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How do food retail choices vary within and between food retail environments?☆,☆☆

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ABSTRACT

There is mixed evidence on whether the local food environment explains differences in food choices. It is valuable in such research to use strong research designs, taking account of the endogeneity of household residential decisions. This article offers a literature review, emphasizing two promising approaches in the most recent research: (1) longitudinal studies of supermarket or retailer entry and exit within particular locations and (2) studies of variation in food choices across multiple households within particular locations. We review how these approaches address the endogeneity problem. Because this literature review indicates the importance of understanding variation across households within locations, our empirical analysis uses nationally representative data from USDA's National Household Food Acquisition and Purchase Survey (FoodAPS) to measure the expected values, variances, and intracluster correlations for selected outcome variables and explanatory variables typical of those used in studies of the food retail environment. We find that geographic variation in supermarket proximity does not account for most of the variation of a household's choice of a primary food retailer and does not account for much of the high-level of variation across households in food security and dietary quality. These results and our review of the literature suggest that food store access may modestly influence food choices, but that other household-level factors may matter more.

1. Introduction

A vibrant research literature has explored the relationship between food retail environments and household-level and individual-level food outcomes, ranging from food spending to fruit and vegetable intake to body weight and body mass index. Early studies, which were mostly cross-sectional and often studied fairly localized populations, largely showed a positive correlation between access to supermarkets and healthier diets and less obesity (see Larson et al., 2009, and Institute of Medicine and National Research Council, 2009 for reviews of these studies). In 2009, the U.S. Department of Agriculture released a Congressionally-mandated report that examined how limited access to supermarkets may impact food choices, diet and health and estimated the national number of people who may have limited access to healthy food (USDA, 2009). The study also highlighted key household, demand-side and key market, supply-side factors which may explain how store access affects food choice, diet and health. Household factors include resources, access to transportation, time constraints and preferences, while market factors include store development costs, retail competition, and aggregate consumer demand. Early studies largely relied on neighborhood measures of store density or distance to the nearest store to measure access, under the assumption that households are constrained by their hyper-local food environment.

Researchers have more recently suggested that the early research suffered from an endogeneity problem, because residential location is itself in part a choice variable, and some people may consider the quality of their food retail environment as a factor in residential decisions. The cross-sectional association between a particular retail access measure (such as being in a supermarket desert) and a particular outcome (such as elevated body weight) might not reflect cause and effect. Moreover, characteristics of the food retail environment may be associated with confounding variables, both observable (such as being in a low-income neighborhood) and unobservable (such as being in a neighborhood where food quality and access are comparatively more highly or less highly valued, for idiosyncratic reasons).

This article offers a literature review and empirical analysis. The literature review emphasizes two promising approaches in the most recent research: (1) longitudinal studies of supermarket or retailer entry

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and exit within particular locations and (2) studies of variation in food choices across multiple households within particular locations. We review how these approaches may address the endogeneity problem. Each approach, in its own way, makes use of variation in particular variables within locations. In approach (1), the key feature is that food retail conditions and food outcomes vary within particular locations, over a time period that is sufficiently short that the endogeneity of household residential decisions is not a major problem. The household population is largely held constant before and after the change in retail conditions. In approach (2), the key feature is that food choices and other outcomes vary across households within a particular place. If the variance in food choices within locations is sufficiently great, it may suggest that factors other than the food retail environment are most important.

Because the literature review indicates the importance of understanding variation across households within locations, our empirical analysis uses nationally representative data from USDA's National Household Food Acquisition and Purchase Survey (FoodAPS) (Economic Research Service, 2017) to measure the expected values, variances, and intracluster correlations for selected outcome variables and explanatory variables typical of those used in studies of the food retail environment. The empirical question is, to what extent do key determinants of food spending and consumption outcomes vary across food environments, and to what extent do they vary across households that share the same food environment?

The article is organized as follows. First, we consider the types of variation across locations and across households that one would expect to see for key explanatory factors in research on the food retail environment. Second, we provide a review of the research literature, focusing on studies that offer a strong research design with promise for addressing the endogeneity challenge. Third, we offer the empirical analysis using FoodAPS data.

2. Classification of environmental and household factors

In conceptual frameworks explicitly or implicitly used in research on food retail environments, food retail characteristics may influence shopping behavior and food spending outcomes, which in turn may influence dietary quality and household food security. This article focuses on the ways that these factors vary across and within neighborhoods, because this variation is important in new research approaches that offer promise for measuring the effect of food retail environments. Here, we systematically classify the potential environmental and household factors according to the types of variation one would expect (Fig. 1). We use the mnemonic GRAPH-M, for the first letters of the following six classes of potentially relevant explanatory variables.

The first two classes describe food retail access qualities, which are expected to vary across locations, but not to vary within locations:

1. (G) Geographic access to retailers (distance to supermarkets and other food retailers)
2. (R) Restaurant food environment (as a competitor or alternative to food retailers)

The third class describes automobile access, an explanatory variable that still is connected to food retail access (as in the previous 2 classes), and yet may vary across households in the same location (as in the later classes):

3. (A) Automobile access (acceptable distance varies with automobile access)

The final three classes are expected to exhibit considerable variation across households within geographic locations:

4. (P) Prices (and price incentives)
5. (H) Household resources for food purchases (income and nutrition assistance benefits)
6. (M) Motivation or preferences.

Average prices in principle may vary across geographic locations, and hence one might alternatively have placed prices among the food retail access variables in the top left box of Fig. 1. In practice, we anticipate that prices paid vary within geographic locations for four reasons: price variation over time is an important component of total price variation; households may strike different tradeoffs between convenience and cost when selecting retailers; the option set of prices in the surrounding environment depends on automobile access or perhaps the ability to take advantage of price discounts because of sales or being able to buy (and store) food in bulk; and some of the most policy-relevant sources of price variation are incentive programs or nutrition assistance initiatives that may vary across households, as in USDA's Healthy Incentive Pilot (Bartlett et al., 2014). In the canonical models of consumer food choices used by economists, prices and household resources have a central role in the budget constraint; motivation and preferences determine food choices from among those options that can be afforded.

In summary, food spending and consumption choices depend in part on neighborhood-level or environment-level factors, in part on household-level constraints, and in part on household level preferences. Most existing research acknowledges or addresses some of these factors, while necessarily giving less attention to others. In analysis, it may be useful to distinguish these factors more formally.

3. Research on neighborhood- and household-factors that influence food choices

Several factors determined the scope of our review of the food

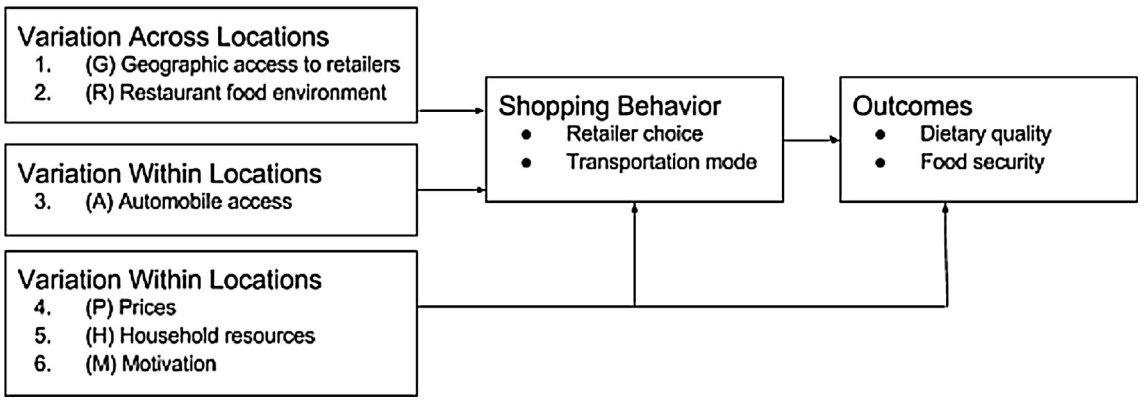

Fig. 1. The conceptual relationship between explanatory factors in the GRAPH-M classification and food shopping, food security, and dietary quality outcome variables.

Table 1
Study methodologies and findings.

Authors and Year	Design and methods[a]	Findings: general and within geographic locations	Which factors were examined?[b]					
			G	R	A	P	H	M
Quasi-experimental studies with new supermarket opening								
Cummins et al. (2014)	Pre/post in 2 neighborhoods, one of which had a new supermarket (SM). Intention to treat analysis; also compares those who did and did not adopt new supermarket.	General: No changes in fruit (F) & vegetable (V) intake or BMI. Effectiveness of new supermarket unclear. Improved perceptions of food access. Within: Observes a single neighborhood in two different circumstances (before and after new supermarket opening). Observes households that did (27%) and did not (73%) adopt the new supermarket. Among adopters, no change in BMI or intake of fruits and vegetables. Improved perception of F & V accessibility.	x		x		x	x
Dubowitz et al. (2015)	Pre/post in 2 neighborhoods, one of which had a new supermarket. Intention to treat analysis. Within neighborhood with new store, compares regular users of the new supermarket to non-users.	General: Improved satisfaction with neighborhood and perception of access to healthy food. Diet quality improvements: fewer calories consumed, less added sugar and fewer calories from solid fat, alcohol, and added sugar. No change in consumption of fruits, vegetables, and whole grains. Within: Observes a single neighborhood in two different circumstances (before and after new supermarket opening). Observes households that did and did not adopt the new supermarket. No difference in BMI or diet quality between regular store users and non-users in the treatment neighborhood. Regular users of the store perceived better access to healthy foods.	x		x		x	x
Studies examining store access and other factors influencing food demand								
Allcott et al. (2015)	Cross-sectional comparison of consumers across measures of store access. Analysis of panel of consumers over multiple time periods as stores enter and exit.	General: No effect of the healthfulness of purchases after a big store entered the area of the consumer. New store reduced travel costs. Within: Controlling for the census tract explains only a small part of difference in healthfulness across consumer income levels. Entry/exit of store shows that only 8% of difference in healthfulness of foods purchased across income levels is due to store supply. Most differences due to demand-side factors.	x		x	x	x	x
Chen et al. (2010)	Cross sectional data from Marion County, IN. Spatial lag models to account for spatial autocorrelation.	General: Increased access to chain grocers decreased BMI modestly.	x				x	x
Dunn et al. (2012)	Cross-sectional econometric model using survey data from the Brazos Valley region of Texas, with distance to major roadway as an instrument for fast food restaurant availability.	General: No effect of fast food availability on consumption or obesity for overall population. Within: Among non-whites, fast food availability is associated with greater consumption of fast food and greater probability of being obese.		x			x	
Handbury et al. (2016)	Cross-sectional analysis of expenditure shares of food groups and nutrient scores of purchases by consumers with income > median to those < median. Analysis of panel of consumers over multiple time periods as stores enter and exit.	General: Median income of a census tract is positively associated with store concentration. Census tract education measures have a negligible relationship with store concentration. Within: Controlling for the county explains about 1/3rd of differences in nutritional quality between high and low income households and controlling for census tract explains about 1/3rd of the difference. Controlling for the exact store where consumers shop explains 50% of the disparity across income. Healthfulness of food purchases are only minimally responsive to store exit/entry.	x			x	x	x
Kyureghian et al. (2012)	Longitudinal analysis of panel of consumers. Fixed and random effects.	General: No association between SM density and F&V purchases. Household income had a modest and positive effect on F & V purchases and a small but positive association on F & V purchases when income was interacted with store density.	x	x		x	x	x
Lin et al. (2014)	Cross-sectional comparison of households with easy, difficult, and very difficult access based on time it takes to get to their usual store and the type of store. Estimated demand system for 13 food groups.	General: Does not compare across geographical areas, but across households with different access levels. Within: SNAP households with very difficult access spend a larger share of their food budget on canned meat and less on beverages than those with easy access. SNAP households with difficult access spend less on non-canned fruit and vegetables, non-canned meat, canned fruit and vegetables, and milk products than those with easy access. Food prices had greater explanatory power of food group purchases.				x	x	x

(*continued on next page*)

Table 1 (*continued*)

Authors and Year	Design and methods[a]	Findings: general and within geographic locations	Which factors were examined?[b]					
			G	R	A	P	H	M
Rahkovsky and Snyder (2015)	Cross-sectional comparison of demand for 14 food groups among consumers with different levels of store access based on census tract level measures from ERS.	General: Living in a low-income low-access area (LILA) is associated with a less healthy diet; 4.3% fewer fruits, 2.4% fewer vegetables; 8.5% more red meat; 10.4% less low-fat milk, 5.2% more diet drinks; and 2.6% more nondiet drinks. Within: Other demographic factors have bigger effect on healthfulness of purchased food (presence of young children, race, education, rurality).	x			x	x	x
Longitudinal studies on the influence of store access on diet quality and health								
Block et al. (2011)	Fixed & random effects estimates of distance to nearest and nearest 5 food stores or restaurants by type on BMI.	General: Supermarket distance had no effect on BMI. Grocery store distance was negatively associated with BMI. Fast food restaurant distance was negatively associated with BMI overall and for women, but there was no association for men.	x	x				x
Boone-Heinonen et al. (2011)	Fixed & random effects estimates of diet quality, whether the individual met the fruit and vegetable recommendation, and times consumed fast food per week.	General: Fast food consumption positively related to fast food availability among low-income consumers, particularly men. Supermarket availability not related to diet quality or F & V intake. Grocery store availability negatively related to diet quality for higher-income women, but positively related to diet quality for low-income men.	x	x			x	x
Lee (2012)	Cross-classified random effects (e.g. individual, school and neighborhood level random effects) using longitudinal data on a cohort of kindergartners.	General: The availability of SM, convenience stores, corner stores, fast food outlets, or other restaurants was not associated with BMI.	x	x			x	x
Powell and Chaloupka (2009)	Longitudinal, fixed effects analysis using children in the Panel Study of Income Dynamic's Child Development Supplement.	General: Among low income children, there was a small negative effect of SM availability and BMI. There was also a negative effect of full service restaurants availability on BMI.	x	x		x	x	x
Stern et al. (2016)	Longitudinal, random effects. Compares nutrition of prepared food product (PFP) purchases by types of stores usually shopped in.	General: Not much difference in dietary quality of purchases across the three store-type clusters. Within: Variation across race/ethnicity in dietary quality of purchases existed regardless of store-shopper-type. Non-Hispanic African American purchased food with higher energy density, sugar, and sodium than non-Hispanic white and Hispanic; also higher share of beverages from SSB and juice, but lower from milk.					x	x
Thomsen et al., (2015)	Longitudinal data on Arkansas schoolchildren and their BMI in kindergarten, 1st, 2nd and 4th grades. Fixed effects estimates. Also examines exposure to food deserts and uses diff-in-diff for children who change food desert status.	General: Children in food deserts (both low-income and low-access areas) have slightly higher BMI. When just considering only the access level of the area (regardless of the income of the area), the effects are not significantly different from zero. The diff-in-difference estimates show that those who switched to a food desert (both low-income and low-access area) had higher BMI and those who switched from a food desert had lower BMI.	x	x			x	

Notes:

[a] SM = Supermarket, F = Fruits, V = Vegetables.

[b] G = Geographic access, R = Restaurant food environment, A = Automobile access, P = Food prices, H = Household resources, M = Motivation/preferences.

environment access literature within the U.S. We build upon previous broad reviews of the literature published in 2009 (Larson et al., 2009; Institute of Medicine and National Research Council, 2009; USDA, 2009). Many studies published since those reviews could be considered second generation studies in that they go beyond correlational relationships and attempt to discern more causal effects of the food environment with data and measurement improvements. The studies we review in greatest detail also address at least some of the 'within' geographic area factors such as automobile access, prices, household resources, and motivation, which are likely to affect food choices and that were previously understudied.

Table 1 summarizes the selected studies, including the broad design and methods used, the findings of the study generally for geographic variables and those findings that apply to the factors that vary within geography. The right-most columns indicate whether the study addressed the different GRAPH-M factors defined in the preceding section. These studies are roughly grouped by their designs and methods. We include studies that have exclusively examined body weight outcomes in Table 1, but do not discuss weight outcomes in great detail. Compared with spending outcomes, body weight is inherently a more distal potential outcome of the food environment as well as many other potential confounding factors. More details on the studies reviewed are provided in Appendix A.

3.1. Quasi-experimental studies with new supermarket opening

Two studies, in Philadelphia (Cummins et al., 2014) and Pittsburgh (Dubowitz et al., 2015), used a quasi-experimental design to measure changes in food outcomes after a new supermarket was introduced, using a similar neighborhood without a new supermarket for comparison. These studies pay attention to variation within geographic areas in two respects: (a) the studies observe each location under two food retail conditions (before and after the new supermarket opened), and (b) the studies compare food outcomes for households that did or did not become regular users of the new supermarket. In both cases, the authors noted how this design sought in principle to address the endogeneity challenge. The introduction of the new supermarket was plausibly treated as exogenous to the residence location decision for people who already lived in the neighborhood. Moreover, many of the potential unobservable confounding variables are plausibly unchanged in the implementation period.

These studies showed either no effects of supermarket access on diet quality (based either on food spending among food groups or food intake) or a small effect. In both of the studies, there was no difference in fruit and vegetable or whole grains consumption between households in the treatment area compared with those in the control area (Cummins et al., 2014; Dubowitz et al., 2015). In Pittsburgh, households in the treatment area consumed relatively fewer calories and fewer calories from solid fats, alcohol and added sugars, but this difference did not seem to be tied to regular use of the new supermarket. In both studies, the perceptions of the food environment improved in the treatment areas.

Both studies compared diet quality of households that shopped at the new store relative to households in those neighborhoods who did not regularly shop at the new store. In both cases, there were no significant differences in the fruit and vegetable intake of regular store users and non-users.

3.2. Store access and other factors influencing food demand

Several new studies used longitudinal data on consumer food purchases, principally from Nielsen's Homescan panel. Two of these studies focused on distinguishing explanatory variables at the neighborhood level from within-neighborhood variation in household characteristics, resources, or motivation. Allcott et al. (2015) find that only a small percentage of the difference in the healthfulness of foods purchased can be explained by controlling for the census tract in which surveyed households live. Handbury et al. (2016) find that of the differences in nutritional quality of purchases between low and high income households, about one-third can be explained by county controls and by another third when census tracts controls are included. However, when low and high income households shop in the same store, about 50 percent of the difference between low- and high-income shoppers remains—meaning about half can be explained by factors other than access and observed household characteristics. Handbury et al. (2016) also observes changes in the healthfulness of household food purchases after changes in the retail environment and found that the healthfulness of households are only minimally responsive to changes.

Kyureghian et al. (2012) found that household income had a modest and positive effect on purchases of fruits and vegetables, but also that living in a higher income area with greater supermarket density had an additional impact on fruit and vegetable purchases, although this effect was small. This analysis did not specifically study variation across households within a geographic location or within customers of a particular retailer.

These studies each explicitly noted the endogeneity challenge with cross-sectional comparisons and explained their strategy for overcoming it using longitudinal data. Allcott et al. (2015) and Handbury et al. (2016) both investigated changes in outcomes associated with food retail entry and exit. Moreover, both studies used within-neighborhood and within-retailer variation to argue that, at the very least, neighborhood characteristics cannot explain a large fraction of the variation in outcomes.

Rahkovsky and Snyder (2015) find that presence of young children, race, education, and rurality provide more explanatory power in determining demand for specific food groups than supermarket access. Lin et al. (2014) find that food prices and education explain more of the differences in food groups demanded.

Dunn et al. (2012) used distance to nearby major roadway as an instrument for availability of fast-food restaurants. The reasoning is that distance to a nearby major roadway may be associated with restaurant location decisions, which in turn influence food outcomes. However, to be a valid instrument, distance to a major roadway would have to be uncorrelated with the main study outcome through pathways other than the availability of fast-food restaurants. If the presence of major roadways is associated with other variables that influence both residential choices and food outcomes, then presence of roadways would not be a useful instrumental variable.

3.3. Longitudinal studies of the influence of store access on diet quality and health

A number of studies have utilized longitudinal data to investigate how food store access affects food intake and body mass index (BMI). These studies differ from the food demand panel studies not only in the outcomes studied, but also in that they cannot observe where households shop for food relative to the stores in their neighborhoods. The studies instead rely on measures of distance to the nearest store, by type, or store density, by type.

Except for the Stern et al. (2016) study, each of the longitudinal studies uses fixed or random effects at the household. These studies have largely found no effect of supermarket access on diet quality or BMI (Block et al., 2011; Boone-Heinonen et al., 2011; Lee, 2012) or a small negative effect of supermarket availability and BMI (Powell and Chaloupka, 2009; Thomsen et al., 2015). Random effects models still require an assumption that the explanatory variable is exogenous, while the fixed effects models used in at least some specifications (Block et al., 2011; Boone-Heinonen et al., 2011; Powell and Chaloupka, 2009; Thomsen et al., 2015) offer more hope of controlling for endogenous unobserved confounding variables, if they are constant over time.

Stern et al. (2016) differs from the other studies in that it uses information on the types of stores at which households usually shop to

classify shoppers into types. The outcome of interest is the nutrient content of prepared food products (PFPs– foods and beverages with barcode and nutrition information) purchased by 3 shopper types—shoppers who mostly use chain supermarkets; those who mostly use mass merchandisers (super stores); and those who use a combination of several types of stores. Results show little difference in the dietary quality of purchases across the types of stores households usually use. On the other hand, differences in the dietary quality of PFPs across racial and ethnic groups persisted no matter what types of stores households primarily used.

3.4. Measures of the food environment

A noticeable absence in the studies examined in Table 1 is attention paid to household access to automobiles and other forms of transportation. Allcott et al. (2015) provide descriptive statistics on travel distance to stores where food was purchased for households with and without cars, but automobile access is not part of the demand analysis. The two quasi-experimental studies and the studies that use household scanner data examined 'realized' access (meaning they can examine where people shopped for food). However, they do not address the question of how households got to the store and the costs that may be associated with those trips (e.g. out-of-pocket travel costs and time costs). These costs could be a less obvious access-related barrier to diet quality and food security, as they could divert resources to spend on food. High travel costs could also determine how frequently households can shop, which could affect the perishability of goods purchased or the ease at which households can take advantage of periodic store sales. Lin et al. (2014) utilize self-reported time spent traveling to the usual food store to define access for SNAP participants and find that those who take more time to travel to a supermarket spent less on non-canned fruits and vegetables, non-canned meats, milk, and canned fruits. The effects of prices of these goods on expenditures on these goods were larger in this study, but the results still suggest possible effects of transportation access on food choice.

Our review, and most of the studies, have focused on supermarket access, since supermarkets are often used as proxies for sources of a wide variety of foods at generally affordable prices. Some of these studies have also examined the relationship between food choice and dietary health and the availability of other food retailers, such as non-chain and smaller grocery stores, convenience stores, and specialty stores (Allcott et al., 2015; Block et al., 2011; Boone-Heinonen, et al. 2011; Kyureghian et al., 2012; Lee 2012; and Powell and Chaloupka, 2009). Both Boone-Heinonen et al. (2011) and Block et al. (2011) found that the availability of grocery stores that were smaller than typical supermarkets was associated with lower diet quality or greater BMI. Other studies did not find a relationship between smaller grocery store availability and diet or BMI. Further the availability of other types of food retailers was not associated with food choices or BMI.

Although it has received less attention, some are concerned that access to restaurants, particularly fast food restaurants may be correlated with poor diet and body weight. Americans spend about 44 percent of their food budget on food away from home (ERS, 2016) and food obtained at restaurants tends to be more caloric and of lower dietary quality (Todd et al., 2010). The relationship between access to restaurants was examined in several of the studies reviewed, Block et al. (2011), Boone-Heinonen et al. (2011), Dunn et al. (2012), Kyureghian et al., (2012), Lee (2012) and Powell and Chaloupka, 2009). Two of the studies found that fast food restaurant access was associated with greater consumption of fast food (Block et al., 2011) and the probability of obesity (Boone-Heinonen et al., 2011). Dunn et al. (2012) found no effect of fast food restaurants for the whole population, but did find effects of fast food restaurant availability and greater consumption of fast food and higher BMI for non-whites in the Brazos Valley region of Texas. These results give at least some impetus for further research in understanding the relationship between restaurant access and diet.

4. FoodAPS evidence on geographic clustering

To sort through the existing literature and prepare the way for productive research in the next stage of work on this topic, it is valuable to contemplate more systematically the manner in which both outcome variables and explanatory variables may vary within and across geographic units at comparatively large and small scales. For example, if a household-level dietary quality measure shows greater variation across different neighborhoods and food environments than within, we may be more encouraged to contemplate local food environment factors as contributors to dietary quality; but if the dietary quality measure varies mainly across different households even within the same neighborhood, we may instead consider household-level conditions or characteristics as the main contributors. Our empirical analysis considers the degree of variation across primary sampling units (PSUs) of two summary level measures of diet quality and nutritional well-being—self-assessed diet quality and food security. We also examine variation in household measures of access (such as distance to the nearest or primarily used food store) across PSUs. We expect that if the food retail environment affects food choices and diet quality, there will be substantial variation across different food retail environments. If they do not vary across retail environments, then it suggests that other factors, such as household level resources, prices and preferences have a greater impact.

4.1. Methods

For a variety of household-level, block group-level, and county-level variables related to this literature on the food retail environment, we used data from USDA's National Household Food Acquisition and Purchase Survey (FoodAPS) to describe the variation within and across geographic locations.

Prior literature uses data on the food environment at geographic levels—usually the county-level or in smaller geographic boundaries such as census tract or zip code. We focus on variance components at the level of the 50 primary sampling units (PSUs) in FoodAPS, which were counties or small groups of adjacent counties. Our main interest is in variation in (a) household-level variables and (b) block group-level variables. Of course, county-level variables have little variation within PSUs, because most PSUs are a single county or, if not, only a small number of counties.

The household-level variables include outcome variables (self-reported dietary quality and household food security), intermediate variables (distance to the primary retailer where most grocery shopping took place, and leading reasons for choosing the primary retailer), variables related to automobile use (both automobile ownership and mode of transportation to the primary retailer), and more basic food environment variables that are typical of the prior literature (such as distance to the nearest supermarket). For food security, we used both a binary indicator of food insecurity among adults in the household (based on affirming 3 or more of the 10 adult-referenced items in USDA's household food security module) and a simple continuous raw score (the number of affirmative responses out of the 10 items). Likewise, for the self-reported dietary quality, we used a binary indicator (having excellent or very good dietary quality), and an integer score ranging from 1 for excellent to 5 for poor dietary quality (using this simple approach as a rough indicator of the degree of self-reported dietary quality, even though the intervals across categories may not actually have equal value).

The block group-level variables are from the "geography component" of FoodAPS, an additional dataset with information about the locations from which FoodAPS households were sampled. These variables included the number of supermarkets and other retailers within distance ranges from the block group's population-weighted centroid, and the poverty rate.

The county-level variables include food retail environment variables typically used in literature that do not have the exact location on

sampled households. These variables are the number of supermarkets and other retailers per 1000 population and the average vehicle ownership rate in the county. An open question is whether variables describing the food retail density per unit population closely reflect the local environment where households in the county actually live.

For the analysis, we estimated weighted means, standard errors, and variances for each variable, using the household sampling weights provided by FoodAPS. The weighting generates nationally representative estimates, accounting for the oversampling of low-income households in the FoodAPS sampling design. FoodAPS used a complex two-stage sampling design, with stratification, selection of primary sampling units (counties or groups of counties) and secondary sampling units (census block groups). All estimates were corrected for complex survey design. The design effect shows the estimated sampling variance for an estimate, relative to the sampling variance one would have observed with the same sample size using a simple random sample. Hence, a design effect of "2" means that the complex survey design doubled the sampling variance of an estimate.

A goal for this article was to estimate intraclass correlation coefficients (ρ), which show the covariance between households in the same PSUs as a fraction of the covariance between households in different PSUs. Intraclass correlations in the population necessarily fall between 0 and 1, inclusive, although the computed estimate in the sample may fall out of this range (one estimated correlation coefficient, for full-service restaurants per 1000 people, falls out of this range). For interpretation, an intracluster correlation coefficient near unity implies that households are fairly similar to each other within PSUs. By contrast, an intracluster correlation coefficient near zero implies that there is as much variation across households within the same PSU as there is across households in different PSUs.

4.2. Results

First, household-level variables generally showed high levels of variation across households within the same PSU (Table 2). The self-reported dietary quality score (ranging from 1 for excellent to 5 for poor) had a mean value of 2.8, and the adult-referenced food insecurity raw score (ranging from 0 for perfect food security to 10 for the most severe food insecurity) had a mean of 1.009. The intraclass correlation was 0.064 for self-reported dietary quality and 0.036 for household food security. There was almost no correlation among households in the same PSU; instead households showed great variation in dietary quality and food security even within the same PSU.

The mean driving distance to the primary retailer was 5.117 miles, while the mean driving distance to the nearest supermarket or superstore was only 2.181 miles, suggesting that households commonly bypassed the nearest major retailer to reach a different retailer that was most-preferred. The intraclass correlation was 0.327 for the distance to the primary retailer and 0.398 for the nearest supermarket or superstore. For these variables, which are more directly about the food retail environment, there was moderately high correlation among households in the same PSU, and yet there still remained considerable variation in distances to retailers even within the same PSU. Overall, household variables showed a large degree of within-PSU variation in shopping distances, transportation mode, household food security, and dietary quality.

Second, block-group and county-level variables showed lower levels of variation across households within the same PSU (Table 3). For households in FoodAPS, the mean number of supermarkets within 1 mile of their population-weighted block-group centroid was 1.373. The intraclass correlation was 0.398, which means there was again moderately high correlation among households in the same PSU. For non-supermarkets (including smaller retailers), the mean number within 1 mile from the block-group centroid was much higher, 2.990. The intraclass correlation was 0.504, suggesting fairly high correlation among households within the same PSU. The mean poverty rate in block groups was approximately 15%, which is close to official estimates. The intraclass correlation was fairly low, 0.147, which means that there was plenty of variation in poverty rates across block groups even within the same PSU.

5. Discussion

Policymakers at the Federal, state and local level have initiated programs to address limitations of the food environment in an effort to reduce obesity and diet-related illnesses. These efforts include direct efforts to alter the food environment (encouraging the development of new or refurbishing stores in underserved areas or limiting the development of fast food restaurants) or efforts that help households directly by providing nutrition education, nutrition assistance, or incentivizing the purchase of health foods. Understanding the levels of variation across households vs. neighborhoods can help guide the types of policies to improve food security and diet that are pursued. For example, if neighborhood factors account for much of the variation in food security

Table 2
Means, variances, and intraclass correlations at the primary sampling unit (PSU) level for household-level variables.

Variable	Mean	SE	Design Effect	Intraclass Correlation (ρ)
Continuous				
Diet quality score, self-reported (1 to 5)[a]	2.806	(0.03477)	6.38	0.064
Food insecurity raw score, adults (0 to 10)[b]	1.009	(0.05801)	4.00	0.036
Distance: primary retailer (miles, driving)	5.117	(0.61694)	28.37	0.327
Distance: primary retailer (miles, straight)	3.797	(0.49191)	30.10	0.348
Distance: nearest supermarket or superstore	2.181	(0.27737)	34.31	0.398
Distance: nearest superstore	3.200	(0.38659)	32.91	0.381
Distance: nearest supermarket	3.182	(0.41952)	31.52	0.365
Distance: nearest Walmart	5.535	(0.44313)	20.71	0.235
Binary				
Food secure	0.841	(0.00949)	3.24	0.027
Excellent or very good dietary quality	0.370	(0.01637)	5.54	0.054
Owns automobile	0.892	(0.01164)	6.75	0.069
Mode for primary: own auto	0.878	(0.01333)	8.01	0.084
Mode for primary: other auto	0.065	(0.00607)	2.93	0.023
Mode for primary: not automobile	0.057	(0.00940)	7.91	0.083
Reason for choosing primary: prices	0.527	(0.01838)	6.53	0.066
Reason for choosing primary: close	0.528	(0.01758)	5.98	0.060

Notes: N = 4825.
[a] Diet quality score ranges from 1 (excellent) to 5 (poor), treated here as continuous variable.
[b] Number of affirmative responses.

Table 3
Means, variances, and intraclass correlations at the primary sampling unit (PSU) level for block-group and county variables.

Variable	Mean	SE	Design Effect	Intraclass Correlation (ρ)
Continuous, block-group level				
Number of supermarkets (0.5 miles)	0.400	(0.06812)	26.585	0.306
Number of supermarkets (1 mile)	1.373	(0.17661)	34.339	0.398
Number of supermarkets (10 miles)	58.714	(12.06107)	62.130	0.730
Number of nonsupermarkets (0.5 miles)	0.834	(0.16408)	38.656	0.450
Number of nonsupermarkets (1 mile)	2.990	(0.49857)	43.220	0.504
Number of farmers' markets (10.5 miles)	0.071	(0.01688)	14.763	0.164
Number of farmers' markets (1 mile)	0.237	(0.03250)	15.056	0.168
Distance from centroid to nearest supermarket	2.948	(0.40113)	37.019	0.430
Poverty rate, persons	0.149	(0.00726)	13.316	0.147
Poverty rate, households	0.142	(0.00610)	11.096	0.121
Continuous, county-level				
Supermarkets per 1000 population	0.121	(0.00361)	25.854	0.297
Nonsupermarkets per 1000 population	0.251	(0.01415)	64.570	0.759
Full-service restaurants per 1000 population	0.798	(0.04352)	88.379	1.044[a]
Limited-service restaurants per 1000 pop.	0.697	(0.02078)	76.027	0.896
Poverty rate, persons	0.146	(0.00532)	58.921	0.692
Poverty rate, households	0.138	(0.00474)	54.243	0.636
Vehicle ownership rate	0.923	(0.00650)	71.422	0.841

Notes: N = 4825.
[a] Estimated coefficient slightly out of range (true intraclass correlation ≤ 1).

or diet quality, then policies that encourage better access to food retail choices, such as increasing the numbers of stores or improving transportation options to those stores, would be advisable. If variation is mainly across households within neighborhoods, then promoting access alone will not greatly affect food security or diet quality. Instead, policies targeted at encouraging better nutrition for households, for example, through food assistance, targeted food price subsidies, or nutrition education may be more appropriate.

In this article, we categorized explanatory variables that have been associated with food spending and dietary quality outcomes (using the rubric "GRAPH-M"), distinguishing between explanatory variables by the amount they are likely to vary within small geographic areas. Second, we reviewed recent literature on food retail environment impacts, especially discussing studies that addressed variation within geographic areas – in particular, longitudinal variation within locations over time as the food environment changes, and cross-sectional variation across households that share identical locations or even identical retailers, and paid particular attention to how these studies address the challenge of accounting for household and retailer choices in where to locate. Third, using nationally representative data from USDA's Food Acquisition and Purchase Survey (FoodAPS), we measured the expected values, variances, and intracluster correlations for selected outcome variables and explanatory variables typical of those used in studies of the food retail environment.

Our empirical analysis found high levels of variation across households, within PSUs and even within census block groups, for leading outcome variables such as household food security or self-reported dietary quality. In other words, even if households share the same local food retail environment, they experience diverse food security and dietary quality outcomes. We found less evidence of variation across households, and greater evidence of geographic clustering, for intermediate variables, such as distance traveled to the primary food retailer. We found still lower levels of variation within counties and census block groups in the distance to nearest supermarket, which is not necessarily the primary food retailer.

To summarize, it really is true that some places have better access than other places do to a supermarket within a very close distance such as 0.5 miles or 1 mile. However, this geographic variation in distance to closest supermarket does not account for most variation in intermediate variables such as distance to the primary food retailer; and it certainly does not account for the high level of variation across households in food security and dietary quality outcome variables.

The results of the published literature corroborate this empirical analysis. Most of the studies either find that access to supermarkets, the proxy for sources of healthy food, is not related to diet or body weight or that the effect is relatively small when compared with the effects of household-level variables such as education, demographics and motivation or compared with the effects of food prices.

This study should be seen as a stepping stone to further research in this area. Our main empirical analysis is descriptive, conceiving of geographically clustering in explanatory variables as a necessary but not sufficient condition for using county- or census block group-level variables to explain variation in food security or dietary quality outcomes. Also, we used the FoodAPS survey weights and took account of the complex survey design in descriptive estimates of variable means and variances, but we could not correct the estimates of intracluster correlation coefficients for complex survey design. We believe that this is harmless, on grounds that our approach does very much take account of intracluster correlations at the county and census tract level, which is the leading motivation for formally accounting for complex survey design. Nonetheless, in future survey analysis, with necessary information about probabilities of selection at each stage of survey sampling, it would be good to use corrected estimates for such analysis.

In conclusion, our literature review and empirical analysis with FoodAPS both point toward further research that takes seriously the variation across households in income, food assistance resources, other constraints, and personal food needs and preferences, in ways that cannot be explained by neighborhood characteristics alone.

Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.foodpol.2018.03.005.

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