of the food regional price parity; in OLS regressions, this association may reflect other unmeasured endogenous factors such as frugality, which may lead individuals towards less expensive cost of living areas and less-healthy cheaper foods. Notably, as shown in **Table 7**, older age, female sex, Black race or Hispanic ethnicity, greater education, employment, and income were associated with higher HEI scores after controlling for cost of living and other household- and county-level covariates. Housing costs, longer distance to a primary food store, and low or very low food security were associated with lower HEI scores. At a county level, rural residence was associated with a higher HEI score, as was having fewer supermarkets or full-service restaurants, having more limited-service restaurants, and having less kitchen availability. These results are counter-intuitive and we suspect that factors producing endogeneity between cost of living and healthfulness of food acquisitions may also be driving these estimates, such as the fact that rural areas that have all of the above features tend to have lower refined grain availability and greater fruit and vegetable availability, which are two food categories heavily weighted in the HEI metric. SNAP participation was associated with a lower HEI score, also contrary to the endogenous treatment effects model; this indicates that associations between SNAP and less healthy food acquisitions may be due to other factors not observed or controlled for, justifying our use of an endogenous treatment effects model in our main analysis.

Table 8 presents the OLS regressions revealing the associations between SNAP participation and county-level cost of living. SNAP participation was generally associated with living in a lower-cost county in these OLS models, subject to endogenous unobserved covariates such as frugality. Living in a lower-

cost county is also associated with older age, male sex, Black race, Hispanic ethnicity, and being unemployed. Living in a higher-cost county was associated with having lower income, driving a farther distance to a primary food store, being less rural, having better food security, and having more availability of supermarkets, non-supermarkets, and full-service restaurants. Interestingly, a higher county-level cost of living was associated with WIC participation and a higher poverty rate and lower area-level prevalence of high school graduation, which may reflect high inequality in high-cost counties. High-cost counties also had greater vehicle density and lower kitchen availability.

Table 9 presents the OLS regressions revealing associations between the interaction of SNAP participation and living in a high cost of living county. The interaction terms were negative for vegetables and protein, positive for fruits, grains, dairy, fats and oils, and added sugars. Negative interaction terms imply less food acquisition in that food category if a person is both on SNAP and lives in a high-cost county. The interaction term had a positive coefficient when regressed against overall HEI score, suggesting that SNAP would improve HEI scores more in a high-cost than in a lower-cost county, consistent with the endogenous treatment effects model result.

Discussion

Major findings

As poverty and economic inequality have been recognized as major social determinants of health, epidemiologists have increasingly sought to understand which social programs might best reduce these burdens. The Supplemental Nutrition Assistance Program (SNAP) remains one of the largest "safety nets" for low-income populations in the United States, and is well recognized for its role in reducing poverty and food insecurity (70). Yet some literature has also correlated SNAP participation to

worse nutrition-related outcomes such as obesity. Such correlative findings may suffer from substantial methodological problems such as the failure to control for unobserved confounders that influence both participation in SNAP and nutritional quality, and misreporting of SNAP participation status in common nutritional datasets (19). In a recent Institute of Medicine review, an expert panel reviewing the SNAP program suggested that further research should use improved methods and datasets to examine how SNAP currently affects nutritional quality and how it modifies the relationship between local food prices and nutritional quality; furthermore, the Institute of Medicine panel suggested that studies should evaluate how SNAP might be further improved to enhance its benefits to nutrition among low-income Americans. One of these potential improvements is to adjust SNAP benefits for local food prices or cost of living, as it is believed that high local food prices and/or high costs of living (i.e., competing expenses such as rents) may exacerbate challenges in affording high nutrient-dense foods for low-income populations. SNAP benefits are not currently adjusted for local food prices or costs of living in the continental U.S.

A practical limitation has prevented pursuit of the IOM panel's suggested research objectives: the largest, nationally-representative dataset on food acquisition and nutrition quality (the National Health and Nutrition Examination Survey, NHANES) lacks reliable data on SNAP participation, and is not sufficiently geographically distributed to facilitate assessments of how variations in cost of living relate to the healthfulness of food acquisitions. The new National Household Food Acquisition and Purchase Survey (FoodAPS, 2012-2013) resolves these deficits, and facilitates inferences around the impact of SNAP on food acquisitions by sampling a nationally-representative group of administratively-confirmed SNAP participants, income-eligible non-participants, and higher-income SNAP-ineligible non-participants. Here, we studied the FoodAPS dataset to understand how cost of living relates to the

healthfulness of food acquisitions, how SNAP participation is related to cost of living, and the degree to which SNAP benefits have different relationships to nutritional quality in geographic areas with varying costs-of-living, including varying food prices. We specifically measured cost of living using indices that might be used in the future to adjust SNAP benefits for local food and living costs, including county-level regional price parities assembled by the U.S. Bureau of Economic Analysis, and county-level geographic adjustments to the Supplemental Poverty Threshold, assembled by the U.S. Census Bureau.

Using data on food equivalents acquired by food category, and a common metric of overall healthfulness of food acquisitions (the Healthy Eating Index, HEI, 2010 edition), we explored three key hypotheses relating the cost of living to the healthfulness of food acquisitions: (i) that a higher area-level cost of living would be associated with less healthy food acquisitions; (ii) that SNAP participation would be associated with living in a lower-cost area after accounting for other observed and unobserved covariates related to both SNAP and area of living; and (iii) that associations between SNAP participation and the healthfulness of food acquisitions would be moderated by area-level cost of living. We envisioned that higher cost of living would induce individuals to sacrifice food budgets for other costs such as rent, inducing less healthy food acquisitions. We also envisioned that because SNAP benefits are adjusted based on national average cost of living indices, the purchasing power of a SNAP dollar would be higher in a lower food-cost area and thereby induce living in lower-cost areas. Finally, we envisioned that the marginal impact of each dollar of SNAP benefits would be affected by area cost of living.

Hypothesis 1: Cost of living and the healthfulness of food acquisitions

We found evidence consistent with our first hypothesis—that higher area-level cost of living was associated with less healthy food acquisitions. In particular, when we defined a high cost of living area as being more than one standard deviation above the mean cost measured by either a regional price parity

or the geographic adjustment to the Supplemental Poverty Measure, we found that living in a higher cost of living county was associated with significantly fewer acquisitions of vegetables, fruits, and whole grains, and was associated with significantly greater acquisitions of refined grains, dairy products, protein, fats and oils, and added sugars. This finding was consistent no matter which metric we chose for the area-level cost of living. Having controlled for individual-level factors such as education level, household-level factors such as income, and county-level factors such as food availability, the estimated effect of living in a high-cost county reduced the overall HEI score by approximately 11%. Clinically-speaking, the observed decrease in HEI is larger than reductions in HEI associated with a significant increase in the risk of cardiovascular disease, type II diabetes, and all-cause mortality. Hence, we would expect such effects are meaningful to public health.

Importantly, we observed that the cost of living metric for food was not the most predictive of changes in the healthfulness of food acquisitions, perhaps because expenditures in other domains of the budget so substantially impact the food budget. For the overall nutritional metric of HEI score, higher rent costs were more strongly associated with reduced healthiness of food acquisitions than higher food costs when measured by county-level cost of living indices. As the food regional price parity was not significantly associated with a reduction in HEI score (because of the wide standard errors around the estimate), the food regional price parity may not capture whatever economic forces are leading to less healthy food acquisitions as well as the rent regional price parity or overall regional price parity. This is an important result for policymakers who may need to choose what metric of cost of living would be utilized if SNAP or related benefits were adjusted for cost of living. An increasing literature suggest that when rent prices are too high, very few funds remain available to low-income households to augment their SNAP budget, and families become reliant on emergency food aid (11); hence, food prices are less

useful as an indicator of food purchasing desperation when essentially no food can be purchased, and high rent prices may constitute the largest expenditure away from the food budget of the most vulnerable low-income households.

Our further subgroup analyses examining the relationships between area-level cost of living and food acquisitions revealed that low-income (<185% of the federal poverty threshold) SNAP non-participants were the most sensitive subgroup affected by overall cost of living metrics, followed by SNAP participants and lastly by higher-income SNAP non-participants. This gradient across the three groups may suggest that greater income mitigates the relationship between area cost of living and the healthfulness of food acquisitions. The finding also suggests that SNAP may be effectively buffering individuals from the negative impacts of higher area-level cost of living—a theory we return to when exploring the results of hypothesis 3, below.

Hypothesis 2: SNAP and area-level cost of living

We rejected our second hypothesis that SNAP would be associated with living in a lower-cost area. While the ordinarily least squares regressions of SNAP against area-level cost of living revealed that SNAP participation was correlated to living in a lower-cost area, our main analysis employed endogeneous treatment effects models that attempted to estimate the effects of SNAP participation while reducing or eliminating unobserved or unmeasured confounders that produce endogeneity between SNAP and area-level cost of living. In these endogenous treatment effects models, we observed SNAP was associated with a higher probability of living in a high-cost county. One potential explanation for the finding is that SNAP participation increases economic mobility—by relieving budgets enough to allow low-income households to live in environments where they would otherwise be "priced out" (11). Alternatively, the association may be due to reverse causality: that high-cost areas more quickly drain

monthly budgets, increasing need for SNAP participation in order to make ends meet, such that SNAP participation is associated with living in high-cost areas. In exploring this hypothesis, it was notable that among the different measures of cost of living, the biggest treatment effect on the treated (estimated effect among those who were observed to be SNAP participants in the data) was from the food regional price parity. This finding is consistent with either explanatory mechanism, but further suggests that self-selection into SNAP enrollment is appropriately selecting households facing the greatest need from a food cost perspective, in that SNAP dollars are most likely to be spent in areas where they are most needed to afford food.

Hypothesis 3: cost of living as a moderator of SNAP's relationship to food acquisition

Our testing of our third hypothesis revealed that indeed county-level cost of living did moderate the relationship between SNAP and the healthiness of food acquisitions, but not in the expected direction. We anticipated that SNAP would be most beneficial to those living in lower-cost areas, as each program dollar would be able to purchase more food in those areas, particularly foods that were of perceived or real higher costs (e.g., fruits and vegetables). Yet in fact SNAP had a neutral impact on the healthfulness of food acquisitions in lower-cost areas, because increased fruit and vegetable acquisitions and lower refined grain acquisitions, attributable to SNAP participation, were counterbalanced by increased acquisitions of fats and oils as well as added sugars. Overall, SNAP increased calories but did not disproportionately increase "healthy" calories; hence, SNAP had a statistically-neutral impact on HEI scores in lower-cost areas.

By contrast, while individuals had a worse dietary profile in higher-cost areas, as discussed above, SNAP made a greater positive impact in such areas, by permitting greater acquisitions of vegetables and fewer refined grains, with less adverse compensation from increased fat and oil or added

sugar acquisitions. One theory to explain these findings may be that in a higher-cost environment, SNAP dollars are used disproportionately to assist households in acquiring those foods that are most out of reach due to high perceived or real prices. The finding may also be a commentary on the nature of the food acquisition environment in lower-cost counties; if lower-cost counties indeed have environments saturated with less-healthy foods as suggested in the public health literature (71), SNAP participation may have limited effects on the healthfulness of food acquisitions because the food environment dominates the purchasing patterns of participants, whereas higher-cost areas may have somewhat healthier food availability. We discuss further assessments of this theory in our discussion of future research studies, below.

Contribution to the existing literature

Substantial existing literature in the fields of sociology, economics, and epidemiology has highlighted the trade-offs that low-income Americans face when attempting to pay for foods. While prior literature has documented trade-offs between energy costs, rent costs, medical care costs and food (2,3,72), our study adds the additional dimension of assessing how costs-of-living among low-income Americans relate to the healthfulness of food acquisitions, and the impact of the largest nutritional assistance program in the country. To our knowledge, this is the first assessment to use nationally-representative survey data to understand how broad costs of living across the country relate to the healthfulness of food acquisitions nationally. Other surveys, such as NHANES, have not collected or provided access to sufficient geocoded information for such analyses. Our analysis provides the important insight that lower-income populations may be particularly vulnerable to less healthy food acquisitions when they face high costs-of-living, at least when they are not enrolled in SNAP. Furthermore, costs of food in a county are not the only—or even the best—metric of which costs-of-

living are associated with less healthy food acquisitions. Rather, rent and other housing costs appear to be a particularly influential factor in influencing the healthfulness of food acquisitions, concordant with literature suggesting that housing-related costs are a major source of stress and financial constraint among low-income households. Interestingly, there was only a 65% correlation between the rent regional price parity and the food regional price parity among all counties in the sample.

It is notable that in our study of the FoodAPS dataset, the analytical sample of low-income non-participants who are theoretically eligible for the SNAP program had a lower income that did SNAP participants. This finding is contrary to the idea that eligible persons who fail to participate in SNAP are those who are minimally-qualified based on income, and who would receive the fewest benefits (i.e., rendering them less motivated to receive benefits, since the burden of enrollment exceeds the benefits of enrollment). By contrast, our findings suggest that eligible non-participants may include the extreme poor, and more rural, White, low-salaried employed persons, whose food acquisitions are disproportionately less healthy in higher cost of living areas. Notably, extensive emerging public health literature indicates that this demographic group has experienced declines in life expectancy associated with numerous financial and social hardships, and associated chronic diseases that include nutritional and psychiatric conditions related to food insecurity and chronic deprivation. Hence, our findings may indicate that outreach to eligible but un-enrolled participations, to buffer them from the adverse nutritional effects of living in higher cost of living areas.

Furthermore, our study is unique in utilizing the FoodAPS dataset, which offers the opportunity to identify SNAP participants who are administratively-confirmed participants in the program. Other surveys such as NHANES are known to mis-identify such participants (19), likely due to the stigma of identification and confusion or lack of awareness of benefits received by an individual or other

household members, which prevents accurate assessments of program impact. Our findings reveal that SNAP participation may serve as a buffer from the adverse effects of high cost of living on healthful food acquisitions, being particularly beneficial to those individuals who live in high-cost counties. A large literature in the sociology discipline has pointed to the benefits of living in lower-poverty areas that typically have higher area-level cost of living. Mostly commonly cited is the Moving to Opportunity Study, in which households randomized to a voucher program permitting movement to a lower-poverty neighborhood experienced subsequent clinically-meaningful reductions in the risk of obesity and type II diabetes as well as some associated mental health benefits (73,74). Given the rich literature supporting the poverty-reducing effects of SNAP, our results suggesting that SNAP's effects include improving the ability to live in—and consume healthier foods in—higher-cost areas may be part of the pathway by which SNAP improves both economic and health mobility.

Another key contribution to the literature from our study is the finding that SNAP may be associated, in ordinarily least square regressions, with poorer nutrition, but endogenous treatment effects models to detect the effects of SNAP while reducing or eliminating the impact of omitted variable bias did not reveal a negative impact of SNAP on nutrition in lower-cost areas and revealed a positive impact of SNAP on nutrition in high-cost areas. This finding suggests that standard regressions and prior literature relying on such regressions to link SNAP participation to adverse nutritional outcomes such as obesity may be confounded by omitted variables that influence both SNAP participation and the likelihood of living in low-quality food environments or being predisposed to acquire less healthy foods.

Limitations

Several notable limitations in our analysis are important to highlight. First, our data are from

catalogued food acquisitions, not 24-hour dietary recalls. Food acquisitions may not reflect food consumption due to food wastage, which is particularly likely for foods that have very short shelf lives, such as vegetables and fruits, or those that have very long shelf lives and are consumed well after they are acquired or are stored rather than consumed, such as canned goods, solid fats and oils, or foods containing a high content of added sugars. Related to the issue of having food acquisitions catalogued rather than true food intake is the potential for missing data. We did not impute missing data as a low proportion of survey-based variables were missing; it is not possible to impute missing food acquisition data, since there is no strategy we are aware of to determine whether a respondent has failed to report a food acquisition. The data are also subject to observational effects in that a participating individual may have changed their food acquisition patterns due to participation in the study.

A further limitation of our analysis is the assumption that household members consume an equal portion of the food acquired at the household level, which is particularly unlikely for households with children. We computed average food acquisitions per person per day from seven-day food diaries catalogued among all respondents in a household. We chose to perform our regressions on individual-level food acquisitions both to assess the face validity of our statistics—which were highly concordant to estimates of food consumption in NHANES, despite FoodAPS being a record of food acquisition rather than consumption—and to provide interpretable regression coefficients that are comparable to the broader nutrition epidemiology literature, which catalogues consumption of food at an individual level. Nevertheless, dividing total household acquisitions among those persons who participated in a given food acquisition "event" (e.g., a meal) will not capture important within-household inequalities in food acquisition, which may be particularly important for understanding differences in the healthfulness of food acquisitions between children and adults.

An additional limitation is that we utilized data on costs geocoded to the county level, not individual, household or local neighborhood-area levels. Our choice of this geographic level was dictated by the availability of cost of living metrics that are routinely updated and would be the most likely indices for adjustment of SNAP benefits in the future if such adjustments were to be instituted. We also controlled for county-level covariates because this was the smallest area level for which we possessed numerous variables of interest concerning the neighborhood environment and population. Furthermore, recent data including data from FoodAPS reveal that Americans typically travel significant distances to their primary food store, even among the lowest-income populations (4); hence, local neighborhood-area prices may be from areas that are not sufficiently wide to account for the distribution of prices for goods and services faced by most households.

Implications for future research

Our findings and the limitations of our current analysis prompt several future research pathways. First, understanding the mechanisms behind some of our findings will be important, as our findings were not concordant with many of our *a priori* hypotheses. In particular, understanding the mechanisms by which SNAP participation is associated with living in a higher-cost area would be important to understanding the economic mobility implications of the program. Furthermore, why SNAP participation was associated with healthier food acquisitions in higher-cost counties will be important to explain to understand how individuals and household choose to utilize nutrition assistance benefits. This may require further analysis of local and store-specific prices and availability of food products. At the time of this writing, FoodAPS developers are still building linkages between the dataset and external data from geocoded store datasets to assemble store-level and neighborhood-level food basket costs, which may be more refined than our county-level price indices in defining local prices, and should be

paired with indices of food availability to understand how consumers make food acquisitions choices in different environments.

Given that our endogenous treatment effects models did not find adverse effects of SNAP on nutritional indicators, older studies using standard regressions to link SNAP to adverse chronic disease outcomes such as obesity should be revisited. Our findings indicate that the links between SNAP and adverse health conditions may have been driven by endogeneity from omitted variable bias, which has important implications for program evaluation and to understanding what mechanisms may be best for improving the nutritional benefits of SNAP and related food assistance programs. Our findings suggest that the program benefits themselves may be less related to unhealthy food acquisitions than the food environment in which participants live.

Implications for policy

Our study intended to shed light on the issue of whether SNAP benefits could improve the healthfulness of food acquisitions if they were adjusted using locally-based (county-level) indices of cost of living, rather than national average living cost data. Our study would have provided a clearer indication that such adjustments would be beneficial if our findings had been consistent with our hypothesis that SNAP benefits to nutritional metrics were larger in lower-cost areas than in higher-cost areas. Yet our findings were contrary to this hypothesis. We found that SNAP was associated with improved nutrition more in higher-cost counties than in lower-cost counties, with our leading theory for this finding being that food environments in lower-cost counties permitted greater acquisition of fats and oils and added sugars with SNAP benefits. Hence, our findings do not necessarily imply that a cost of living adjustment using currently available county-level cost of living metrics would improve the healthfulness of food acquisitions among SNAP participants currently living in lower-cost areas.

However, our findings do imply that SNAP participation itself is associated with a higher probability of living in a higher-cost area, and improves nutrition in those areas; hence, via this more circuitous pathway, it is possible that adjusting SNAP benefits for county-level cost of living may improve nutrition. The sociology literature in particular suggests that higher-cost areas that are typically lower in poverty may have substantial health benefits for low-income individuals who move to such areas. Hence, any economic mobility benefits of SNAP might be enhanced though cost of living adjustments; conversely, however, if SNAP benefits are reduced by cost of living adjustments among those populations living in lower-cost areas, it is possible that SNAP participation would no longer have a neutral impact, but have a negative impact, if such benefits become disproportionately used on fats and oils or added sugars, for example. A direct experiment or pilot study involving cost-adjusted SNAP benefits may be the most definitive strategy for identifying the effects of benefit modification for living costs.

Regardless of whether benefits are adjusted, we found that it was unlikely for food cost metrics alone to sufficiently capture the key cost of living factors that drive the relationship between area cost of living and the healthfulness of food acquisitions among low-income Americans. Rather, we found that overall cost of living indices, and particularly indices strongly driven by rent and housing costs, were often more significantly related to the healthfulness of food acquisitions than were food cost indices. Hence, the economic trade-offs taking place within low-income households that affect the healthfulness of what the food budget is spent on may be critically driven by large expenditures such as housing. This finding calls for an expansion of what data are utilized to consider the value of benefits and the influences of economic factors on the benefits of nutrition assistance programs and other safety nets targeting low-income Americans.

Conclusions

By linking data from the National Household Food Acquisition and Purchase Survey (FoodAPS) to data on county-level cost of living, we found that higher area-level cost of living was associated with less healthy food acquisitions. Additionally, we found that SNAP participation was associated with a higher probability of living in a high-cost county, net of individual, household, and county-level covariates; SNAP participation was also associated with a significant improvement in the healthfulness of food acquisitions in high-cost counties, but had a neutral impact in lower-cost counties.

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Figures and Tables

Table 1: Descriptive statistics of participants in the National Household Food Acquisition and Purchase Survey (2012-2013) by Supplemental Nutrition Assistance Program (SNAP) participation status and income level. The Stata commands svy, subpop were applied to data from each subpopulation (SNAP participants, non-participants <185% of the federal poverty level, and non-participants >=185% of the federal poverty level) to adjust estimates for stratification and clustering, and to apply sample weights. 95% confidence intervals are provided in parentheses for continuous variables. FPL: federal poverty threshold level.

Characteristic	**Definition/units**	**SNAP participants**	**Non-participants <185% FPL**	**Non-participants >=185% FPL**
Household sample size	Number of households	1,581	1,391	1,852
Individual sample size	Number of individuals	5,414	3,863	5,036
Weighted individual sample size	Population represented	51,642,828	61,670,710	186,959,075
Age	Years	30.0 (2.0-67.0)	37.5 (4.0-78.0)	38.9 (4.0-72.0)
Older adults	% Age >=65 years	5.9	15.9	13.0
Sex	% Female	53.6	53.7	51.3
White race	% White	63.0	75.4	83.3
Black race	% Black	26.7	15.3	9.8
Hispanic ethnicity	% Hispanic	31.2	27.8	12.2
Education	% Completed high-school	47.5	58.9	73.3
Employment	% Employed (1=yes)	28.9	34.3	55.9
Household size	Number of non-guest residents	4.2 (1.0-9.0)	3.6 (1.0-8.0)	3.1 (1.0-6.0)
Income	Total income as % of federal poverty threshold for household size	138.6 (0.0-357.0)	100.8 (0.0-180.0)	503.9 (206.0-1048.0)
Housing cost	Household's monthly rent/mortgage expense, $	577.1 (0.0-1500.0)	720.6 (0.0-2000.0)	1,014 (0.0-2400.0)
Distance to primary food store	Miles, Euclidean distance	3.1 (0.2-13.3)	3.5 (0.2-14.3)	3.9 (0.4-14.1)

Rural residence residence	% Rural residence	22.7	27.5	35.4
Food security status	% low or very low food security on USDA 30-day Adult Food Security Scale	42.7	31.9	6.9
WIC	% households with a member participating in the Women, Infants and Children program	22.4	14.1	3.0
Supermarkets	Per 1,000 people, in county of residence	12.0 (6.1-21.4)	11.8 (6.4-21.4)	12.1 (6.7-21.7)
Non-supermarkets (non-supermarket food retailer)	Per 1,000 people, in county of residence	28.4 (13.3-52.8)	25.8 (9.7-51.5)	23.4 (7.1-44.0)
Full-service restaurants ("sit down" table service)	Per 1,000 people, in county of residence	74.0 (42.1-111.0)	78.6 (41.2-142.4)	82.1 (45.3-142.4)
Limited-service restaurants ("fast food")	Per 1,000 people, in county of residence	69.2 (34.8-88.4)	69.4 (42.1-91.0)	69.6 (42.1-91.0)
Poverty rate	% of people below poverty threshold, in county of residence	16.2 (9.6-25.8)	15.6 (7.7-23.6)	13.8 (6.6-21.8)
Area-level household income	Median, in county of residence (2012 inflation-adj $)	50,360 (32,960-78,187)	52,825 (35,093-81,093)	55,405 (36,875-87,751)
Area-level educational attainment	% of population 25+ years old with high school education	84.7 (73.9-92.6)	84.0 (75.6-92.8)	87.0 (75.4-94.5)
Vehicle density	% of occupied housing units with at least one vehicle available	91.6 (82.3-95.8)	92.1 (82.3-96.8)	93.0 (86.4-97.1)
Kitchen availability	% of occupied housing units with complete kitchen facilities available	99.1 (98.3-99.6)	99.0 (98.3-99.7)	99.1 (98.3-99.6)
Regional price parity, overall	Overall cost of living, relative to national	97.6 (89.6-1.21)	100.4 (89.6-122.2)	99.3 (89.6-121.4)

	average (100% = average)			
Regional price parity, rents	Rent/mortgage costs, relative to national average (100% = average)	95.8 (65.4-156.7)	103.8 (70.6-181.3)	102.4 (70.6-181.3)
Regional price parity, food	Food costs, relative to national average (100% = average)	98.7 (94.9-112.3)	100.1 (94.9-112.3)	100.0 (84.8-112.3)
Regional price parity, all goods	Cost of goods, relative to national average (100% = average)	98.8 (95.0-108.9)	99.8 (95.0-108.9)	99.3 (92.6-108.9)
Regional price parity, all services	Cost of services, relative to national average (100% = average)	98.1 (88.4-119.0)	100.2 (88.4-119.0)	98.7 (88.4-119.0)
Geographic adjustment to Supplemental Poverty Measure	Gross rents for two-bedroom apartments with complete Kitchen availability and plumbing, relative to national average (100% = average)	98.6 (75.3-155.9)	104.6 (75.6-166.9)	103.8 (75.6-166.9)

Table 2: Food acquired at home and away from home among participants in the National Household Food Acquisition and Purchase Survey (2012-2013) by Supplemental Nutrition Assistance Program (SNAP) participation status and income level. The Stata commands svy linearized, subpop were applied to data from each subpopulation (SNAP participants, non-participants <=185% of the federal poverty level, and non-participants >185% of the federal poverty level) to adjust estimates for stratification and clustering, and to apply sample weights. Acquisitions are expressed both in grams per household per week in each food category and food pattern equivalents (e.g., cup-equivalents, ounce-equivalents) per household per week. Acquisitions per person per day were calculated by dividing the amount of food acquired by each respondent by the reported number of persons among whom that food was shared. Standard errors are provided in parentheses. FPL: federal poverty threshold level. FPE: food pattern equivalents.

Food category	**Household level food acquisitions**						**Person level food acquisitions**						**FPE units**
	in grams/week			in FPE/week			in grams/day			in FPE/day			
	SNAP participants	Non-participants <=185% FPL	Non-participants >185% FPL	SNAP participants	Non-participants <=185% FPL	Non-participants >185% FPL	SNAP participants	Non-participants <=185% FPL	Non-participants >185% FPL	SNAP participants	Non-participants <=185% FPL	Non-participants >185% FPL	
Vegetables	7800 (351)	6628 (317)	7371 (239)	35.1 (2.0)	29.8 (1.4)	34.4 (1.4)	334 (19)	389 (19)	414 (13)	1.5 (0.1)	1.8 (0.1)	2.0 (0.1)	Cup-eq
Fruits	7014 (573)	4722 (365)	5078 (255)	18.9 (1.3)	15.6 (1.2)	17.0 (0.9)	290 (24)	256 (20)	282 (16)	0.8 (0.1)	0.9 (0.1)	0.9 (0.1)	Cup-eq
Whole grains	1690 (168)	1178 (105)	1247 (58)	24.9 (6.0)	15.6 (1.5)	20.4 (2.0)	66 (5)	62 (6)	68 (4)	0.9 (0.1)	0.9 (0.1)	1.2 (0.1)	Oz-eq
Refined grains	8536 (484)	6228 (348)	6854 (243)	170.3 (11.9)	121.9 (8.5)	128.2 (4.9)	361 (20)	335 (16)	370 (15)	7.1 (0.4)	6.5 (0.3)	7.0 (0.4)	Oz-eq
Dairy	10377 (398)	8082 (472)	8966 (357)	42.4 (2.2)	33.4 (1.9)	38.3 (2.1)	439 (21)	436 (22)	485 (18)	1.8 (0.1)	1.9 (0.1)	2.0 (0.1)	Cup-eq
Protein	8529 (463)	5858 (256)	6774 (233)	121.8 (6.3)	81.7 (3.8)	97.2 (3.9)	369 (20)	337 (19)	381 (13)	5.5 (0.3)	4.8 (0.2)	5.6 (0.3)	Oz-eq
Fats and oils	18089 (624)	13113 (626)	14580 (417)	1664 (97)	1102 (60)	1266 (57)	780 (39)	747 (36)	804 (26)	72.1 (4.4)	67.0 (4.7)	71.1 (4.0)	Grams
Added sugars	21550 (1054)	14212 (817)	15983 (764)	747 (58)	432 (32)	480 (35)	941 (48)	749 (35)	884 (45)	31.4 (2.4)	23.0 (1.4)	25.9 (1.9)	Tsp-eq
Total kcals/person/day	-	-	-	-	-	-	-	-	-	2588 (122)	2336 (114)	2567 (105)	Kcals

Table 3: Comparison of food acquisition estimates from the National Household Food Acquisition and Purchase Survey (2012-2013) by Supplemental Nutrition Assistance Program (SNAP) participation status and income level to independent estimates of food consumption from the National Health and Nutrition Examination Survey (2007-2010) and U.S. National Dietary Guidelines (2015-2020). The Stata commands svy linearized, subpop were applied to data from each subpopulation (SNAP participants, non-participants <=185% of the federal poverty level, and non-participants >185% of the federal poverty level) to adjust estimates for stratification and clustering, and to apply sample weights. FPE: food pattern equivalents. Standard errors in parentheses. HEI: Healthy Eating Index, 2010.

Food category	Acquisitions in food pattern equivalents/day, National Food Acquisition and Purchasing Survey (2012-2013)			Consumption in food pattern equivalents/day, National Health and Nutrition Examination Survey (2007-2010)	National Dietary Guidelines (2015-2020), for sedentary persons Age 40 yrs w/ a mean recommended caloric intake (2,200 kcal/day)	FPE units
	SNAP participants	Non-participants <=185% FPL	Non-participants >185% FPL	All persons	All persons	
Vegetables	1.5 (0.1)	1.8 (0.1)	2.0 (0.1)	1.5 (0.02)	3.0	Cup-eq
Fruits	0.8 (0.1)	0.9 (0.1)	0.9 (0.1)	1.1 (0.03)	2.0	Cup-eq
Whole grains	0.9 (0.1)	0.9 (0.1)	1.2 (0.1)	0.8 (0.02)	3.5	Oz-eq
Refined grains	7.1 (0.4)	6.5 (0.3)	7.0 (0.4)	5.5 (0.06)	3.5	Oz-eq
Dairy	1.8 (0.1)	1.9 (0.1)	2.0 (0.1)	1.8 (0.03)	3.0	Cup-eq
Protein	5.5 (0.3)	4.8 (0.2)	5.6 (0.3)	5.7 (0.07)	6.0	Oz-eq
Fats and oils	72.1 (4.4)	67.0 (4.7)	71.1 (4.0)	56.8 (0.7)	29.0	Grams
Added sugars	31.4 (2.4)	23.0 (1.4)	25.9 (1.9)	16.8 (0.3)	13.8	Tsp-eq
HEI score	54.4 (0.2)	54.7 (0.2)	55.0 (0.1)	55.4 (0.7)	100	Scale 0 (worst) to 100 (best)

Table 4: Average effect of living in a high-cost area (at least one standard deviation above the mean national cost) on food acquisitions and overall Healthy Eating Index (HEI) scores. Cost of living is measured by regional price parities (RPPs), either overall, or by category of expenditure (rent, food, all goods, or all services); the geographic adjustment to the Supplemental Poverty Measure is provided as an alternative cost-of-living metric. Estimates of average effect are based on an endogenous treatment effects model applied to data from participants in the National Household Food Acquisition and Purchase Survey (2012-2013). All regressions control for individual-, household-, and county-level factors detailed in the text. Standard errors in parentheses. FPE: food pattern equivalents. RPP: regional price parity.

Metric of cost-of-living	Food category								Calories	HEI score
	Vegetables	Fruits	Whole grains	Refined grains	Dairy	Protein	Fats and oils	Added sugars		
	Units									
	Cup-eq	Cup-eq	Oz-eq	Oz-eq	Cup-eq	Oz-eq	Grams	Tsp-eq	Kcals/person/day	Scale from 0 (worst) to 100 (best)
Overall cost of living (RPP)	-0.65 (0.04)***	-0.14 (0.02)***	-0.11 (0.03)***	2.35 (0.12)***	0.28 (0.04)***	0.86 (0.11)***	36.63 (1.89)***	9.40 (0.84)***	542.92 (45.60)***	-6.0 (0.9)***
Rent cost (RPP)	-0.65 (0.04)***	-0.14 (0.02)***	-0.11 (0.03)***	2.35 (0.12)***	0.28 (0.04)***	0.86 (0.11)***	36.63 (1.89)***	9.40 (0.84)***	542.92 (45.60)***	-6.0 (0.9)***
Food cost (RPP)	-0.41 (0.04)***	-0.17 (0.02)***	-0.06 (0.04)	2.68 (0.13)***	0.33 (0.04)***	0.64 (0.12)***	31.74 (1.40)***	9.63 (0.66)***	471.50 (40.91)***	-1.4 (1.0)
All goods (RPP)	-0.34 (0.03)***	-0.10 (0.01)***	0.38 (0.04)***	2.67 (0.11)***	0.24 (0.03)***	1.38 (0.10)***	43.45 (1.97)***	11.54 (0.82)***	884.54 (66.84)***	-4.5 (0.8)***
All services (RPP)	-0.35 (0.03)***	-0.11 (0.02)***	0.36 (0.04)***	2.80 (0.12)***	0.34 (0.04)***	1.10 (0.10)***	45.07 (2.46)***	16.15 (1.05)***	869.22 (73.18)***	-4.1 (0.8)***
Geographic adjustment to Supplemental Poverty Measure	-0.67 (0.04)***	-0.18 (0.02)***	-0.05 (0.04)	3.05 (0.13)***	0.36 (0.04)***	1.35 (0.11)***	47.71 (2.11)***	12.57 (0.92)***	766.35 (52.10)***	-2.1 (0.9)*

* = p<0.05; ** = p<0.01; *** = p<0.001

Table 5: Average treatment effect of SNAP participation on the probability of living in a high-cost area (at least one standard deviation above the mean national cost). Cost of living is measured by regional price parities (RPPs), either overall, or by category of expenditure (rent, food, all goods, or all services); the geographic adjustment to the Supplemental Poverty Measure is provided as an alternative cost-of-living metric. Estimates of average effect are based on an endogenous treatment effects model applied to data from participants in the National Household Food Acquisition and Purchase Survey (2012-2013). All regressions control for individual-, household-, and county-level factors detailed in the text. Standard errors in parentheses. FPE: food pattern equivalents.

Cost-of-living metric	Average treatment effect		Average treatment effect on the treated	
	Probability of living in high-cost county given non-participant in SNAP	Increased probability given SNAP participation	Probability of living in high-cost county given non-participant in SNAP	Increased probability given SNAP participation
Overall regional price parity	0.20 (0.01)***	0.44 (0.01)***	0.00 (0.00)***	0.22 (0.00)***
Rent regional price parity	0.20 (0.01)***	0.44 (0.01)***	0.00 (0.00)***	0.22 (0.00)***
Food regional price parity	0.27 (0.02)***	0.39 (0.02)***	0.00 (0.01)	0.24 (0.01)***
Goods regional price parity	0.26 (0.02)***	0.40 (0.02)***	0.01 (0.00)*	0.22 (0.00)***
Services regional price parity	0.20 (0.01)***	0.43 (0.01)***	0.00 (0.00)***	0.22 (0.00)***
Geographic adjustment to the Supplemental Poverty Measure	0.27 (0.02)***	0.36 (0.02)***	0.08 (0.03)**	0.17 (0.02)***

*=p<0.05, **=p<0.01, ***=p<0.001

Table 6. Interactions between SNAP participation, cost of living, and food acquisitions. Coefficients for each food category are in units of food pattern equivalents (e.g., cup-equivalents, ounce-equivalents) as detailed in Table 2, whereas the Healthy Eating Index (HEI) is on a scale from 0 (worst) to 100 (best).

(A) Average treatment effect

Food category	Low-cost area (Overall regional price parity)		High-cost area (Overall regional price parity)	
	Acquisition if not participating in SNAP	Change in acquisition if participating in SNAP	Acquisition if not participating in SNAP	Change in acquisition if participating in SNAP
Vegetables	1.98 (0.22)***	0.73 (0.01)***	0.75 (0.01)***	0.09 (0.01)***
Fruits	0.63 (0.07)***	0.31 (0.00)***	0.17 (0.09)	0.01 (0.90)
Whole grains	0.60 (0.10)***	0.60 (0.01)***	0.27 (0.23)	-0.03 (0.02)
Refined grains	9.54 (1.33)***	-4.54 (1.33)**	2.86 (0.07)***	-1.49 (0.08)***
Dairy	2.41 (0.23)***	0.90 (0.06)***	0.92 (0.08)***	0.13 (0.08)
Protein	4.27 (0.53)***	2.71 (0.17)***	1.80 (0.01)***	1.12 (0.03)***
Fats and oils	124.1 (15.4)***	28.95 (0.83)***	32.88 (2.92)***	9.53 (2.95)**
Added sugars	9.76 (0.08)***	9.29 (0.39)***	9.35 (0.10)***	7.14 (0.18)***
Kcals/person/day	1232.30 (49.27)***	1167.4 (90.45)***	958.58 (12.47)***	517.83 (17.23)***
HEI score	54.48 (0.74)***	-0.51 (0.76)	40.67 (1.04)***	19.77 (1.68)***

*=p<0.05, **=p<0.01, ***=p<0.001

(B) Average treatment effect on the treated

Food category	Low-cost area (Overall regional price parity)		High-cost area (Overall regional price parity)	
	Acquisition if not participating in SNAP	Change in acquisition if participating in SNAP	Acquisition if not participating in SNAP	Change in acquisition if participating in SNAP
Vegetables	1.32 (0.02)***	0.05 (0.02)**	1.48 (0.02)***	0.05 (0.02)**
Fruits	0.67 (0.01)***	0.03 (0.00)***	0.03 (0.02)	0.00 (0.01)
Whole grains	0.10 (0.29)	0.01 (0.03)	0.49 (0.42)	-0.05 (0.04)
Refined grains	11.63 (2.24)***	-4.81 (2.24)*	7.61 (0.12)***	0.26 (0.13)
Dairy	1.49 (0.10)***	0.32 (0.10)**	1.59 (0.14)***	0.31 (0.14)*
Protein	3.51 (0.28)***	1.51 (0.28)***	5.27 (0.04)***	0.01 (0.00)**
Fats and oils	63.44 (1.40)***	6.62 (1.35)***	65.05 (5.13)***	11.63 (5.81)
Added sugars	26.07 (0.16)***	0.45 (0.08)***	29.80 (0.23)***	0.00 (0.01)
Kcals/person/day	1833.17 (82.95)***	560.44 (82.36)***	2626.21 (23.15)***	31.35 (16.31)
HEI score	54.44 (1.25)***	-0.32 (1.25)	29.43 (1.88)***	25.13 (0.02)***

*=p<0.05, **=p<0.01, ***=p<0.001

Table 7: Ordinary least squares regressions testing hypothesis 1: that increased cost of living is associated with less healthy food acquisitions. Subtables (A)-(H) correspond to food pattern equivalents of food categories 1 through 8 (vegetables through added sugars) as the outcome (in food patterns equivalent units), while subtable (I) corresponds to kilocalories per person per day as the outcome and (J) corresponds to the Healthy Eating Index as the outcome. All regressions include survey sample weights to account for differential sampling and response. * = p<0.05; ** = p<0.01; *** = p<0.001

(A)

Covariate	Change in acquisition of vegetables					
Cost of living metric	Overall RPP	Rent RPP	Food RPP	Good RPP	Services RPP	Geographic adjustment to the Supplemental Poverty Measure
Cost of living	-0.1097 (0.0117)***	-0.1097 (0.0117)***	-0.0727 (0.0102)***	-0.0698 (0.0112)***	-0.0765 (0.0113)***	-0.069 (0.0114)***
Age	0.0288 (0.001)***	0.0288 (0.001)***	0.0289 (0.001)***	0.0289 (0.001)***	0.0289 (0.001)***	0.0289 (0.001)***
Age squared	-0.0002 (0)***	-0.0002 (0)***	-0.0002 (0)***	-0.0002 (0)***	-0.0002 (0)***	-0.0002 (0)***
Sex (1=female)	0.1343 (0.0085)***	0.1343 (0.0085)***	0.1343 (0.0085)***	0.1341 (0.0085)***	0.1341 (0.0085)***	0.1342 (0.0085)***
White race	0.1015 (0.0123)***	0.1015 (0.0123)***	0.1055 (0.0123)***	0.1037 (0.0123)***	0.1034 (0.0123)***	0.1023 (0.0123)***
Black race	-0.1575 (0.0158)***	-0.1575 (0.0158)***	-0.1506 (0.0158)***	-0.1522 (0.0157)***	-0.1532 (0.0157)***	-0.1562 (0.0158)***
Hispanic	-0.1757 (0.012)***	-0.1757 (0.012)***	-0.1652 (0.0119)***	-0.1712 (0.012)***	-0.1711 (0.012)***	-0.1722 (0.012)***
Education >= high school	-0.1819 (0.0111)***	-0.1819 (0.0111)***	-0.1826 (0.0111)***	-0.183 (0.0111)***	-0.1832 (0.0111)***	-0.1826 (0.0111)***
Employed (1=yes)	-0.0409 (0.009)***	-0.0409 (0.009)***	-0.0413 (0.009)***	-0.0406 (0.009)***	-0.0409 (0.009)***	-0.0407 (0.009)***
Household size	-0.1872 (0.0024)***	-0.1872 (0.0024)***	-0.1876 (0.0024)***	-0.1871 (0.0024)***	-0.1873 (0.0024)***	-0.187 (0.0024)***
Income	0.326	0.326	0.4	0.399	0.392	0.34 (0.151)*

($/10^4)	(0.151)*	(0.151)*	(0.151)*	(0.151)**	(0.151)**	
Housing cost ($/10^4)	0.717 (0.036)***	0.717 ().036)***	0.725 (0.0361)****	0.716 (0.036)***	0.718 (0.036)***	0.714 (0.036)***
Distance to primary food store	0.0086 (0.001)***	0.0086 (0.001)***	0.0085 (0.001)***	0.0087 (0.001)***	0.0087 (0.001)***	0.0088 (0.001)***
Rural residence	0.1408 (0.0115)***	0.1408 (0.0115)***	0.136 (0.0115)***	0.136 (0.0115)***	0.1382 (0.0116)***	0.1333 (0.0115)***
Food security status	-0.0788 (0.0092)***	-0.0788 (0.0092)***	-0.0802 (0.0092)***	-0.079 (0.0092)***	-0.0786 (0.0092)***	-0.0794 (0.0092)***
WIC	0.0405 (0.0127)**	0.0405 (0.0127)**	0.0383 (0.0127)**	0.0383 (0.0127)**	0.039 (0.0127)**	0.0385 (0.0127)**
Supermarkets	0.4258 (0.1166)***	0.4258 (0.1166)***	0.3119 (0.1154)**	0.366 (0.1167)**	0.3676 (0.1165)**	0.3232 (0.1158)**
Non-supermarkets	-0.6554 (0.0446)***	-0.6554 (0.0446)***	-0.6812 (0.0444)***	-0.676 (0.0445)***	-0.666 (0.0447)***	-0.6839 (0.0444)***
Full-service restaurants	-0.0424 (0.0174)*	-0.0424 (0.0174)*	-0.0474 (0.0175)**	-0.0557 (0.0173)**	-0.0523 (0.0174)**	-0.0512 (0.0175)**
Limited-service restaurants	-0.1355 (0.0348)***	-0.1355 (0.0348)***	-0.11 (0.0347)**	-0.0945 (0.0344)**	-0.104 (0.0346)**	-0.107 (0.035)**
Poverty rate	1.7455 (0.1879)***	1.7455 (0.1879)***	1.5159 (0.188)***	1.64 (0.1875)***	1.6397 (0.1874)***	1.6662 (0.1876)***
Area-level household income	0 (0)***	0 (0)***	0 (0)**	0 (0)**	0 (0)***	0 (0)**
Area-level educational attainment	-1.1778 (0.1094)***	-1.1778 (0.1094)***	-1.096 (0.1092)***	-1.0815 (0.11)***	-1.1001 (0.1099)***	-1.0663 (0.1096)***
Vehicle density	0.7893 (0.1587)***	0.7893 (0.1587)***	0.6746 (0.1582)***	0.7238 (0.1584)***	0.744 (0.1585)***	0.75 (0.1587)***
Kitchen availability	7.1063 (1.2728)***	7.1063 (1.2728)***	8.9548 (1.2373)***	9.0047 (1.2451)***	8.5776 (1.2548)***	8.4611 (1.2731)***
SNAP participation	-0.0574 (0.0093)***	-0.0574 (0.0093)***	-0.0574 (0.0093)***	-0.058 (0.0093)***	-0.0577 (0.0093)***	-0.0578 (0.0093)***

Intercept	-5.4052 (1.2176) ***	-5.4052 (1.2176) ***	-7.207 (1.1815) ***	-7.324 (1.1889) ***	-6.9144 (1.1984) ***	-6.8099 (1.2191)***
Observations	230,323	230,323	230,323	230,323	230,323	230,323
R-squared	0.0698	0.0698	0.0696	0.0696	0.0696	0.0696

(B)

Covariates	Change in acquisition of fruits					
Cost of living metric	Overall RPP	Rent RPP	Food RPP	Good RPP	Services RPP	Geographic adjustment to the Supplemental Poverty Measure
Cost of living	0.0074 (0.0052)	0.0074 (0.0052)	0.0463 (0.0045)***	0.0314 (0.005)***	0.0186 (0.005)***	0.0265 (0.0051)***
Age	0.0017 (0.0004)***	0.0017 (0.0004)***	0.0017 (0.0004)***	0.0017 (0.0004)***	0.0017 (0.0004)***	0.0017 (0.0004)***
Age squared	0 (0)***	0 (0)***	0 (0)***	0 (0)***	0 (0)***	0 (0)***
Sex (1=female)	0.0702 (0.0038)***	0.0702 (0.0038)***	0.0698 (0.0038)***	0.0701 (0.0038)***	0.0701 (0.0038)***	0.07 (0.0038)***
White race	0.0166 (0.0055)**	0.0166 (0.0055)**	0.0155 (0.0055)**	0.0166 (0.0055)**	0.0166 (0.0055)**	0.0171 (0.0055)**
Black race	-0.0155 (0.007)*	-0.0155 (0.007)*	-0.0175 (0.007)*	-0.0163 (0.007)*	-0.0158 (0.007)*	-0.0147 (0.007)*
Hispanic	0.1373 (0.0053)***	0.1373 (0.0053)***	0.1381 (0.0053)***	0.1403 (0.0053)***	0.1385 (0.0053)***	0.1401 (0.0054)***
Education >= high school	0.0741 (0.005)***	0.0741 (0.005)***	0.0738 (0.005)***	0.0741 (0.005)***	0.0742 (0.005)***	0.074 (0.005)***
Employed (1=yes)	-0.0835 (0.004)***	-0.0835 (0.004)***	-0.0825 (0.004)***	-0.0831 (0.004)***	-0.0833 (0.004)***	-0.0832 (0.004)***
Household size	-0.0641 (0.0011)***	-0.0641 (0.0011)***	-0.0636 (0.0011)***	-0.064 (0.0011)***	-0.064 (0.0011)***	-0.064 (0.0011)***
Income ($/10^4)	1.842 (0.0672)***	1.852 (0.0672)***	1.814 (0.0672)***	1.822 (0.0672)***	1.832 (0.0672)***	1.847 (0.0671)***
Housing cost ($/10^4)	0.369 (0.0161)***	0.369 (0.0161)***	0.361 (0.0161)***	0.368 (0.0161)***	0.368 (0.0161)***	0.368 (0.0161)***
Distance to primary food store	0.0141 (0.0004)***	0.0141 (0.0004)***	0.0143 (0.0004)***	0.0141 (0.0004)***	0.0141 (0.0004)***	0.0141 (0.0004)***
Rural residence	-0.0718 (0.0051)***	-0.0718 (0.0051)***	-0.0789 (0.0051)***	-0.0764 (0.0051)***	-0.0743 (0.0052)***	-0.0745 (0.0051)***
Food security status	-0.1194 (0.0041)***	-0.1194 (0.0041)***	-0.119 (0.0041)***	-0.1197 (0.0041)***	-0.1196 (0.0041)***	-0.1194 (0.0041)***
WIC	0.1215 (0.0057)***	0.1215 (0.0057)***	0.1204 (0.0057)***	0.1208 (0.0057)***	0.1211 (0.0057)***	0.1209 (0.0057)***
Supermarkets	0.2295 (0.052)***	0.2295 (0.052)***	0.1963 (0.0514)***	0.1854 (0.052)***	0.211 (0.0519)***	0.2102 (0.0516)***
Non-supermarkets	0.0529 (0.0199)**	0.0529 (0.0199)**	0.0376 (0.0198)	0.0409 (0.0198)*	0.0457 (0.0199)*	0.0462 (0.0198)*
Full-service restaurants	-0.0379 (0.0078)***	-0.0379 (0.0078)***	-0.0513 (0.0078)***	-0.043 (0.0077)***	-0.0406 (0.0077)***	-0.0437 (0.0078)***
Limited-service restaurants	0.0576 (0.0155)***	0.0576 (0.0155)***	0.0926 (0.0154)***	0.0736 (0.0153)***	0.0658 (0.0154)***	0.0751 (0.0156)***
Poverty rate	0.6329 (0.0837)***	0.6329 (0.0837)***	0.7065 (0.0837)***	0.6315 (0.0835)***	0.6362 (0.0835)***	0.6229 (0.0836)***

Area-level household income	0 (0)***	0 (0)***	0 (0)***	0 (0)***	0 (0)***	0 (0)***
Area-level educational attainment	0.4898 (0.0487)***	0.4898 (0.0487)***	0.6222 (0.0486)***	0.5702 (0.049)***	0.5278 (0.049)***	0.5494 (0.0488)***
Vehicle density	0.2604 (0.0707)***	0.2604 (0.0707)***	0.2666 (0.0705)***	0.2449 (0.0706)**	0.2508 (0.0706)***	0.2383 (0.0707)**
Kitchen availability	-4.7157 (0.5673)***	-4.7157 (0.5673)***	-3.7175 (0.5513)***	-4.1097 (0.5548)***	-4.402 (0.5591)***	-4.0275 (0.5673)***
SNAP participation	0.0711 (0.0041)***	0.0711 (0.0041)***	0.0708 (0.0041)***	0.0711 (0.0041)***	0.071 (0.0041)***	0.0711 (0.0041)***
Intercept	4.6897 (0.5427)***	4.6897 (0.5427)***	3.5488 (0.5264)***	4.017 (0.5298)***	4.3503 (0.534)***	3.9579 (0.5432)***
Observations	230,323	230,323	230,323	230,323	230,323	230,323
R-squared	0.0637	0.0637	0.0642	0.0639	0.0638	0.0639

(C)

Covariates	Change in acquisition of whole grains					
Cost of living metric	Overall RPP	Rent RPP	Food RPP	Good RPP	Services RPP	Geographic adjustment to the Supplemental Poverty Measure
Cost of living	0.1023 (0.0152)***	0.1023 (0.0152)***	-0.025 (0.0132)	0.0143 (0.0146)	0.0271 (0.0146)	0.1105 (0.0148)***
Age	0.01 (0.0013)***	0.01 (0.0013)***	0.0099 (0.0013)***	0.0099 (0.0013)***	0.0099 (0.0013)***	0.01 (0.0013)***
Age squared	-0.0001 (0)***	-0.0001 (0)***	-0.0001 (0)***	-0.0001 (0)***	-0.0001 (0)***	-0.0001 (0)***
Sex (1=female)	0.1478 (0.011)***	0.1478 (0.011)***	0.1485 (0.011)***	0.1482 (0.011)***	0.1482 (0.011)***	0.1477 (0.011)***
White race	-0.248 (0.016)***	-0.248 (0.016)***	-0.25 (0.016)***	-0.2504 (0.016)***	-0.2502 (0.016)***	-0.2475 (0.016)***
Black race	-0.4635 (0.0205)***	-0.4635 (0.0205)***	-0.4664 (0.0205)***	-0.4675 (0.0205)***	-0.4674 (0.0205)***	-0.4627 (0.0205)***
Hispanic	-0.3772 (0.0156)***	-0.3772 (0.0156)***	-0.3903 (0.0155)***	-0.3876 (0.0156)***	-0.3864 (0.0156)***	-0.374 (0.0156)***
Education >= high school	0.2145 (0.0145)***	0.2145 (0.0145)***	0.216 (0.0145)***	0.2157 (0.0145)***	0.2157 (0.0145)***	0.2147 (0.0145)***
Employed (1=yes)	-0.2536 (0.0117)***	-0.2536 (0.0117)***	-0.2555 (0.0117)***	-0.2546 (0.0117)***	-0.2544 (0.0117)***	-0.2531 (0.0117)***
Household size	-0.0572 (0.0031)***	-0.0572 (0.0031)***	-0.0577 (0.0031)***	-0.0575 (0.0031)***	-0.0574 (0.0031)***	-0.0574 (0.0031)***
Income ($/10^4)	0.212 (0.196)	0.212 (0.196)	0.193 (0.196)	0.172 (0.196)	0.169 (0.196)	0.213 (0.196)
Housing cost ($/10^4)	-0.0259 (0.0469)	-0.0259 (0.0469)	-0.0163 (0.0469)	-0.0218 (0.0469)	-0.0241 (0.0469)	-0.0254 (0.0468)
Distance to primary food store	0.011 (0.0013)***	0.011 (0.0013)***	0.0105 (0.0013)***	0.0107 (0.0013)***	0.0108 (0.0013)***	0.011 (0.0013)***
Rural residence	-0.1037 (0.015)***	-0.1037 (0.015)***	-0.0826 (0.0149)***	-0.0898 (0.015)***	-0.0925 (0.015)***	-0.1037 (0.0149)***
Food security status	-0.1999 (0.012)***	-0.1999 (0.012)***	-0.1992 (0.012)***	-0.1992 (0.012)***	-0.1995 (0.012)***	-0.1996 (0.012)***
WIC	0.0789 (0.0166)***	0.0789 (0.0166)***	0.0838 (0.0166)***	0.0826 (0.0166)***	0.082 (0.0166)***	0.0792 (0.0166)***
Supermarkets	-0.1158 (0.1517)	-0.1158 (0.1517)	0.0819 (0.1501)	0.0315 (0.1518)	0.0122 (0.1515)	-0.0755 (0.1506)
Non-supermarkets	0.1554 (0.0579)**	0.1554 (0.0579)**	0.2175 (0.0577)***	0.2001 (0.0579)**	0.1913 (0.0581)**	0.1639 (0.0577)**
Full-service restaurants	0.522 (0.0227)***	0.522 (0.0227)***	0.5575 (0.0227)***	0.5459 (0.0226)***	0.5423 (0.0226)***	0.5167 (0.0227)***
Limited-service restaurants	-0.9248 (0.0453)***	-0.9248 (0.0453)***	-1.0308 (0.0451)***	-0.9986 (0.0447)***	-0.9879 (0.045)***	-0.9103 (0.0455)***
Poverty rate	3.2654	3.2654	3.3496	3.38	3.3768	3.3069

	(0.2443)***	(0.2443)***	(0.2444)***	(0.2438)***	(0.2438)***	(0.2439)***
Area-level household income	0 (0)***	0 (0)***	0 (0)***	0 (0)***	0 (0)***	0 (0)***
Area-level educational attainment	1.2371 (0.1422)***	1.2371 (0.1422)***	0.8522 (0.142)***	0.9819 (0.1431)***	1.0223 (0.143)***	1.2745 (0.1424)***
Vehicle density	-3.6996 (0.2063)***	-3.6996 (0.2063)***	-3.5892 (0.2057)***	-3.6008 (0.206)***	-3.6156 (0.2062)***	-3.7151 (0.2064)***
Kitchen availability	6.5199 (1.6552)***	6.5199 (1.6552)***	2.2837 (1.6091)	3.3536 (1.6191)*	3.7907 (1.6317)*	6.8999 (1.6553)***
SNAP participation	0.0689 (0.0121)***	0.0689 (0.0121)***	0.0696 (0.0121)***	0.0694 (0.0121)***	0.0693 (0.0121)***	0.0692 (0.0121)***
Intercept	-5.6066 (1.5834)***	-5.6066 (1.5834)***	-1.1017 (1.5364)	-2.2921 (1.5461)	-2.7493 (1.5584)	-6.0388 (1.5851)***
Observations	230,323	230,323	230,323	230,323	230,323	230,323
R-squared	0.0273	0.0273	0.0271	0.0271	0.0271	0.0273

(D)

Covariates	Change in acquisition of refined grains					
Cost of living metric	Overall RPP	Rent RPP	Food RPP	Good RPP	Services RPP	Geographic adjustment to the Supplemental Poverty Measure
Cost of living	0.5461 (0.0368)***	0.5461 (0.0368)***	0.1898 (0.0321)***	0.4626 (0.0354)***	0.4985 (0.0355)***	0.7781 (0.036)***
Age	0.1048 (0.0032)***	0.1048 (0.0032)***	0.1042 (0.0032)***	0.1046 (0.0032)***	0.1047 (0.0032)***	0.1047 (0.0032)***
Age squared	-0.0012 (0)***	-0.0012 (0)***	-0.0011 (0)***	-0.0012 (0)***	-0.0011 (0)***	-0.0012 (0)***
Sex (1=female)	0.3501 (0.0267)***	0.3501 (0.0267)***	0.3513 (0.0267)***	0.3508 (0.0267)***	0.3507 (0.0267)***	0.3484 (0.0267)***
White race	0.2966 (0.0387)***	0.2966 (0.0387)***	0.2799 (0.0387)***	0.2862 (0.0387)***	0.2881 (0.0387)***	0.3042 (0.0387)***
Black race	-0.2097 (0.0497)***	-0.2097 (0.0497)***	-0.2374 (0.0497)***	-0.2377 (0.0497)***	-0.2315 (0.0497)***	-0.1978 (0.0497)***
Hispanic	-0.3439 (0.0378)***	-0.3439 (0.0378)***	-0.4025 (0.0376)***	-0.3523 (0.0378)***	-0.3538 (0.0378)***	-0.3011 (0.0379)***
Education >= high school	-0.234 (0.0352)***	-0.234 (0.0352)***	-0.229 (0.0352)***	-0.2289 (0.0352)***	-0.2281 (0.0352)***	-0.2352 (0.0351)***
Employed (1=yes)	-0.271 (0.0284)***	-0.271 (0.0284)***	-0.2732 (0.0284)***	-0.2708 (0.0284)***	-0.2689 (0.0284)***	-0.2652 (0.0284)***
Household size	-0.4373 (0.0075)***	-0.4373 (0.0075)***	-0.437 (0.0075)***	-0.4376 (0.0075)***	-0.4366 (0.0075)***	-0.438 (0.0075)***
Income ($/10^4)	-7.91 (0.475)***	-7.91 (0.475)***	-8.182 (0.476)***	-8.332 (0.476)***	-8.281 (0.476)***	-7.845 (0.475)***
Housing cost ($/10^4)	2.862 (0.114)***	2.862 (0.114)***	2.854 (0.114)***	2.861 (0.114)***	2.849 (0.114)****	2.847 (0.114)***
Distance to primary food store	0.0766 (0.0031)***	0.0766 (0.0031)***	0.076 (0.0031)***	0.0766 (0.0031)***	0.0768 (0.0031)***	0.0772 (0.0031)***
Rural residence	-0.0346 (0.0363)	-0.0346 (0.0363)	0.0199 (0.0363)	-0.0324 (0.0364)	-0.045 (0.0365)	-0.0625 (0.0362)
Food security status	-0.2168 (0.0292)***	-0.2168 (0.0292)***	-0.2112 (0.0292)***	-0.2174 (0.0292)***	-0.2196 (0.0292)***	-0.2163 (0.0292)***
WIC	0.0249 (0.0402)	0.0249 (0.0402)	0.0411 (0.0402)	0.0321 (0.0402)	0.0282 (0.0402)	0.0197 (0.0401)
Supermarkets	-4.0753 (0.3681)***	-4.0753 (0.3681)***	-3.3387 (0.3643)***	-3.9846 (0.3684)***	-3.9813 (0.3676)***	-4.0863 (0.3651)***
Non-supermarkets	0.9861 (0.1406)***	0.9861 (0.1406)***	1.1854 (0.14)***	1.031 (0.1405)***	0.9701 (0.1409)***	0.9575 (0.14)***
Full-service restaurants	-0.1728 (0.055)**	-0.1728 (0.055)**	-0.091 (0.0552)	-0.1325 (0.0547)*	-0.1534 (0.0549)**	-0.2567 (0.0551)***
Limited-service restaurants	-0.1194 (0.1099)	-0.1194 (0.1099)	-0.3986 (0.1094)***	-0.2425 (0.1085)*	-0.186 (0.1091)	0.1257 (0.1103)
Poverty rate	0.0452	0.0452	0.9477	0.5339	0.5383	0.1346

	(0.5929)	(0.5929)	(0.5933)	(0.5915)	(0.5914)	(0.5915)
Area-level household income	0 (0)***	0 (0)***	0 (0)***	0 (0)***	0 (0)***	0 (0)***
Area-level educational attainment	-0.3482 (0.3451)	-0.3482 (0.3451)	-1.3275 (0.3446)***	-0.4541 (0.3472)	-0.3576 (0.3469)	0.4301 (0.3455)
Vehicle density	1.0595 (0.5006)*	1.0595 (0.5006)*	1.6372 (0.4993)**	1.3001 (0.4998)**	1.1746 (0.5002)*	0.7635 (0.5004)
Kitchen availability	76.3886 (4.0164)***	76.3886 (4.0164)***	62.5276 (3.9055)***	70.0939 (3.9288)***	72.6686 (3.9591)***	85.1344 (4.0145)***
SNAP participation	1.0151 (0.0293)***	1.0151 (0.0293)***	1.0164 (0.0293)***	1.0185 (0.0293)***	1.0163 (0.0293)***	1.0166 (0.0293)***
Intercept	-71.8519 (3.8421)***	-71.8519 (3.8421)***	-57.6445 (3.7292)***	-65.7481 (3.7515)***	-68.1891 (3.7812)***	-81.281 (3.8441)***
Observations	230,323	230,323	230,323	230,323	230,323	230,323
R-squared	0.0445	0.0445	0.0437	0.0443	0.0444	0.0455

(E)

Covariates	Change in acquisition of dairy					
Cost of living metric	Overall RPP	Rent RPP	Food RPP	Good RPP	Services RPP	Geographic adjustment to the Supplemental Poverty Measure
Cost of living	0.1297 (0.01)***	0.1297 (0.01)***	0.0031 (0.0087)	0.0911 (0.0096)***	0.0878 (0.0096)***	0.1851 (0.0097)***
Age	0.0126 (0.0009)***	0.0126 (0.0009)***	0.0124 (0.0009)***	0.0125 (0.0009)***	0.0125 (0.0009)***	0.0125 (0.0009)***
Age squared	-0.0002 (0)***	-0.0002 (0)***	-0.0002 (0)***	-0.0002 (0)***	-0.0002 (0)***	-0.0002 (0)***
Sex (1=female)	0.0624 (0.0072)***	0.0624 (0.0072)***	0.063 (0.0072)***	0.0627 (0.0072)***	0.0627 (0.0072)***	0.062 (0.0072)***
White race	0.3358 (0.0105)***	0.3358 (0.0105)***	0.3327 (0.0105)***	0.3333 (0.0105)***	0.3336 (0.0105)***	0.3377 (0.0105)***
Black race	-0.1957 (0.0134)***	-0.1957 (0.0134)***	-0.2007 (0.0134)***	-0.2021 (0.0134)***	-0.2008 (0.0134)***	-0.1929 (0.0134)***
Hispanic	-0.1114 (0.0102)***	-0.1114 (0.0102)***	-0.1268 (0.0102)***	-0.1157 (0.0102)***	-0.1172 (0.0102)***	-0.1012 (0.0102)***
Education >= high school	0.0717 (0.0095)***	0.0717 (0.0095)***	0.0732 (0.0095)***	0.0729 (0.0095)***	0.0731 (0.0095)***	0.0714 (0.0095)***
Employed (1=yes)	-0.0906 (0.0077)***	-0.0906 (0.0077)***	-0.0921 (0.0077)***	-0.0908 (0.0077)***	-0.0906 (0.0077)***	-0.0892 (0.0077)***
Household size	-0.1131 (0.002)***	-0.1131 (0.002)***	-0.1134 (0.002)***	-0.1132 (0.002)***	-0.113 (0.002)***	-0.1132 (0.002)***
Income ($/10^4)	-0.495 (0.128)***	-0.495 (0.128)***	-0.537 (0.128)***	-0.585 (0.128)***	-0.571 (0.128)***	-0.479 (0.128)***
Housing cost ($/10^4)	0.712 (0.0307)***	0.712 (0.0307)***	0.718 (0.0307)***	0.713 (0.0307)***	0.711 (0.0307)***	0.711 (0.0307)***
Distance to primary food store	0.0276 (0.0008)***	0.0276 (0.0008)***	0.0272 (0.0008)***	0.0275 (0.0008)***	0.0275 (0.0008)***	0.0277 (0.0008)***
Rural residence	-0.0027 (0.0098)	-0.0027 (0.0098)	0.0178 (0.0098)	0.0013 (0.0098)	0.0009 (0.0099)	-0.0094 (0.0098)
Food security status	-0.0686 (0.0079)***	-0.0686 (0.0079)***	-0.0675 (0.0079)***	-0.0685 (0.0079)***	-0.0688 (0.0079)***	-0.0685 (0.0079)***
WIC	0.0389 (0.0108)***	0.0389 (0.0108)***	0.044 (0.0108)***	0.0412 (0.0108)***	0.0408 (0.0108)***	0.0376 (0.0108)**
Supermarkets	-0.9916 (0.0994)***	-0.9916 (0.0994)***	-0.7753 (0.0984)***	-0.9364 (0.0995)***	-0.9184 (0.0993)***	-0.9947 (0.0986)***
Non-supermarkets	0.1549 (0.038)***	0.1549 (0.038)***	0.2194 (0.0378)***	0.1749 (0.0379)***	0.169 (0.0381)***	0.1479 (0.0378)***
Full-service restaurants	-0.1434 (0.0149)***	-0.1434 (0.0149)***	-0.11 (0.0149)***	-0.1296 (0.0148)***	-0.1311 (0.0148)***	-0.1634 (0.0149)***
Limited-service restaurants	-0.126 (0.0297)***	-0.126 (0.0297)***	-0.2295 (0.0296)***	-0.1683 (0.0293)***	-0.1652 (0.0295)***	-0.0675 (0.0298)*
Poverty rate	-0.2466	-0.2466	-0.0911	-0.1246	-0.1207	-0.2256

	(0.1601)	(0.1601)	(0.1602)	(0.1598)	(0.1597)	(0.1598)
Area-level household income	0 (0)***	0 (0)***	0 (0)***	0 (0)***	0 (0)***	0 (0)***
Area-level educational attainment	2.2235 (0.0932)***	2.2235 (0.0932)***	1.8513 (0.0931)***	2.1376 (0.0938)***	2.1231 (0.0937)***	2.4094 (0.0933)***
Vehicle density	0.6727 (0.1352)***	0.6727 (0.1352)***	0.8114 (0.1348)***	0.7438 (0.135)***	0.7288 (0.1351)***	0.6021 (0.1352)***
Kitchen availability	10.3971 (1.0847)***	10.3971 (1.0847)***	5.9681 (1.0547)***	8.3891 (1.0611)***	8.5766 (1.0694)***	12.4861 (1.0843)***
SNAP participation	0.1941 (0.0079)***	0.1941 (0.0079)***	0.1947 (0.0079)***	0.1949 (0.0079)***	0.1945 (0.0079)***	0.1944 (0.0079)***
Intercept	-10.1894 (1.0376)***	-10.1894 (1.0376)***	-5.5367 (1.0071)***	-8.1792 (1.0132)***	-8.3186 (1.0213)***	-12.4413 (1.0383)***
Observations	230,323	230,323	230,323	230,323	230,323	230,323
R-squared	0.0665	0.0665	0.0658	0.0662	0.0661	0.0673

(F)

Covariates	Change in acquisition of protein					
Cost of living metric	Overall RPP	Rent RPP	Food RPP	Good RPP	Services RPP	Geographic adjustment to the Supplemental Poverty Measure
Cost of living	0.0424 (0.0322)	0.0424 (0.0322)	-0.0992 (0.028)***	0.1121 (0.0309)***	0.0295 (0.031)	0.1579 (0.0314)***
Age	0.1064 (0.0028)***	0.1064 (0.0028)***	0.1063 (0.0028)***	0.1065 (0.0028)***	0.1064 (0.0028)***	0.1065 (0.0028)***
Age squared	-0.001 (0)***	-0.001 (0)***	-0.001 (0)***	-0.001 (0)***	-0.001 (0)***	-0.001 (0)***
Sex (1=female)	-0.1212 (0.0233)***	-0.1212 (0.0233)***	-0.1202 (0.0233)***	-0.1215 (0.0233)***	-0.1211 (0.0233)***	-0.1219 (0.0233)***
White race	0.3126 (0.0338)***	0.3126 (0.0338)***	0.3136 (0.0338)***	0.3123 (0.0338)***	0.3119 (0.0338)***	0.3158 (0.0338)***
Black race	0.2695 (0.0434)***	0.2695 (0.0434)***	0.2716 (0.0434)***	0.2661 (0.0434)***	0.2678 (0.0434)***	0.2745 (0.0434)***
Hispanic	-0.2019 (0.033)***	-0.2019 (0.033)***	-0.2105 (0.0328)***	-0.1931 (0.033)***	-0.2037 (0.033)***	-0.185 (0.0331)***
Education >= high school	-0.0853 (0.0307)**	-0.0853 (0.0307)**	-0.0839 (0.0307)**	-0.0851 (0.0307)**	-0.0848 (0.0307)**	-0.0863 (0.0307)**
Employed (1=yes)	-0.5655 (0.0248)***	-0.5655 (0.0248)***	-0.5684 (0.0248)***	-0.5644 (0.0248)***	-0.5655 (0.0248)***	-0.5635 (0.0248)***
Household size	-0.5957 (0.0066)***	-0.5957 (0.0066)***	-0.5968 (0.0066)***	-0.5956 (0.0066)***	-0.5957 (0.0066)***	-0.5957 (0.0066)***
Income ($/10^4)	2.908 (0.415)***	2.908 (0.415)***	2.949 (0.415)***	2.834 (0.415)***	2.883 (0.415)***	2.943 (0.415)***
Housing cost ($/10^4)	1.693 (0.0992)***	1.693 (0.0992)***	1.714 (0.0994)***	1.689 (0.0992)***	1.693 (0.00993)***	1.689 (0.0992)***
Distance to primary food store	0.0238 (0.0027)***	0.0238 (0.0027)***	0.023 (0.0027)***	0.0241 (0.0027)***	0.0238 (0.0027)***	0.0241 (0.0027)***
Rural residence	0.1947 (0.0317)***	0.1947 (0.0317)***	0.2194 (0.0316)***	0.1806 (0.0318)***	0.1957 (0.0318)***	0.1779 (0.0316)***
Food security status	-0.0461 (0.0255)	-0.0461 (0.0255)	-0.0464 (0.0255)	-0.047 (0.0255)	-0.0462 (0.0255)	-0.0466 (0.0255)
WIC	0.1369 (0.0351)***	0.1369 (0.0351)***	0.1415 (0.0351)***	0.135 (0.0351)***	0.1375 (0.0351)***	0.1331 (0.0351)***
Supermarkets	2.1521 (0.3213)***	2.1521 (0.3213)***	2.3217 (0.3178)***	2.022 (0.3215)***	2.1747 (0.3208)***	2.0341 (0.3189)***
Non-supermarkets	-0.8158 (0.1227)***	-0.8158 (0.1227)***	-0.7536 (0.1222)***	-0.8505 (0.1226)***	-0.8116 (0.123)***	-0.8563 (0.1223)***
Full-service restaurants	0.4039 (0.048)***	0.4039 (0.048)***	0.4482 (0.0482)***	0.3898 (0.0478)***	0.4077 (0.0479)***	0.3687 (0.0481)***
Limited-service restaurants	-0.6727 (0.0959)***	-0.6727 (0.0959)***	-0.7954 (0.0955)***	-0.6289 (0.0947)***	-0.6849 (0.0952)***	-0.5669 (0.0964)***
Poverty rate	11.4431 (0.5175)***	11.4431 (0.5175)***	11.3535 (0.5176)***	11.4567 (0.5163)***	11.484 (0.5162)***	11.3815 (0.5166)***

Area-level household income	0 (0)*	0 (0)*	0 (0)***	0 (0)	0 (0)*	0 (0)
Area-level educational attainment	1.7041 (0.3012)***	1.7041 (0.3012)***	1.2488 (0.3007)***	1.9436 (0.303)***	1.6737 (0.3028)***	2.0637 (0.3017)***
Vehicle density	0.0875 (0.437)	0.0875 (0.437)	0.1366 (0.4356)	0.0496 (0.4362)	0.1051 (0.4366)	-0.0457 (0.4371)
Kitchen availability	37.302 (3.5059)***	37.302 (3.5059)***	33.1374 (3.4077)***	38.905 (3.429)***	36.7303 (3.4558)***	41.4561 (3.506)***
SNAP participation	0.8834 (0.0256)***	0.8834 (0.0256)***	0.8844 (0.0256)***	0.8838 (0.0256)***	0.8836 (0.0256)***	0.8834 (0.0256)***
Intercept	-38.0579 (3.3538)***	-38.0579 (3.3538)***	-33.4826 (3.2538)***	-39.8694 (3.2743)***	-37.4713 (3.3005)***	-42.4741 (3.3572)***
Observations	230,323	230,323	230,323	230,323	230,323	230,323
R-squared	0.0774	0.0774	0.0774	0.0774	0.0774	0.0775

(G)

Covariates	Change in acquisition of fats and oils					
Cost of living metric	Overall RPP	Rent RPP	Food RPP	Good RPP	Services RPP	Geographic adjustment to the Supplemental Poverty Measure
Cost of living	9.5756 (0.8897)***	9.5756 (0.8897)***	3.4126 (0.7739)***	10.6087 (0.8543)***	8.5808 (0.8578)***	10.5073 (0.8686)***
Age	1.0868 (0.0764)***	1.0868 (0.0764)***	1.0758 (0.0764)***	1.0858 (0.0764)***	1.0834 (0.0764)***	1.0816 (0.0764)***
Age squared	-0.0109 (0.0009)***	-0.0109 (0.0009)***	-0.0108 (0.0009)***	-0.0109 (0.0009)***	-0.0108 (0.0009)***	-0.0108 (0.0009)***
Sex (1=female)	10.5683 (0.6444)***	10.5683 (0.6444)***	10.5884 (0.6446)***	10.5685 (0.6444)***	10.5786 (0.6444)***	10.5561 (0.6444)***
White race	-8.5168 (0.9352)***	-8.5168 (0.9352)***	-8.8103 (0.9352)***	-8.6852 (0.9349)***	-8.6675 (0.935)***	-8.4664 (0.9351)***
Black race	-8.524 (1.2001)***	-8.524 (1.2001)***	-9.0121 (1.2003)***	-9.0558 (1.1997)***	-8.9061 (1.1997)***	-8.4459 (1.2001)***
Hispanic	-17.1172 (0.9138)***	-17.1172 (0.9138)***	-18.1412 (0.9081)***	-16.9564 (0.9135)***	-17.3082 (0.9126)***	-16.803 (0.9155)***
Education >= high school	1.1326 (0.8488)	1.1326 (0.8488)	1.2192 (0.8489)	1.2139 (0.8486)	1.2364 (0.8487)	1.1431 (0.8487)
Employed (1=yes)	-2.7595 (0.6855)***	-2.7595 (0.6855)***	-2.7953 (0.6858)***	-2.719 (0.6854)***	-2.7253 (0.6856)***	-2.7073 (0.6855)***
Household size	-6.802 (0.1819)***	-6.802 (0.1819)***	-6.7954 (0.1821)***	-6.8011 (0.1819)***	-6.7903 (0.182)***	-6.8171 (0.1819)***
Income ($/10^4)	-28.96 (11.48)*	-28.96 (11.48)*	-33.788 (11.487)**	-37.734 (11.485)	-35.411 (11.482)**	-28.774 (11.479)*
Housing cost ($/10^4)	22.285 (2.745)***	22.285 (2.745)***	22.133 (2.749)***	22.116 (2.745)***	22.06 (2.746)***	22.33 (2.745)***
Distance to primary food store	1.4371 (0.0749)***	1.4371 (0.0749)***	1.4285 (0.075)***	1.4471 (0.0749)***	1.4398 (0.0749)***	1.4387 (0.0749)***
Rural residence	0.5389 (0.8762)	0.5389 (0.8762)	1.48 (0.8755)	0.1123 (0.8787)	0.389 (0.8808)	0.5202 (0.8738)
Food security status	-5.0586 (0.7046)***	-5.0586 (0.7046)***	-4.959 (0.7047)***	-5.0972 (0.7046)***	-5.1061 (0.7047)***	-5.0337 (0.7045)***
WIC	0.0331 (0.97)	0.0331 (0.97)	0.316 (0.9698)	0.08 (0.9696)	0.0968 (0.9699)	0.0518 (0.9697)
Supermarkets	-8.4219 (8.8875)	-8.4219 (8.8875)	4.4086 (8.7942)	-11.3325 (8.8925)	-6.5077 (8.875)	-4.8496 (8.8205)
Non-supermarkets	9.8983 (3.3949)**	9.8983 (3.3949)**	13.3578 (3.3804)***	9.4298 (3.3917)**	9.7119 (3.4024)**	10.6286 (3.3818)**
Full-service restaurants	-2.6647 (1.3283)*	-2.6647 (1.3283)*	-1.2571 (1.3325)	-2.523 (1.3213)	-2.2832 (1.3249)	-3.2124 (1.3318)*
Limited-service restaurants	5.5755 (2.6529)*	5.5755 (2.6529)*	0.7551 (2.642)	5.1688 (2.62)*	4.2847 (2.6337)	7.0821 (2.6652)**
Poverty rate	-3.7636	-3.7636	12.1787	4.0067	4.9281	0.0086

	(14.3157)	(14.3157)	(14.3222)	(14.2795)	(14.2807)	(14.2902)
Area-level household income	0 (0.0001)	0 (0.0001)	0.0001 (0.0001)**	0 (0.0001)	0 (0.0001)	0 (0.0001)
Area-level educational attainment	-12.2337 (8.3324)	-12.2337 (8.3324)	-29.1211 (8.3186)***	-5.9621 (8.3819)	-12.9118 (8.3749)	-8.2134 (8.3455)
Vehicle density	21.8935 (12.0877)	21.8935 (12.0877)	32.0187 (12.0527)**	24.2531 (12.0659)*	24.0615 (12.0776)*	20.2523 (12.0894)
Kitchen availability	274.7445 (96.978)**	274.7445 (96.978)**	34.0148 (94.2843)	233.0091 (94.8457)*	204.6176 (95.5951)*	316.2784 (96.9787)**
SNAP participation	16.9698 (0.708)***	16.9698 (0.708)***	16.9921 (0.7081)***	17.0326 (0.7079)***	16.9903 (0.708)***	17.0007 (0.7079)***
Intercept	-259.1367 (92.7704)**	-259.1367 (92.7704)**	-12.6172 (90.0269)	-227.1002 (90.5659)*	-189.6767 (91.2993)*	-305.9259 (92.8629)**
Observations	230,323	230,323	230,323	230,323	230,323	230,323
R-squared	0.0211	0.0211	0.0207	0.0213	0.021	0.0212

(H)

Covariates	Change in acquisition of added sugars					
Cost of living metric	Overall RPP	Rent RPP	Food RPP	Good RPP	Services RPP	Geographic adjustment to the Supplemental Poverty Measure
Cost of living	3.6312 (0.3617)***	3.6312 (0.3617)***	1.9743 (0.3146)***	3.1593 (0.3474)***	3.0432 (0.3487)***	4.6085 (0.3531)***
Age	0.3847 (0.0311)***	0.3847 (0.0311)***	0.3808 (0.0311)***	0.3833 (0.0311)***	0.3832 (0.0311)***	0.3831 (0.0311)***
Age squared	-0.0048 (0.0004)***	-0.0048 (0.0004)***	-0.0048 (0.0004)***	-0.0048 (0.0004)***	-0.0048 (0.0004)***	-0.0048 (0.0004)***
Sex (1=female)	3.6572 (0.262)***	3.6572 (0.262)***	3.6596 (0.262)***	3.661 (0.262)***	3.662 (0.262)***	3.6491 (0.262)***
White race	-1.4637 (0.3802)***	-1.4637 (0.3802)***	-1.5882 (0.3802)***	-1.5323 (0.3801)***	-1.5227 (0.3801)***	-1.4281 (0.3802)***
Black race	-1.7413 (0.4879)***	-1.7413 (0.4879)***	-1.9519 (0.488)***	-1.929 (0.4878)***	-1.8857 (0.4878)***	-1.6857 (0.4879)**
Hispanic	-6.5238 (0.3715)***	-6.5238 (0.3715)***	-6.8876 (0.3692)***	-6.5693 (0.3715)***	-6.6197 (0.371)***	-6.3179 (0.3722)***
Education >= high school	0.8895 (0.3451)*	0.8895 (0.3451)*	0.9163 (0.3451)**	0.9231 (0.3451)**	0.9291 (0.3451)**	0.8871 (0.345)*
Employed (1=yes)	-1.6052 (0.2787)***	-1.6052 (0.2787)***	-1.6026 (0.2788)***	-1.6026 (0.2787)***	-1.5959 (0.2787)***	-1.5753 (0.2787)***
Household size	-1.4898 (0.074)***	-1.4898 (0.074)***	-1.481 (0.074)***	-1.4916 (0.074)***	-1.4863 (0.074)***	-1.4949 (0.074)***
Income ($/10^4)	-27.615 (4.667)***	-27.615 (4.667)***	-29.814 (4.67)***	-30.471 (4.67)***	-29.976 (4.668)***	-27.357 (4.667)***
Housing cost ($/10^4)	2.005 (1.116)	2.005 (1.116)	1.823 (1.118)	1.993 (1.116)	1.937 (1.116)	1.996 (1.116)
Distance to primary food store	0.6096 (0.0304)***	0.6096 (0.0304)***	0.6105 (0.0305)***	0.6101 (0.0305)***	0.6098 (0.0305)***	0.612 (0.0304)***
Rural residence	0.6868 (0.3562)	0.6868 (0.3562)	0.9215 (0.3559)*	0.6863 (0.3573)	0.6718 (0.3581)	0.5863 (0.3552)
Food security status	-1.321 (0.2865)***	-1.321 (0.2865)***	-1.2789 (0.2865)***	-1.3262 (0.2865)***	-1.3359 (0.2865)***	-1.3147 (0.2864)***
WIC	-3.4429 (0.3944)***	-3.4429 (0.3944)***	-3.3559 (0.3943)***	-3.3976 (0.3943)***	-3.4109 (0.3943)***	-3.4576 (0.3942)***
Supermarkets	0.9239 (3.6134)	0.9239 (3.6134)	5.1184 (3.5752)	1.3758 (3.6159)	2.0007 (3.6084)	1.5289 (3.5858)
Non-supermarkets	5.0193 (1.3803)***	5.0193 (1.3803)***	6.0523 (1.3743)***	5.2753 (1.3791)***	5.0726 (1.3834)***	5.0511 (1.3748)***
Full-service restaurants	-6.25 (0.5401)***	-6.25 (0.5401)***	-5.9424 (0.5417)***	-6.0008 (0.5373)***	-6.0523 (0.5387)***	-6.6412 (0.5414)***
Limited-service restaurants	2.4217 (1.0786)*	2.4217 (1.0786)*	1.197 (1.0741)	1.6618 (1.0653)	1.7712 (1.0708)	3.5485 (1.0835)**
Poverty rate	2.2486	2.2486	9.2471	5.4713	5.6053	3.2403

	(5.8203)	(5.8203)	(5.8225)	(5.8063)	(5.8062)	(5.8095)
Area-level household income	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Area-level educational attainment	-7.2344 (3.3877)*	-7.2344 (3.3877)*	-11.375 (3.3818)**	-7.6659 (3.4082)*	-8.1687 (3.405)*	-3.7939 (3.3928)
Vehicle density	11.304 (4.9145)*	11.304 (4.9145)*	15.1185 (4.8999)**	12.8414 (4.9062)**	12.3248 (4.9105)*	9.9755 (4.9147)*
Kitchen availability	63.0633 (39.4282)	63.0633 (39.4282)	-9.7941 (38.3301)	23.5079 (38.566)	30.0069 (38.8667)	101.0661 (39.4252)*
SNAP participation	5.5688 (0.2878)***	5.5688 (0.2878)***	5.5721 (0.2879)***	5.5914 (0.2878)***	5.5772 (0.2879)***	5.5795 (0.2878)***
Intercept	-58.8376 (37.7175)	-58.8376 (37.7175)	13.9249 (36.5993)	-20.7638 (36.8257)	-25.5933 (37.1201)	-100.1715 (37.7519)**
Observations	230,323	230,323	230,323	230,323	230,323	230,323
R-squared	0.016	0.016	0.0157	0.0159	0.0159	0.0163

(I)

Covariates	Change in acquisition of kcals/person/day					
Cost of living metric	All	Rent	Food	Good	Service	Geo
Cost of living	213.6908 (17.4955)***	213.6908 (17.4955)***	100.7439 (15.4089)***	198.7354 (16.7829)***	180.5345 (16.9247)***	271.9475 (17.0996)***
Age	33.6024 (1.5269)***	33.6024 (1.5269)***	33.3127 (1.527)***	33.5386 (1.5269)***	33.4989 (1.5269)***	33.5307 (1.5264)***
Age squared	-0.3549 (0.0176)***	-0.3549 (0.0176)***	-0.3519 (0.0176)***	-0.3546 (0.0176)***	-0.3538 (0.0176)***	-0.3541 (0.0176)***
Sex (1=female)	207.3737 (12.8789)***	207.3737 (12.8789)***	207.4339 (12.8822)***	207.5431 (12.8791)***	207.5899 (12.8799)***	206.96 (12.8761)***
White race	-29.7101 (18.6833)	-29.7101 (18.6833)	-37.7365 (18.6818)*	-33.6793 (18.6774)	-33.4675 (18.679)	-27.2528 (18.6801)
Black race	-175.4031 (23.8863)***	-175.4031 (23.8863)***	-191.0138 (23.8704)***	-186.6609 (23.863)***	-185.0327 (23.8661)***	-170.8012 (23.8827)***
Hispanic	-401.8737 (18.1745)***	-401.8737 (18.1745)***	-421.5158 (18.0905)***	-402.9677 (18.1714)***	-406.664 (18.1583)***	-390.4421 (18.2023)***
Education >= high school	40.6816 (16.9642)*	40.6816 (16.9642)*	42.5034 (16.9673)*	42.6204 (16.9632)*	43.045 (16.9641)*	40.5004 (16.9599)*
Employed (1=yes)	-133.7668 (13.6947)***	-133.7668 (13.6947)***	-133.4033 (13.7011)***	-133.4263 (13.6954)***	-133.023 (13.697)***	-132.1955 (13.6925)***
Household size	-200.0934 (3.6364)***	-200.0934 (3.6364)***	-199.7431 (3.6398)***	-200.1667 (3.6364)***	-199.8874 (3.6371)***	-200.3827 (3.6353)***
Income	-0.0835 (0.0229)***	-0.0835 (0.0229)***	-0.0964 (0.023)***	-0.101 (0.0229)***	-0.0977 (0.0229)***	-0.0817 (0.0229)***
Housing cost	0.0743 (0.0055)***	0.0743 (0.0055)***	0.0737 (0.0055)***	0.0742 (0.0055)***	0.074 (0.0055)***	0.0742 (0.0055)***
Distance to primary food store	34.6677 (1.4968)***	34.6677 (1.4968)***	34.6459 (1.4992)***	34.7478 (1.4971)***	34.6918 (1.4973)***	34.8112 (1.4963)***
Rural residence	-3.4757 (17.4462)	-3.4757 (17.4462)	16.4352 (17.4042)	-5.8944 (17.5052)	-3.6526 (17.5425)	-10.6362 (17.3907)
Food security status	-127.332 (14.0753)***	-127.332 (14.0753)***	-124.1741 (14.0768)***	-127.776 (14.0764)***	-127.9995 (14.0783)***	-127.2321 (14.0713)***
WIC	-22.4535 (19.3852)	-22.4535 (19.3852)	-16.3039 (19.3807)	-20.1978 (19.3797)	-20.4531 (19.3838)	-23.5373 (19.3768)
Supermarkets	-121.7797 (176.7616)	-121.7797 (176.7616)	120.3072 (175.2386)	-118.2932 (176.8537)	-66.7768 (176.5952)	-80.2491 (175.5576)
Non-supermarkets	339.6398 (66.3065)***	339.6398 (66.3065)***	385.7711 (66.2006)***	348.2456 (66.2584)***	335.6688 (66.4553)***	348.3814 (66.1193)***
Full-service restaurants	-210.3131 (25.1438)***	-210.3131 (25.1438)***	-171.7034 (25.0527)***	-198.5301 (24.9553)***	-194.4596 (25.0089)***	-238.8015 (25.2208)***
Limited-service restaurants	97.7063 (50.6484)	97.7063 (50.6484)	-18.0903 (49.8796)	61.9368 (49.8432)	51.5819 (50.0645)	174.925 (50.9076)**
Poverty rate	267.1659 (273.8725)	267.1659 (273.8725)	799.4013 (271.8986)**	452.8953 (272.3408)	506.6017 (272.1586)	276.5304 (272.7734)
Area-level household income	-0.0043 (0.001)***	-0.0043 (0.001)***	-0.001 (0.0009)	-0.0041 (0.001)***	-0.0037 (0.001)***	-0.0049 (0.001)***

Area-level educational attainment	95.709 (165.9443)	95.709 (165.9443)	-191.6975 (166.0107)	112.0125 (166.8807)	47.6546 (166.8517)	297.8486 (166.1989)
Vehicle density	1837.181 (126.0363)***	1837.181 (126.0363)***	1729.557 (125.9621)***	1917.709 (127.3076)***	1796.765 (125.8842)***	1871.693 (125.7321)***
Kitchen availability	14961.37 (1936.219)***	14961.37 (1936.219)***	9927.348 (1877.159)***	12985.27 (1892.467)***	12962.7 (1907.152)***	17336.27 (1935.719)***
SNAP participation	425.0196 (14.1497)***	425.0196 (14.1497)***	425.5168 (14.1531)***	426.369 (14.1496)***	425.5673 (14.1506)***	425.5873 (14.1462)***
Intercept	-14301.97 (1850.147)***	-14301.97 (1850.147)***	-9158.007 (1788.17)***	-12445.57 (1804.575)***	-12276.34 (1818.698)***	-16896.19 (1851.454)***
	0 (0)***	0 (0)***	0 (0)***	0 (0)***	0 (0)***	0 (0)***
Observations	230,323	230,323	230,323	230,323	230,323	230,323
R-squared	0.0388	0.0388	0.0383	0.0387	0.0386	0.0392

(J)

Covariates	Change in HEI score					
Cost of living metric	Overall RPP	Rent RPP	Food RPP	Good RPP	Services RPP	Geographic adjustment to the Supplemental Poverty Measure
Cost of living	0.1507 (0.0278)***	0.1507 (0.0278)***	0.0424 (0.0242)	0.1705 (0.0267)***	0.1703 (0.0268)***	0.1945 (0.0272)***
Age	0.2863 (0.0024)***	0.2863 (0.0024)***	0.2862 (0.0024)***	0.2863 (0.0024)***	0.2863 (0.0024)***	0.2863 (0.0024)***
Age squared	-0.0027 (0)***	-0.0027 (0)***	-0.0027 (0)***	-0.0027 (0)***	-0.0027 (0)***	-0.0027 (0)***
Sex (1=female)	0.8019 (0.0201)***	0.8019 (0.0201)***	0.8023 (0.0201)***	0.8019 (0.0201)***	0.8019 (0.0201)***	0.8016 (0.0201)***
White race	-0.6794 (0.0292)***	-0.6794 (0.0292)***	-0.6838 (0.0292)***	-0.682 (0.0292)***	-0.6815 (0.0292)***	-0.6778 (0.0292)***
Black race	0.0839 (0.0375)*	0.0839 (0.0375)*	0.0766 (0.0375)*	0.0755 (0.0375)*	0.0778 (0.0375)*	0.0863 (0.0375)*
Hispanic	0.2705 (0.0286)***	0.2705 (0.0286)***	0.2539 (0.0284)***	0.2734 (0.0286)***	0.2714 (0.0285)***	0.2794 (0.0286)***
Education >= high school	0.3887 (0.0265)***	0.3887 (0.0265)***	0.3902 (0.0265)***	0.39 (0.0265)***	0.3903 (0.0265)***	0.3886 (0.0265)***
Employed (1=yes)	0.1422 (0.0214)***	0.1422 (0.0214)***	0.1414 (0.0214)***	0.1429 (0.0214)***	0.1434 (0.0214)***	0.1435 (0.0214)***
Household size	-0.0524 (0.0057)***	-0.0524 (0.0057)***	-0.0524 (0.0057)***	-0.0524 (0.0057)***	-0.0521 (0.0057)***	-0.0526 (0.0057)***
Income ($/10^4)	1.09 (0.359)**	1.09 (0.359)**	1.02 (0.359)	0.95 (0.359)**	0.975 (0.359)**	1.102 (0.359)**
Housing cost ($/10^4)	-0.367 (0.0858)***	-0.367 (0.0858)***	-0.357 (0.0859)***	-0.37 (0.0858)***	-0.373 (0.0858)***	-0.357 (0.0858)***
Distance to primary food store	-0.0176 (0.0023)***	-0.0176 (0.0023)***	-0.0178 (0.0023)***	-0.0175 (0.0023)***	-0.0174 (0.0023)***	-0.0175 (0.0023)***
Rural residence	0.2329 (0.0274)***	0.2329 (0.0274)***	0.2497 (0.0274)***	0.2255 (0.0275)***	0.2235 (0.0275)***	0.2282 (0.0273)***
Food security status	-0.1016 (0.022)***	-0.1016 (0.022)***	-0.1001 (0.022)***	-0.1022 (0.022)***	-0.1028 (0.022)***	-0.1013 (0.022)***
WIC	0.5077 (0.0303)***	0.5077 (0.0303)***	0.5125 (0.0303)***	0.5083 (0.0303)***	0.5074 (0.0303)***	0.507 (0.0303)***
Supermarkets	-1.5117 (0.2778)***	-1.5117 (0.2778)***	-1.2986 (0.2749)***	-1.5638 (0.278)***	-1.5403 (0.2774)***	-1.4904 (0.2758)***
Non-supermarkets	-0.1971 (0.1061)	-0.1971 (0.1061)	-0.138 (0.1057)	-0.2062 (0.106)	-0.2207 (0.1064)*	-0.197 (0.1057)
Full-service restaurants	-0.3059 (0.0415)***	-0.3059 (0.0415)***	-0.28 (0.0417)***	-0.3045 (0.0413)***	-0.3088 (0.0414)***	-0.3231 (0.0416)***
Limited-service restaurants	0.9541 (0.0829)***	0.9541 (0.0829)***	0.8682 (0.0826)***	0.9501 (0.0819)***	0.9607 (0.0823)***	1.0037 (0.0833)***
Poverty rate	0.3167	0.3167	0.5518	0.4379	0.4434	0.3556

	(0.4476)	(0.4476)	(0.4477)	(0.4464)	(0.4464)	(0.4468)
Area-level household income	0 (0)***	0 (0)***	0 (0)***	0 (0)***	0 (0)***	0 (0)***
Area-level educational attainment	-1.8695 (0.2605)***	-1.8695 (0.2605)***	-2.1729 (0.26)***	-1.7595 (0.2621)***	-1.7669 (0.2618)***	-1.7169 (0.2609)***
Vehicle density	2.2086 (0.3779)***	2.2086 (0.3779)***	2.3684 (0.3767)***	2.2432 (0.3772)***	2.2095 (0.3776)***	2.1498 (0.378)***
Kitchen availability	-10.5467 (3.0318)**	-10.5467 (3.0318)**	-14.6418 (2.9472)***	-11.1081 (2.9653)***	-10.5699 (2.9884)***	-8.8552 (3.0319)**
SNAP participation	-0.0697 (0.0221)**	-0.0697 (0.0221)**	-0.0693 (0.0221)**	-0.0688 (0.0221)**	-0.0695 (0.0221)**	-0.0693 (0.0221)**
Intercept	56.5581 (2.9003)***	56.5581 (2.9003)***	60.7823 (2.8141)***	56.9579 (2.8315)***	56.4971 (2.8541)***	54.7214 (2.9032)***
Observations	230,323	230,323	230,323	230,323	230,323	230,323
R-squared	0.1487	0.1487	0.1486	0.1487	0.1487	0.1488

-: Ordinary least squares regressions testing hypothesis 2: that SNAP participation is associated with living in a lower cost of living area. Regressions include survey sample weights to account for differential sampling and response. * = p<0.05; ** = p<0.01; *** = p<0.001

	Change in probability of living in a high-cost area					
Cost of living metric for outcome	Overall RPP	Rent RPP	Food RPP	Good RPP	Services RPP	Geographic adjustment to the Supplemental Poverty Measure
Covariates						
Age	-0.0007 (0.0002)**	-0.0007 (0.0002)**	0.0001 (0.0002)	-0.0001 (0.0002)	-0.0002 (0.0002)	-0.0002 (0.0002)
Age squared	0 (0)**	0 (0)**	0 (0)	0 (0)	0 (0)	0 (0)
Sex (1=female)	0.0115 (0.0021)***	0.0115 (0.0021)***	0.0117 (0.0023)***	0.0068 (0.0021)**	0.009 (0.0021)***	0.0138 (0.0021)***
White race	-0.0054 (0.0029)	-0.0054 (0.0029)	0.0205 (0.0032)***	0.0046 (0.0029)	-0.0002 (0.0029)	-0.0119 (0.0029)***
Black race	-0.0165 (0.0036)***	-0.0165 (0.0036)***	0.0093 (0.004)*	0.0101 (0.0037)**	-0.0101 (0.0037)**	-0.02 (0.0036)***
Hispanic	-0.1165 (0.0028)***	-0.1165 (0.0028)***	-0.0608 (0.0031)***	-0.135 (0.0028)***	-0.1253 (0.0028)***	-0.1271 (0.0028)***
Education >= high school	0.0004 (0.0024)	0.0004 (0.0024)	0.0062 (0.0026)*	0.0014 (0.0024)	-0.0021 (0.0024)	-0.002 (0.0024)
Employed (1=yes)	-0.0058 (0.0021)**	-0.0058 (0.0021)**	-0.0123 (0.0024)***	-0.0077 (0.0022)***	-0.0085 (0.0022)***	-0.0089 (0.0022)***
Household size	0.0033 (0.0005)***	0.0033 (0.0005)***	-0.005 (0.0006)***	0.0029 (0.0005)***	0.0019 (0.0005)***	0.0042 (0.0005)***
Income ($/10^4)	-0.62 (0.0747)***	-0.62 (0.0747)***	-0.322 (0.0825)**	-0.496 (0.076)***	-0.46 (0.0758)***	-0.581 (0.0753)***
Housing cost ($/10^4)	0.0498 (0.0075)***	0.0498 (0.0075)***	0.101 (0.0082)***	0.0491 (0.0076)***	0.0521 (0.0076)***	0.0412 (0.0075)***
Distance to primary food store	-0.0017 (0.0002)***	-0.0017 (0.0002)***	-0.0046 (0.0003)***	-0.0018 (0.0003)***	-0.0019 (0.0002)***	-0.001 (0.0002)***
Rural residence	-0.1829 (0.0028)***	-0.1829 (0.0028)***	-0.1703 (0.0031)***	-0.1712 (0.0029)***	-0.1787 (0.0029)***	-0.1884 (0.0029)***
Food security status	0.009 (0.0019)***	0.009 (0.0019)***	-0.0109 (0.0021)***	0.0083 (0.002)***	0.0101 (0.002)***	0.0083 (0.002)***
WIC	0.0275 (0.0026)***	0.0275 (0.0026)***	0.0252 (0.0028)***	0.0152 (0.0026)***	0.0274 (0.0026)***	0.0301 (0.0026)***
Supermarkets	2.0403 (0.0282)***	2.0403 (0.0282)***	1.4664 (0.0311)***	2.1276 (0.0287)***	2.0222 (0.0286)***	1.7591 (0.0284)***
Non-supermarkets	0.4815 (0.0103)***	0.4815 (0.0103)***	0.3486 (0.0114)***	0.448 (0.0105)***	0.5125 (0.0104)***	0.3087 (0.0104)***
Full-service restaurants	0.25 (0.0045)***	0.25 (0.0045)***	0.3368 (0.005)***	0.2189 (0.0046)***	0.2502 (0.0046)***	0.276 (0.0046)***
Limited-service restaurants	-0.9057 (0.0084)***	-0.9057 (0.0084)***	-1.0491 (0.0093)***	-0.8327 (0.0086)***	-0.9014 (0.0085)***	-1.0018 (0.0085)***

Poverty rate	1.365 (0.045)***	1.365 (0.045)***	-0.5246 (0.0497)***	1.0621 (0.0458)***	1.0474 (0.0457)***	1.505 (0.0454)***
Area-level household income	0 (0)***	0 (0)***	0 (0)***	0 (0)***	0 (0)***	0 (0)***
Area-level educational attainment	-2.4975 (0.0246)***	-2.4975 (0.0246)***	-2.7909 (0.0271)***	-2.6542 (0.025)***	-2.6466 (0.0249)***	-2.4548 (0.0248)***
Vehicle density	0.8337 (0.0385)***	0.8337 (0.0385)***	-0.1663 (0.0425)***	0.7765 (0.0392)***	0.7916 (0.039)***	0.6883 (0.0388)***
Kitchen availability	-33.5129 (0.2834)***	-33.5129 (0.2834)***	-29.0668 (0.3131)***	-29.4001 (0.2885)***	-31.774 (0.2876)***	-34.0333 (0.2857)***
SNAP (1=participant)	-0.0049 (0.002)*	-0.0049 (0.002)*	0.0012 (0.0022)	-0.0118 (0.002)***	-0.0071 (0.002)***	-0.0034 (0.002)
Intercept	35.1516 (0.2676)***	35.1516 (0.2676)***	32.0741 (0.2957)***	31.4474 (0.2724)***	33.5628 (0.2716)***	35.8165 (0.2698)***
Observations	135,627	135,627	135,627	135,627	135,627	135,627
R-squared	0.5176	0.5176	0.4279	0.5073	0.5058	0.5127

Table 9: Ordinary least squares regressions testing hypothesis 3: that the relationship between SNAP participation and food acquisition is moderated by area cost of living. Subtables (A)-(H) correspond to food pattern equivalents of food categories 1 through 8 (vegetables through added sugars) as the outcome (in food pattern equivalents units), while subtable (I) corresponds to kilocalories per person per day as the outcome and (J) corresponds to the Healthy Eating Index as the outcome. Each table includes an interaction term for participation in SNAP interacted with living in a high-cost area, either by overall regional price parity as the metric of cost of living, or by food regional price parity as the metric of cost of living. All regressions include survey sample weights to account for differential sampling and response. * = p<0.05; ** = p<0.01; *** = p<0.001

(A)

Covariate	Change in acquisition of vegetables	
Cost of living metric	Overall RPP	Food RPP
Age	0.0267 (0.0013)***	0.0268 (0.0013)***
Age squared	-0.0002 (0)***	-0.0002 (0)***
Sex (1=female)	0.1063 (0.012)***	0.1054 (0.012)***
White race	0.0553 (0.0166)**	0.0559 (0.0166)**
Black race	-0.204 (0.0208)***	-0.2028 (0.0208)***
Hispanic	-0.2501 (0.0161)***	-0.2431 (0.0161)***
Education >= high school	-0.163 (0.0137)***	-0.1623 (0.0137)***
Employed (1=yes)	-0.0954 (0.0124)***	-0.0956 (0.0124)***
Household size	-0.188 (0.003)***	-0.1884 (0.003)***
Income ($/10^4)	1.249 (0.432)**	1.272 (0.432)**
Housing cost ($/10^4)	0.911 (0.0431)***	0.913 (0.0431)***
Distance to primary food store	0.0072 (0.0014)***	0.0072 (0.0014)***
Rural residence	0.2179 (0.0166)***	0.2096 (0.0165)***
Food security status	-0.0834 (0.0112)***	-0.0841 (0.0112)***

WIC	0.0588 (0.0149)***	0.0577 (0.0149)***
Supermarkets	-0.598 (0.1657)***	-0.7098 (0.1644)***
Non-supermarkets	-0.441 (0.0597)***	-0.4596 (0.0596)***
Full-service restaurants	-0.2206 (0.0266)***	-0.2314 (0.0267)***
Limited-service restaurants	0.1457 (0.0505)**	0.1856 (0.0507)***
Poverty rate	2.7404 (0.2614)***	2.6084 (0.2605)***
Area-level household income	0 (0)***	0 (0)***
Area-level educational attainment	-1.5401 (0.1463)***	-1.435 (0.1465)***
Vehicle density	0.3844 (0.2227)	0.321 (0.2226)
Kitchen availability	8.0199 (1.7048)***	9.6985 (1.6803)***
snap	-0.1352 (0.0121)***	-0.1233 (0.0121)***
SNAP-cost interaction	-0.0545 (0.0098)***	-0.0226 (0.0091)*
Intercept	-6.0353 (1.6247)***	-7.7546 (1.6012)***
Observations	135,627	135,627
R-squared	0.0684	0.0683

(B)

Covariate	Change in acquisition of fruits	
Cost of living metric	Overall RPP	Food RPP
Age	0.003 (0.0005)***	0.0029 (0.0005)***
Age squared	0 (0)	0 (0)
Sex (1=female)	0.0439 (0.005)***	0.0436 (0.005)***
White race	0.0373 (0.0069)***	0.0346 (0.0069)***
Black race	0.003 (0.0086)	0.0009 (0.0086)
Hispanic	0.1704 (0.0067)***	0.1684 (0.0067)***
Education >= high school	0.0786 (0.0057)***	0.0787 (0.0057)***
Employed (1=yes)	-0.064 (0.0051)***	-0.0636 (0.0051)***
Household size	-0.069 (0.0013)***	-0.0686 (0.0013)***
Income ($/10^4)	-022 (0.179)	-0.223 (0.179)
Housing cost ($/10^4)	0.454 (0.0179)***	0.451 (0.0179)
Distance to primary food store	0.0204 (0.0006)***	0.0206 (0.0006)***
Rural residence	-0.0877 (0.0069)***	-0.0903 (0.0068)***
Food security status	-0.1225 (0.0047)***	-0.1214 (0.0047)***
WIC	0.146 (0.0062)***	0.1458 (0.0062)***
Supermarkets	-0.5423 (0.0687)***	-0.5581 (0.0682)***
Non-supermarkets	0.2485 (0.0247)***	0.2481 (0.0247)***
Full-service restaurants	-0.0603 (0.011)***	-0.0714 (0.0111)***
Limited-service restaurants	0.0646 (0.0209)**	0.0939 (0.021)***
Poverty rate	1.2914 (0.1084)***	1.3705 (0.108)***
Area-level household income	0 (0)***	0 (0)***

Area-level educational attainment	0.4424 (0.0607)***	0.5121 (0.0607)***
Vehicle density	-0.2659 (0.0924)**	-0.2231 (0.0923)*
Kitchen availability	-5.4358 (0.7071)***	-5.0195 (0.6966)***
snap	0.0773 (0.005)***	0.0848 (0.005)***
SNAP-cost interaction	0.0279 (0.0041)***	0.043 (0.0038)***
Intercept	4.9826 (0.6739)***	4.4475 (0.6638)***
Observations	135,627	135,627
R-squared	0.0757	0.0763

(C)

Covariate	Change in acquisition of whole grains	
Cost of living metric	Overall RPP	Food RPP
Age	0.0108 (0.0019)***	0.0105 (0.0019)***
Age squared	-0.0001 (0)**	-0.0001 (0)**
Sex (1=female)	0.1643 (0.0174)***	0.1652 (0.0174)***
White race	-0.5929 (0.024)***	-0.5968 (0.0241)***
Black race	-0.7991 (0.0302)***	-0.8032 (0.0302)***
Hispanic	-0.623 (0.0234)***	-0.6351 (0.0233)***
Education >= high school	0.2685 (0.0199)***	0.2677 (0.0199)***
Employed (1=yes)	-0.3386 (0.018)***	-0.338 (0.018)***
Household size	-0.037 (0.0044)***	-0.036 (0.0044)***
Income ($/10^4)	7.213 (0.627)***	7.177 (0.627)***
Housing cost ($/10^4)	0.178 (0.0626)**	0.178 1 (0.0626)**
Distance to primary food store	0.0116 (0.0021)***	0.0119 (0.0021)***
Rural residence	-0.1123 (0.024)***	-0.1036 (0.024)***
Food security status	-0.2399 (0.0163)***	-0.2378 (0.0163)***
WIC	0.0626 (0.0216)**	0.064 (0.0216)**
Supermarkets	-1.6465 (0.2404)***	-1.5067 (0.2386)***
Non-supermarkets	0.8362 (0.0866)***	0.8619 (0.0864)***
Full-service restaurants	0.293 (0.0386)***	0.2958 (0.0388)***
Limited-service restaurants	-0.8946 (0.0733)***	-0.9181 (0.0736)***
Poverty rate	4.3844 (0.3792)***	4.6584 (0.3779)***
Area-level household	0 (0)***	0 (0)***

income		
Area-level educational attainment	0.8057 (0.2122)***	0.7355 (0.2125)**
Vehicle density	-5.044 (0.3231)***	-4.9071 (0.3229)***
drive	2.8652 (0.2106)***	2.7291 (0.2089)***
Kitchen availability	4.5716 (2.4731)	2.6744 (2.4376)
snap	0.0329 (0.0175)	0.0245 (0.0175)
SNAP-cost interaction	0.1078 (0.0142)***	0.0798 (0.0132)***
Intercept	-3.8055 (2.357)	-1.9835 (2.3228)
Observations	135,627	135,627
R-squared	0.0323	0.0321

(D)

Covariate	Change in acquisition of refined grains	
Cost of living metric	Overall RPP	Food RPP
Age	0.0922 (0.0041)***	0.0918 (0.0041)***
Age squared	-0.0009 (0)***	-0.0009 (0)***
Sex (1=female)	0.4 (0.0378)***	0.4058 (0.0378)***
White race	-0.0397 (0.0523)	-0.0359 (0.0524)
Black race	-0.2025 (0.0657)**	-0.2035 (0.0658)**
Hispanic	-0.7198 (0.0509)***	-0.7518 (0.0507)***
Education >= high school	-0.2587 (0.0434)***	-0.2628 (0.0434)***
Employed (1=yes)	-0.2832 (0.0392)***	-0.2835 (0.0392)***
Household size	-0.4309 (0.0096)***	-0.4298 (0.0096)***
Income ($/10^4)	-12.997 (1.364)***	-13.112 (1.365)***
Housing cost ($/10^4)	3.595 (0.136)***	3.593 (0.136)***
Distance to primary food store	0.1326 (0.0045)***	0.1323 (0.0045)***
Rural residence	-0.0337 (0.0523)	0.0181 (0.0522)
Food security status	-0.2878 (0.0355)***	-0.2869 (0.0355)***
WIC	0.1512 (0.0471)**	0.158 (0.0471)**
Supermarkets	-5.8804 (0.5234)***	-5.2388 (0.5194)***
Non-supermarkets	2.2466 (0.1884)***	2.3469 (0.1881)***
Full-service restaurants	0.0246 (0.0841)	0.1123 (0.0845)
Limited-service restaurants	0.1256 (0.1595)	-0.1678 (0.1601)
Poverty rate	7.5429 (0.8254)***	8.0345 (0.8226)***
Area-level household income	0 (0)***	0 (0)***
Area-level educational attainment	-0.4576 (0.4619)	-1.2093 (0.4626)**

Vehicle density	-1.0346 (0.7034)	-0.8112 (0.7029)
Kitchen availability	61.8326 (5.3835)***	51.7184 (5.3067)***
snap	1.1929 (0.0381)***	1.1084 (0.0381)***
SNAP-cost interaction	0.2157 (0.031)***	0.0041 (0.0287)
Intercept	-59.9126 (5.1306)***	-49.2575 (5.0566)***
Observations	135,627	135,627
R-squared	0.0501	0.0498

(E)

Covariate	Change in acquisition of dairy	
Cost of living metric	Overall RPP	Food RPP
Age	0.0118 (0.001)***	0.0116 (0.001)***
Age squared	-0.0001 (0)***	-0.0001 (0)***
Sex (1=female)	0.0136 (0.0095)	0.0152 (0.0095)
White race	0.2361 (0.0131)***	0.2332 (0.0131)***
Black race	-0.1962 (0.0164)***	-0.2001 (0.0164)***
Hispanic	-0.1595 (0.0127)***	-0.1744 (0.0127)***
Education >= high school	0.0963 (0.0108)***	0.0949 (0.0108)***
Employed (1=yes)	-0.1848 (0.0098)***	-0.1843 (0.0098)***
Household size	-0.1419 (0.0024)***	-0.1408 (0.0024)***
Income ($/10^4)	-2.288 (0.341)***	-2.334 (0.341)***
Housing cost ($/10^4)	0.937 (0.034)***	0.931 (0.034)***
Distance to primary food store	0.0324 (0.0011)***	0.0326 (0.0011)***
Rural residence	0.0255 (0.0131)	0.0399 (0.013)**
Food security status	-0.0841 (0.0089)***	-0.082 (0.0089)***
WIC	0.0891 (0.0118)***	0.0912 (0.0118)***
Supermarkets	-1.4844 (0.1307)***	-1.2773 (0.1298)***
Non-supermarkets	0.3349 (0.0471)***	0.3707 (0.047)***
Full-service restaurants	-0.2546 (0.021)***	-0.2409 (0.0211)***
Limited-service restaurants	0.1634 (0.0398)***	0.105 (0.04)**
Poverty rate	0.3703 (0.2062)	0.6787 (0.2056)**
Area-level household income	0 (0)***	0 (0)***
Area-level educational	2.3557 (0.1154)***	2.1971 (0.1156)***

attainment		
Vehicle density	1.5702 (0.1757)***	1.7215 (0.1756)***
Kitchen availability	18.4356 (1.3447)***	15.4456 (1.326)***
snap	0.2523 (0.0095)***	0.234 (0.0095)***
SNAP-cost interaction	0.1242 (0.0077)***	0.0722 (0.0072)***
Intercept	-18.6849 (1.2816)***	-15.6937 (1.2636)***
Observations	135,627	135,627
R-squared	0.0857	0.0846

(F)

Covariate	Change in acquisition of protein	
Cost of living metric	Overall RPP	Food RPP
Age	0.1251 (0.0036)***	0.1252 (0.0036)***
Age squared	-0.0012 (0)***	-0.0012 (0)***
Sex (1=female)	-0.1747 (0.0336)***	-0.1754 (0.0336)***
White race	-0.0035 (0.0465)	-0.0004 (0.0465)
Black race	0.3895 (0.0584)***	0.3927 (0.0584)***
Hispanic	-0.3263 (0.0452)***	-0.3177 (0.0451)***
Education >= high school	-0.0518 (0.0386)	-0.0513 (0.0386)
Employed (1=yes)	-0.9609 (0.0348)***	-0.9614 (0.0349)***
Household size	-0.5795 (0.0085)***	-0.5803 (0.0085)***
Income ($/10^4)	-3.287 (1.213)**	-3.262 (1.213)**
Housing cost ($/10^4)	2.005 (0.121)***	2.01 (0.121)***
Distance to primary food store	0.0312 (0.004)***	0.0309 (0.004)***
Rural residence	0.4975 (0.0465)***	0.4919 (0.0464)***
Food security status	0.0134 (0.0315)	0.0117 (0.0315)
WIC	0.1583 (0.0419)***	0.1574 (0.0419)***
Supermarkets	3.0403 (0.4652)***	2.9468 (0.4615)***
Non-supermarkets	-0.6213 (0.1675)***	-0.6389 (0.1671)***
Full-service restaurants	0.5449 (0.0747)***	0.545 (0.0751)***
Limited-service restaurants	-0.257 (0.1417)	-0.2462 (0.1423)
Poverty rate	16.5517 (0.7337)***	16.3483 (0.731)***
Area-level household income	0 (0)***	0 (0)***

Area-level educational attainment	2.3642 (0.4106)***	2.3998 (0.4111)***
Vehicle density	-0.6527 (0.6252)	-0.755 (0.6246)
drive	1.9179 (0.4075)***	2.0132 (0.4042)***
Kitchen availability	34.3474 (4.7849)***	35.5805 (4.7158)***
snap	0.9302 (0.0338)***	0.9347 (0.0338)***
SNAP-cost interaction	-0.0795 (0.0276)**	-0.0629 (0.0255)*
Intercept	-36.5534 (4.5602)***	-37.7128 (4.4936)***
Observations	135,627	135,627
R-squared	0.0861	0.0861

(G)

Covariate	Change in acquisition of fats and oils	
Cost of living metric	Overall RPP	Food RPP
Age	1.2836 (0.0483)***	1.2793 (0.0483)***
Age squared	-0.0116 (0.0006)***	-0.0115 (0.0006)***
Sex (1=female)	8.5377 (0.4471)***	8.5813 (0.4472)***
White race	0.6779 (0.6185)	0.658 (0.619)
Black race	8.0296 (0.7769)***	7.9796 (0.7771)***
Hispanic	-12.2177 (0.6013)***	-12.5304 (0.5991)***
Education >= high school	2.731 (0.5128)***	2.6981 (0.5128)***
Employed (1=yes)	-8.4309 (0.4634)***	-8.4263 (0.4634)***
Household size	-6.0662 (0.1134)***	-6.049 (0.1134)***
Income ($/10^4)	64.691 (16.125)***	63.65 (16.126)***
Housing cost ($/10^4)	36.18 (1.609)***	36.10 (1.61)***
Distance to primary food store	1.6262 (0.053)***	1.6277 (0.0531)***
Rural residence	2.4528 (0.6183)***	2.8424 (0.6164)***
Food security status	-3.5758 (0.4193)***	-3.5475 (0.4194)***
WIC	0.5354 (0.5569)	0.5891 (0.5569)
Supermarkets	-26.4108 (6.1854)***	-21.2379 (6.1372)**
Non-supermarkets	17.4438 (2.2265)***	18.2934 (2.2226)***
Full-service restaurants	0.882 (0.9937)	1.4132 (0.9982)
Limited-service restaurants	-9.7655 (1.8845)***	-11.695 (1.8922)***
Poverty rate	100.6032 (9.7546)***	106.3655 (9.7211)***
Area-level household income	0.0003 (0)***	0.0004 (0)***
Area-level educational attainment	47.6844 (5.4591)***	42.6326 (5.466)***
Vehicle density	-19.2996 (8.3124)*	-16.5467 (8.3057)*
Kitchen availability	389.0452 (63.6202)***	310.7975 (62.7095)***
snap	15.6823 (0.4499)***	15.1086 (0.4501)***

SNAP-cost interaction	2.3946 (0.3664)***	0.8837 (0.3387)**
Intercept	-417.3511 (60.6323)***	-336.8238 (59.7551)***
Observations	135,627	135,627
R-squared	0.0881	0.0879

(H)

Covariate	Change in acquisition of added sugars	
Cost of living metric	Overall RPP	Food RPP
Age	0.5216 (0.0183)***	0.5206 (0.0183)***
Age squared	-0.0058 (0.0002)***	-0.0058 (0.0002)***
Sex (1=female)	2.7438 (0.1693)***	2.7491 (0.1693)***
White race	3.0518 (0.2342)***	3.0349 (0.2344)***
Black race	4.8005 (0.2942)***	4.7817 (0.2942)***
Hispanic	-3.876 (0.2277)***	-3.936 (0.2268)***
Education >= high school	0.0915 (0.1942)	0.0868 (0.1941)
Employed (1=yes)	-3.1789 (0.1754)***	-3.1762 (0.1755)***
Household size	-1.4775 (0.0429)***	-1.4726 (0.0429)***
Income ($/10^4)	-25.384 (6.106)***	-25.565 (6.105)***
Housing cost ($/10^4)	6.475 (0.609)***	6.456 (0.609)***
Distance to primary food store	0.5469 (0.0201)***	0.5482 (0.0201)***
Rural residence	1.7875 (0.2341)***	1.8355 (0.2334)***
Food security status	-1.5852 (0.1588)***	-1.5753 (0.1588)***
WIC	-3.0214 (0.2109)***	-3.014 (0.2108)***
Supermarkets	5.7006 (2.3421)*	6.4404 (2.3236)**
Non-supermarkets	8.0486 (0.843)***	8.1813 (0.8415)***
Full-service restaurants	-4.3931 (0.3763)***	-4.366 (0.3779)***
Limited-service restaurants	-3.2527 (0.7136)***	-3.4074 (0.7164)***
Poverty rate	31.4413 (3.6935)***	32.7657 (3.6804)***
Area-level household income	0 (0)***	0.0001 (0)***
Area-level educational attainment	8.1859 (2.067)***	7.7441 (2.0694)***
Vehicle density	-8.2539 (3.1474)**	-7.5955 (3.1445)*
Kitchen availability	107.9243 (24.0892)***	97.6518 (23.7418)***
snap	5.6182 (0.1703)***	5.566 (0.1704)***
SNAP-cost	0.5247 (0.1388)***	0.363 (0.1282)**

interaction		
Intercept	-110.3159 (22.9579)***	-100.2963 (22.6232)***
Observations	135,627	135,627
R-squared	0.0758	0.0758

(I)

Covariate	Change in kilocalories/person/day	
Cost of living metric	Overall RPP	Food RPP
Age	37.4988 (1.2033)***	37.3395 (1.2033)***
Age squared	-0.3656 (0.0142)***	-0.3639 (0.0142)***
Sex (1=female)	164.001 (11.1319)***	164.9818 (11.132)***
White race	80.5028 (15.3961)***	78.3529 (15.4092)***
Black race	104.6139 (19.2504)***	100.8695 (19.2516)***
Hispanic	-349.8915 (14.9167)***	-357.3436 (14.8752)***
Education >= high school	53.8587 (12.7669)***	53.2153 (12.768)***
Employed (1=yes)	-262.3515 (11.5309)***	-261.7551 (11.5323)***
Household size	-187.9727 (2.8225)***	-187.3265 (2.823)***
Income	-0.0343 (0.0401)	-0.0365 (0.0401)
Housing cost	0.1066 (0.004)***	0.1064 (0.004)***
Distance to primary food store	42.0453 (1.3207)***	42.1828 (1.3216)***
Rural residence	68.3213 (15.319)***	77.076 (15.2507)***
Food security status	-125.2916 (10.4339)***	-123.7915 (10.436)***
WIC	5.3686 (13.8621)	6.7269 (13.8617)
Supermarkets	-461.4209 (151.9407)**	-368.0763 (151.0981)*
Non-supermarkets	701.3832 (54.6747)***	714.1627 (54.6359)***
Full-service restaurants	-213.851 (22.6361)***	-200.1242 (22.6236)***
Limited-service restaurants	-49.6616 (43.7776)	-91.0862 (43.5921)*
Poverty rate	3186.945 (237.0871)***	3404.771 (235.3594)***
Area-level household income	0.0074 (0.0009)***	0.0086 (0.0008)***
Area-level educational attainment	1180.219 (135.8952)***	1102.95 (136.0946)***
Vehicle density	619.1396 (99.3471)***	571.6953 (99.2529)***

Kitchen availability	16412.4 (1578.274)***	14713.96 (1551.604)***
snap	431.6374 (11.1895)***	422.7793 (11.2035)***
Snap-cost interaction	70.4185 (9.024)***	44.5117 (8.4075)***
Intercept	-16838.61 (1499.23)***	-15121.55 (1471.873)***
Observations	135,627	135,627
R-squared	0.1077	0.1075

(J)

Covariate	Change in HEI score	
Cost of living metric	Overall RPP	Food RPP
Age	0.3021 (0.003)***	0.302 (0.003)***
Age squared	-0.0029 (0)***	-0.0029 (0)***
Sex (1=female)	0.956 (0.0278)***	0.9566 (0.0278)***
White race	-0.6208 (0.0384)***	-0.6222 (0.0384)***
Black race	0.2403 (0.0482)***	0.2387 (0.0482)***
Hispanic	0.3151 (0.0373)***	0.3093 (0.0372)***
Education >= high school	0.1632 (0.0318)***	0.1627 (0.0318)***
Employed (1=yes)	0.3715 (0.0288)***	0.3717 (0.0288)***
Household size	-0.0166 (0.007)*	-0.0161 (0.007)*
Income ($/10^4)	-1.545 (1.001)	-1.562 (1.001)
Housing cost ($/10^4)	-0.399 (0.0999)***	-0.402 (0.0999)***
Distance to primary food store	-0.0137 (0.0033)***	-0.0136 (0.0033)***
Rural residence	0.1918 (0.0384)***	0.1968 (0.0383)***
Food security status	-0.1168 (0.026)***	-0.1159 (0.026)***
WIC	0.4287 (0.0346)***	0.4295 (0.0346)***
Supermarkets	-2.0617 (0.3839)***	-1.986 (0.3809)***
Non-supermarkets	-0.4681 (0.1382)**	-0.4547 (0.1379)**
Full-service restaurants	-0.3384 (0.0617)***	-0.3345 (0.0619)***
Limited-service restaurants	0.8095 (0.117)***	0.7909 (0.1174)***
Poverty rate	-3.4832 (0.6055)***	-3.3591 (0.6033)***
Area-level household income	0 (0)*	0 (0)*
Area-level	-1.7552	-1.8067

educational attainment	(0.3388)***	(0.3392)***
Vehicle density	0.6007 (0.5159)	0.662 (0.5155)
Kitchen availability	-27.8803 (3.9488)***	-28.9513 (3.8918)***
snap	-0.118 (0.0279)***	-0.124 (0.0279)***
Snap-cost interaction	0.0495 (0.0227)*	0.0318 (0.021)
Intercept	75.3744 (3.7634)***	76.4328 (3.7085)***
Observations	135,627	135,627
R-squared	0.1645	0.1644

Figure 1: Distributions of the cost of living, as measured by overall regional price parities for the year 2012, among participants in the National Household Food Acquisition and Purchase Survey (2012-2013), by Supplemental Nutrition Assistance Program (SNAP) participation status and income level. Legend: SNAP = SNAP participants, Lo-inc non-SNAP = non-participants <185% of the federal poverty level, and Hi-inc non-SNAP = non-participants >=185% of the federal poverty level.

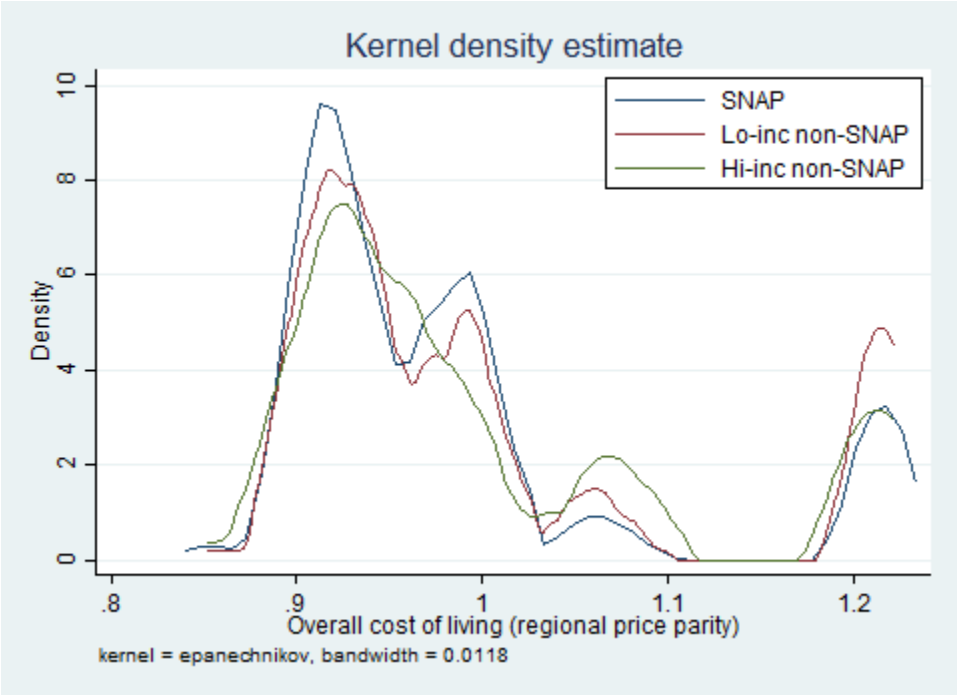

Figure 2: Subgroup analyses of the association between living in a high cost-of-living area (as defined by the overall regional price parity) and change in the Healthy Eating Index (HEI) 2010 score among SNAP participants, non-participants below 185% of the federal poverty threshold, and non-participants above 185% of the federal poverty threshold. A decline in HEI score indicates a worse nutrition profile; the mean HEI score in the analytical sample was 55, and the range of possible HEI scores is 0 (worst) to 100 (best). Legend: RPP = regional price parity; Geoadj SPM = geographical adjustment to the Supplemental Poverty Measure.

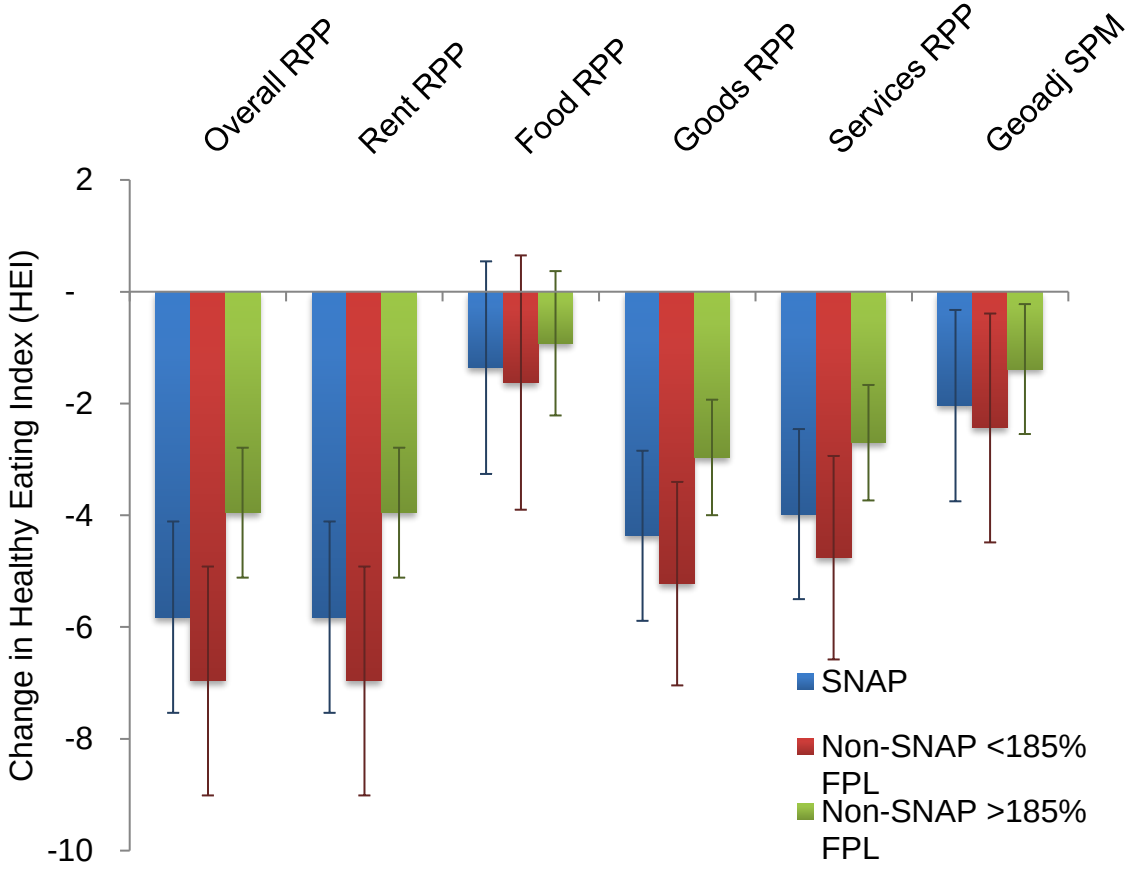

Figure 3: Interactions between SNAP participation and cost of living when the outcome of interest is the Healthy Eating Index-2010 score. Estimates are from an endogenous treatment effects parameter, estimating the average treatment effect of SNAP. Cost of living at the area (county) level is defined by the overall regional price parity, where high-cost is one standard deviation above the mean.