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A discrete choice approach to modeling food store access

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Abstract. Assessments of access to healthful food frequently use GIS to measure the distance and concentration of food outlets relative to where residents live. These descriptive approaches do not account for food shopping behavior, which may vary based on the attributes of food shoppers and their activity space—places where they live, work, access resources, and socialize. Building on transportation research about accessibility, we reframe the issue of food access and equity from one about 'what is nearby?' to 'where do people shop?'. We use a conditional logit model to analyze disaggregate data from a door-to-door survey of food shopping choice and food store surveys conducted in a predominantly non-Hispanic Black and middle-income and low-income section of Philadelphia. Our results highlight the importance of distance from home to food stores, overall, but they also emphasize the influence on food store choice of the race and sex of food shoppers, travel mode, and where they spend time other than at home, as well as food prices and the availability of healthful foods. This approach to understanding food access holds promise for future research that can link store choice to specific food purchases and health outcomes as well as for refining place-based strategies for improving access to healthful foods.

Keywords: food access, supermarkets, GIS, discrete choice, Philadelphia, food deserts, NEMS-S

Introduction

An extensive body of research has documented the lack of access to healthful foods and disproportionate exposure to unhealthful foods in low-income and minority communities (Beaulac et al, 2009; Treuhaft and Karpyn, 2010; van der Ploeg et al, 2009) and the impact these 'food deserts' have on obesity and chronic disease (Baker et al, 2006; Bodor et al, 2010;

Caspi et al, 2012; Kipke et al, 2007; Lopez, 2007; Morland et al, 2002). Most of this research has relied on descriptive approaches to understanding access, using GIS and other measures to assess the geographic proximity of food outlets to where people live (Charriere et al, 2010; Gordon et al, 2011; Sadler et al, 2011; Walker et al, 2010). These models are limited conceptually because they do not account for the many factors other than distance from home that create barriers to access and, as a consequence, may ignore important sources of social inequity (Krukowski et al, 2012; Neutens et al, 2010; Weiss et al, 2011). More importantly, these distance-based descriptive models fail to account for actual behavior (Crane and Daniere, 1996), which recent studies have found generally involves driving to a food store other than the one closest to home for most households (Drewnowski et al, 2012; Handy and Clifton, 2001; Hillier et al, 2011; Hirsch and Hillier, 2013; Laska et al, 2010; Ohls et al, 1999; Thompson et al, 2011). Recent studies have called for incorporating individual-level (disaggregate) data on shopping behavior into studies of food access (Forsyth et al, 2010; USDA, 2009) in order to overcome these limitations.

In this paper, we turn to the conceptual and methodological work of transportation and marketing scholars to better understand food access. After briefly reviewing this literature, we present a conceptual model of food store choice that considers the interaction among individual-level, household-level, and neighborhood-level attributes with food store attributes and the proximity of food stores to where people live as well as where they spend time. We then test this conceptual model with data from a door-to-door survey about food shopping and food store surveys using a discrete choice model in the form of a conditional logit model. We conclude with ideas for refining the statistical models presented and the implications of understanding food store choice for improving food access and health.

Behavioral models of access to healthy food

Historically, rather than focusing specifically on food access transportation planners have focused broadly on accessibility, defined as the "spatial distribution of potential destinations, the ease of reaching each destination, and the magnitude, quality, and character of the activities found there" (Handy and Niemeier, 1997, page 1175). The cost of travel, measured both in time and money, is considered the main resistance or impedance while the destination is considered the main attraction or motivation (Koenig, 1980). Transportation planners have acknowledged that individuals and groups within a specified zone do not necessarily experience transportation options and potential activities in the same way, particularly across socioeconomic groups (Handy and Niemeier, 1997). Although car ownership is an important factor in decisions about travel mode and destination choice, the planning literature highlights how even households that own a car do not necessarily all use the car in the same way (Blumenberg, 2008; Clifton, 2004).

This interest in the influence of individual and household attributes on travel mode and destination choices led to the development of disaggregate choice, or behavioral, modeling (Lerman and Manski, 1979; McFadden, 1974). These models are now commonly used by economists and transportation and marketing experts to describe choices made by people and organizations among a finite, exhaustive, and mutually exclusive set of alternatives. The statistical models that fall within the 'discrete choice' category are based on a common theoretical framework (McFadden, 1974) and estimate the probability of an individual making a particular choice based on attributes of that individual and the alternatives the person is considering. The transportation literature also provides a critique of home-based measures of accessibility and points to multipurpose trips and trip chaining—or linking trips to multiple destinations—as important considerations (Ewing et al, 1994; Kryzek, 2003; Lerman and Manski, 1979). Several marketing studies have focused specifically on agglomeration effects and 'bundling' to understand how a desire for efficiency may influence shopping trip, purchase, and destination (Arentze et al, 2005; Dellaert et al, 1998; Oppewal and Holyoake, 2004).

Despite recent widespread interest in the topic of food access in low-income neighborhoods, choice modeling has rarely been applied to understanding food shopping, and the limited number of marketing studies that have used choice models to understand food shopping do not approach store choice from a public health or disparities framework (Arnold et al, 1981; Bell et al, 1998; Briesch et al, 2009; Fotheringham, 1988). Discrete choice experiments, where study participants are exposed to a number of hypothetical scenarios, or choice sets, are common within the health care and health economics literature (Ryan et al, 2008), but discrete choice models have not been reported in public health studies of food access.

Conceptualization of food store choice

Our conceptualization of food store choice builds on research in the public health, transportation, and marketing fields. Choices about where to shop for food matter not only for commercial reasons, but also have implications for food purchases, diet, weight status, and health of vulnerable populations.

Shoppers' race/ethnicity, sex, age, and education level have all been shown to be associated with store choice and shopping patterns (Ayala et al, 2005; Handy and Clifton, 2001; Krukowski et al, 2012; Morland and Filomena, 2008; Rose et al, 2010; Yoo et al, 2006). So, too, have socioeconomic status and car ownership (Paez et al, 2010). Low-income households are more likely to prioritize cost savings and use comparison shopping (Dunkley et al, 2004; Webber et al, 2010). People who own vehicles usually use them to shop for food (Handy, 1996). People who do not own cars may borrow them, get a ride from a friend or relative, or take a taxi in order to do their food shopping (Clifton, 2000).

Although most households drive or are driven to do their food shopping, access to public transportation may be relevant to the remaining percentage as well as to those exercizing what Clifton (2004) calls a 'secondary mobility strategy'—a back-up plan when driving is not viable. The geographic area defined by locations such as work, school, and child care where people spend time—'nonresidence anchor points' (Widener et al, 2013)—and the paths they travel between these locations has been the focus of a limited amount of research on food shopping and food access (Clifton, 2004; Kerr et al, 2012; Krukowski et al, 2012; Thomas, 2011; Webber et al, 2010; Zenk et al, 2011a). The study of these 'activity spaces' incorporates a temporal as well as a geographic dimension (Kwan 1998; 2000) and allows for consideration of space–time behavior such as commuting to work (Widener et al, 2013) and trip chaining.

The attributes of food stores influence consumers' choices. Relevant attributes include the type and size of store, price, selection, and quality of products, and store cleanliness, safety, and customer service (Handy and Clifton, 2001; Krukowski et al, 2012; Wang and Lo, 2007; Webber et al, 2010; Yoo et al, 2006).

Methods

We tested our conceptual model using data collected for a study about food shopping and physical activity opportunities conducted within six contiguous ZIP codes in west and southwest Philadelphia. We conducted door-to-door surveys with residents of thirty randomly selected blocks within the study area during the summer of 2010. Eligible participants were adults who were the primary food shoppers for their households, could speak and understand English, and did not have physical limitations that precluded being physically active (Hillier et al, 2012). All procedures were approved by the University of Pennsylvania Institutional Review Board.

Individual attributes and store choice

The door-to-door survey assessed participants' sex (recorded by interviewer), self-reported race/ethnicity, employment status (full-time or part-time), student status (full-time or part-time), receipt of public assistance including Supplementary Nutrition Assistance Program (SNAP) or cash benefits, and car ownership. The location of the store where participants reported doing most of their food shopping, the location of the place where they reported spending most of their time when they were not at home, and the centroid of the residents' face block (used as a proxy for home address since home address was not recorded in the survey) were geocoded using ArcGIS 10.1 (see figure 1). If participants traveled 3 miles or more from their home to the place where they spend time when they are not at home, they were coded as commuters. Participants also identified their usual mode of transportation to and from the food store. Dichotomous variables were created, indicating whether or not participants drove or received a ride and whether they used public transportation or not to reach their primary grocery shopping destinations.

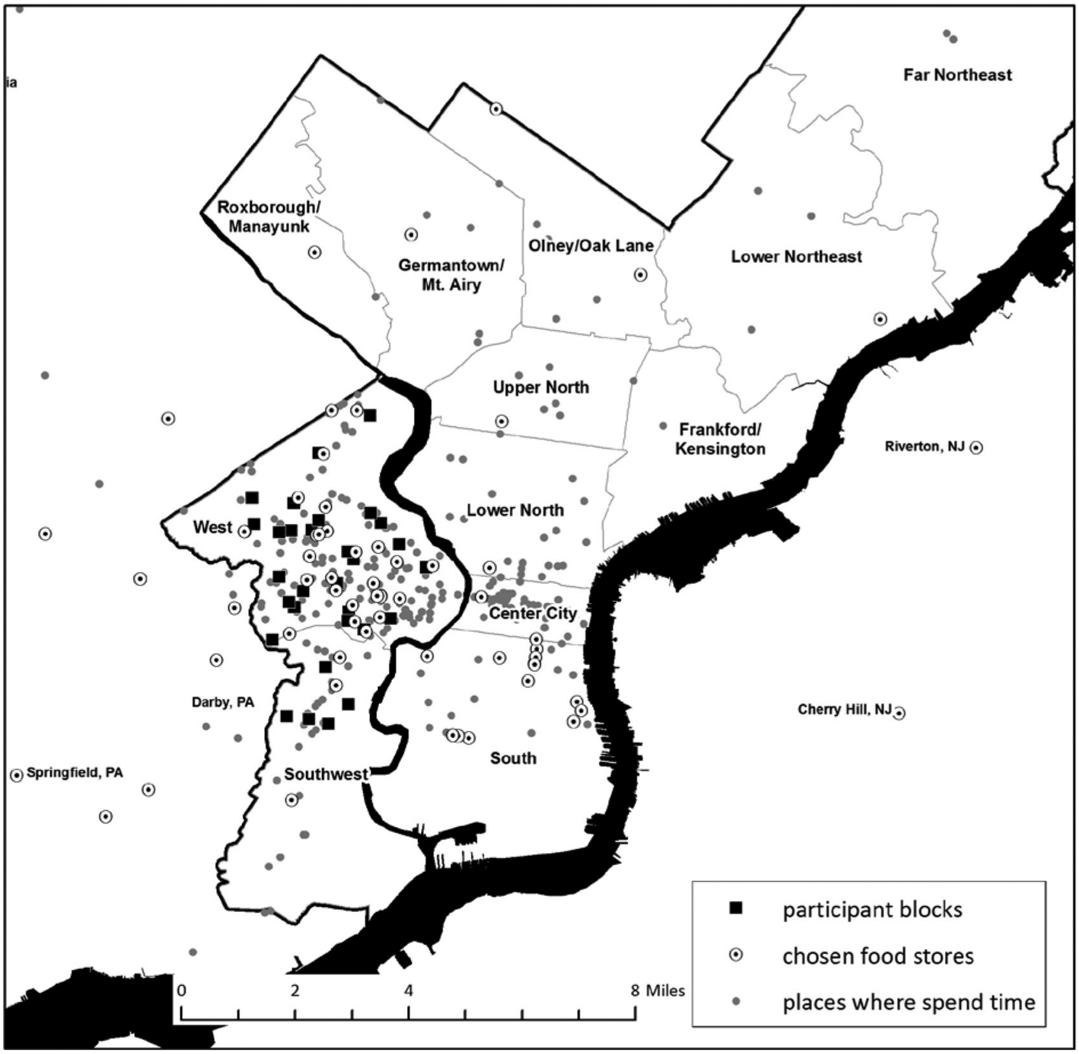

Figure 1. Map of participant blocks, chosen food stores, and places where survey participants spend time.

Food store attributes

We identified food stores within the study area using a list of all stores authorized to accept SNAP benefits. Trained research assistants used this administrative dataset as the starting point for a complete enumeration, visited all SNAP stores to confirm their location and status, and noted additional stores not on the SNAP list. All food stores within the study area as well as those stores outside the study area that were identified by participants as stores where they did most of their food shopping ($n = 373$) were surveyed using the Nutrition Environment Measure Survey in Stores (NEMS-S) (Glanz et al, 2007). Scores for each store were calculated according to the availability, quality, and price of specific food items. A score for the relative price of healthful foods was calculated by comparing the price of conventional items, such as whole-fat milk or white bread, with healthful alternatives, such as reduced-fat milk or whole-grain bread. If the more healthful item was less expensive than the conventional item, the store received a point; if the more healthful item was more expensive the store lost a point (Cannuscio et al, 2013). Data collected through NEMS-S were also used to construct an absolute-price measure combining the price of a ½ gallon of milk (least expensive variety) and 24-oz loaf of whole-grain bread. The square footage of food stores was obtained from the Trade Dimension's Retail Site database.

To measure the accessibility of public transportation from stores, we excluded bus transit (measuring only the proximity to subway, trolley, and train stops) because the study area is saturated with bus routes, with limited variation in bus access across the study area. We calculated the network distance from the centroid of the face block of residence and from chosen stores to the nearest trolley, subway, or high-speed or regional rail station with ArcGIS 10.1 using shapefiles from the Southeast Public Transit Association. We then categorized stores as being within ¼ mile of a trolley, subway, or train stop or not.

Conditional logit model

See table 1 for details of the variables included in the conditional logit model.

Given a set of individuals (households), $i \in I$, and stores, $s \in S$, if the set of store alternatives relevant for individual i is denoted by $s_i \subseteq S$, then our conditional logit model takes the general form

$$P_i(s) = \frac{\exp(V_{is})}{\sum_{s' \in S_i} \exp(V_{is'})}, \qquad s \in S_i, \quad i \in I, \tag{1}$$

where $P_i(s)$ denotes the probability that store s is chosen by individual i from set S_i. These choice probabilities are assumed to depend on the value, V_{is}, of each store s to individual i. As in linear regression, these values are assumed to be representable as linear functions of a relevant set of store attributes (x_{sj}: $j = 1, ..., J$), such as size and availability of healthful foods at store s. These values may differ among individuals, depending on attributes, (z_{ik}: $k = 1, ..., K$), such as the sex and race of the individual. Such value differences can be captured by interacting individual attributes with each store attribute. The primary measure of accessibility was the travel distance from individual i's residence to each store s, designated as Home Distance, $d_1(is)$. However, we were also interested in the distance to store s from the place where i spends the most time (such as job location), here designated as Place Distance, $d_2(is)$. As with store attributes, the value of these distance accessibilities may differ among individuals. For example, such distances may be less important for car owners. Again, such effects can be captured by interacting these distances with individual attributes. Hence in the most general model considered here, values of stores for individuals are taken to be linear functions of the form:

$$V_{is} = \sum_{j=1}^{J} \left[\beta_j x_{sj} + \sum_{k=1}^{K} \beta_{kj} z_{ik} x_{sj} \right] + \sum_{h=1}^{2} \left[\theta_h d_h(is) + \sum_{k=1}^{K} \theta_{kh} z_{ik} d_h(is) \right], \tag{2}$$

Table 1. Variables included in conditional logit models.

Variable	Measure
Individual attributes	
Sex	Female or not
Black	Black/African American or not
Public Assistance	Receive Supplement Nutrition Assurance Program/cash assistance or not
Commute	Travel 3 miles or more from home to place where most time is spent when not at home, or not
Home Distance	Network distance in miles from home address to each store in the choice set
Distance	
Distance	Network distance in miles from home to chosen store
Extra Distance	Network distance in miles from the supermarket closest to participant's home to each store in the choice set
Place Distance	Network distance in miles from place where most time is spent when not at home to each store in the choice set
Store attributes	
Availability	Nutrition Environment Measure Survey score for availability of healthful food items in 10 categories; values from 0–37
Relative Price	Price of healthful food items relative to standard item; values from 0–18
Absolute Price	Cost in $ of gallon of milk, 16 oz of whole wheat bread, 8 oz Cheerios
Square-footage	Square footage
SEPTA	Within ¼ mile of subway, trolley, or train stop

where the first term on the right-hand side involves store attributes together with individual interaction effects and the second term involves distances (residential and place) together with their individual interaction effects.

Following standard terminology, coefficients β_j and θ_h are referred to as the 'main effects' for store attribute j and distance attribute h, respectively. Similarly, for any given individual attribute k coefficients β_{kj} and θ_{kh} are referred to as 'interaction effects' between k and, respectively, store attribute j, and distance attribute h. To interpret these coefficients note, for example, that the effects of store attribute j can be isolated by considering two hypothetical stores s and s' that differ only with respect to attribute j. To capture the effects of a unit change in attribute j suppose in addition that $x_{sj} - x_{s'j} = 1$. Then, the relative likelihood of any individual i choosing store s versus s' is seen from expressions (1) and (2) to be of the form:

$$P_i(s)/P_i(s') = \exp\left[\beta_j(x_{sj} - x_{s'j}) + \sum_{k=1}^{K} \beta_{kj} z_{ik}(x_{sj} - x_{s'j})\right] = \exp\left(\beta_j + \sum_{k=1}^{K} \beta_{kj} z_{ik}\right). \qquad (3)$$

So, in this context it is clear that 'main effect' β_j reflects that component of change in the relative likelihood of choosing s versus s' which is common to *all* individuals i.(1) Similarly, β_{kj} reflects the additional component of change in this relative likelihood that is specific to individuals with kth attribute level z_{ik}.(2) Parallel interpretations can be given to the distance parameters θ_h and θ_{kh}.

(1) Technically one should add 'for all individuals for whom both s and s' are relevant options', but since β_j is clearly independent of these particular option choices, we ignore this complication.

(2) By taking logs in equation (3), these can also be interpreted as linear changes in 'log odds', similar to logistic regression. Alternatively, one can obtain interpretations in terms of 'elasticities' and 'cross-elasticities' of substitution, as for example in section 3.6 of Train (2009).

Store choices and choice sets

We defined the relevant store choice for each individual i to be that store where most food shopping was done. We identified the relevant choice set S_i for each individual i to be the set of all store choices made by individuals on i's block.[(3)] Ideally, this choice set would include all the store choice options actually perceived by each individual to be relevant. But since these data are typically not available (and indeed may not even be fully known to individuals themselves), it is necessary to define such sets exogenously.[(4)]

Model specifications and results

Individual and household attributes

Of the residents who were contacted in person, 82.6% completed a survey. Of the 467 participants who completed the survey and provided the name and address of a store that could be located and surveyed using NEMS, 65.5% were women, 73.0% were non-Hispanic Black, 31.7% were receiving some type of public assistance, 69.3% either drove themselves or got a ride with a friend or relative, and 11.4% used public transportation to do their primary food shopping.

Food store choice and store attributes

Nearly three out of five participants (59.4%) reported that they do most of their shopping at one of six stores from three different national supermarket chains. Participants overwhelmingly chose supermarkets from a national chain (86.2%), with a much smaller proportion of participants choosing national discount, or limited assortment, supermarkets (11.5%), small locally owned grocery stores (1.3%), or superstores like Target or Walmart (0.9%).

The distance between study participants' homes and store choices (Home Distance) ranged from 0.05 miles to 28.9 miles, with an average of 1.9 miles (median of 1.34 miles). Participants frequently chose to shop at a store other than the closest store. This extra distance (Extra Distance) ranged from 0 to 28.5 miles, with an average of 1.5 miles (median of 1.0 miles). For 299 of the 467 study participants, data were also available for the place where they spent the most time when not at home. For these participants, this distance (Place Distance) ranged from 0.01 miles to 20.9 miles, with an average of 3.0 miles (median of 2.1 miles).

Conditional logit models

Two alternative specifications of expression (2) above were explored.[(5)] Model 1 used distance from home to chosen store (Home Distance) as the basic measure of accessibility to shopping. Model 2 also included Place Distance as well as the dummy variable distinguishing people who travel 3 miles or more to the place where they spend most time when not at home (Commute).

Model 1

The initial set of store attribute variables used for analysis included a number of variables that exhibited inflated standard errors due to collinearity effects, namely store size, NEMS-S availability scores, and full service supermarket status.[(6)] Among these, NEMS-S availability

[(3)] As one additional restriction, we require that each choice set contain at least three store alternatives. This necessitated combining four small blocks with their nearest-neighbor blocks to meet this restriction, while at the same time preserving spatial locality as much as possible. The resulting choice sets ranged in size from four to eleven stores.

[(4)] For additional discussion of such choice-set identification issues see, for example, Fotheringham (1988) and Pelligrini (1997).

[(5)] All conditional logit models in this study were estimated using the Matlab program, conditlogit.m, written by James LeSage, which is available online as part of his suite of Matlab programs at http://www.spatial-econometrics.com.

[(6)] Experimentation with simulated data shows that conditional logit models tend to be even more sensitive to collinearity effects than linear regression.

score was considered to be of most importance for the purposes of this research because it is a measure of the presence of healthful food. Further experimentation showed that store size could also be included without seriously affecting standard errors. None of the individual-level variables exhibited serious collinearity problems. The results of model 1 are shown in table 2 where, for example, Square-footage–Black denotes the interaction effect between a store attribute, store size (Square-footage), and an individual attribute, being Black/African American (Black).

One of two significant main effects was the negative effect of distance from home (Home Distance), suggesting that physical proximity is indeed an important factor in determining store choice. Several significant interaction effects indicate that, based on the attributes of the individual, distance plays a different role in store choice. Women were less likely to be influenced by distance while Blacks, overall, were more likely to shop closer to home than the overall population. The effect of driving or riding to the food store diminished the negative effect of distance, but overall, those who drove or rode were still more likely to choose stores closer to home.

Being located within ¼ mile of a transit stop was not a significant factor in store choice overall, but it was significant for residents who used public transportation to do their shopping (Transit user–SEPTA). The interaction between transit access and extra distance was significant and negative, indicating that those choosing stores near transit stops were less likely to travel an extra distance beyond the closest store.

Relative Price was significant and positive, indicating that, overall, participants chose stores with higher relative food prices. The interaction effect with Black was significant and negative, indicating that Black participants were less likely than non-Black participants to choose stores with higher relative prices. Similarly, participants who drove or were driven to do their food shopping were less likely than those who used transit, walked, or cycled to choose stores with higher relative prices. Absolute Price was not significant as a main effect, but the interaction effect with Extra Distance was significant and negative, indicating that those who travel further beyond the closest store were less likely to choose a store with higher absolute prices than those who traveled to the closest store. The availability of healthful foods was significant when interacting with the extra distance traveled beyond the closest supermarket (Availability–Extra Distance), indicating that participants traveled further to go to stores with higher NEMS-S scores.

Model 2(7)

Home Distance remained highly significant and negative in model 2. No interaction effects with Home Distance were significant at the $p < 0.05$ level, but Drive/Ride was marginally significant at $p = 0.055$ and positive, suggesting again that driving and riding to the store moderates the effect of distance. Place Distance was also significant and negative as a main effect, indicating that, overall, participants were more likely to choose stores closer to places where they spend time than stores further away. The interaction effect with Drive/Ride was marginally significant at $p = 0.052$, indicating that driving or riding to the store also reduces the effect of Place Distance.

In this model, the interactions between a store's proximity to public transportation and using transit (SEPTA–Transit use) as well as being Black (SEPTA–Black) was significant and positive, indicating that transit users and Black participants were more likely to choose stores near transit stops. As with model 1, the interaction effect Relative Price–Drive/Ride was significant and negative, indicating that those driving or riding to do their food shopping were less

(7) For purposes of comparison, model 1 was rerun using only the 299 participants included in model 2. Essentially all results were the same, with slightly lower levels of significance reflecting the smaller sample size, so only the full-sample model is reported here.

Table 2. Results from conditional logit models.

Variable	Model 1 (standard model)			Model 2 (with activity space)		
	parameter	*Z*-value	*p*-value	parameter	*Z*-value	*p*-value
Square-footage	−0.007	−0.725	0.468	−0.001	−0.104	0.917
Square-footage–Black	0.012	1.580	0.114	0.006	0.514	0.608
Square-footage–Sex	−0.001	−0.080	0.936	0.001	0.142	0.887
Square-footage–Public Assistance	0.005	0.730	0.465	−0.004	−0.389	0.697
Square-footage–Driver Ride	0.005	0.702	0.483	0.003	0.241	0.809
Square-footage–Extra Distance	0.003	1.832	0.067	0.006	1.929	0.054
Availability	0.023	0.834	0.404	0.012	0.261	0.794
Availability–Black	−0.036	−1.412	0.158	−0.022	−0.558	0.577
Availability–Sex	0.001	0.048	0.962	−0.016	−0.426	0.670
Availability–Public Assistance	−0.010	−0.393	0.694	0.054	1.373	0.170
Availability–Driver/Ride	0.034	1.245	0.213	0.022	0.500	0.617
Availability–Extra Distance	0.031	2.795	0.005	0.042	2.142	0.032
Relative Price	0.090	2.522	0.012	0.061	1.169	0.243
Relative Price–Black	−0.066	−2.029	0.042	−0.028	−0.584	0.559
Relative Price–Sex	0.012	0.395	0.693	0.044	1.023	0.306
Relative Price–Public Assistance	−0.018	−0.524	0.600	−0.005	−0.104	0.918
Relative Price–Drive/Ride	−0.069	−1.991	0.046	−0.100	−1.961	0.050
Relative Price–Extra Distance	0.010	1.109	0.268	0.022	1.649	0.099
Absolute Price	0.215	1.057	0.291	0.224	0.739	0.460
Absolute Price–Black	0.000	0.001	1.000	0.000	0.000	1.000
Absolute Price–Sex	0.005	0.029	0.977	−0.037	−0.161	0.872
Absolute Price–Public Assistance	0.241	1.313	0.189	0.256	1.007	0.314
Absolute Price–Drive/Ride	−0.157	−0.884	0.376	−0.179	−0.686	0.493
Absolute Price–Extra Distance	−0.152	−2.951	0.003	−0.167	−1.969	0.049
SEPTA	0.140	0.540	0.589	−0.115	−0.362	0.717
SEPTA–Black	0.444	1.714	0.087	0.809	2.338	0.019
SEPTA–Sex	0.024	0.097	0.923	−0.108	−0.334	0.738
SEPTA–Public Assistance	−0.239	−0.933	0.351	−0.367	−1.119	0.263
SEPTA–Transit use	1.322	2.924	0.003	2.644	2.478	0.013
SEPTA–Extra Distance	−0.230	−3.019	0.003	−0.136	−1.204	0.229
Home Distance	−0.654	−5.347	0.000	−0.608	−2.718	0.007
Home Distance–Black	−0.171	−2.783	0.005	−0.074	−0.630	0.529
Home Distance–Sex	0.239	3.013	0.003	0.182	1.513	0.130
Home Distance–Public Assistance	0.041	0.648	0.517	−0.036	−0.303	0.762
Home Distance–Drive/Ride	0.410	3.769	0.000	0.405	1.919	0.055
Place Distance				−0.523	−2.058	0.040
Place Distance–Black				−0.207	−1.317	0.188
Place Distance–Sex				0.061	0.414	0.679
Place Distance–Public Assistance				−0.150	−0.992	0.321
Place Distance–Drive/Ride				0.412	1.737	0.082
Place Distance–Commute				0.244	1.940	0.052
Sample size	$n = 467$			$n = 299$		
Success rate	38.3% (13.2% random)			44.5% (19.6% random)		

likely to choose stores with higher relative prices. Similarly, the interaction effect Absolute Price–Extra Distance was significant and negative, indicating that those traveling further beyond the closest store were less likely to choose stores with higher relative prices.

Consideration of goodness of fit

While there is no universally accepted measure of 'fit' for conditional logit models, the success rate reported at the end of table 2 is the simplest to interpret.(8) This rate is defined as the percentage of choice situations in which the highest estimated choice probability corresponds to the alternative actually chosen. This is particularly appropriate in view of our definition of 'store choice' as the most frequently chosen alternative. In conditional logit models there are many more choice alternatives (here ranging from four to eleven), so the significance of these success rates should be compared with random predictions.(9) The present success rates are seen to be more than two and a half times larger than would be expected by chance alone. While there is still much room for improvement, identification of significant explanatory variables is meaningful even when goodness of fit (in terms of R^2) is imperfect.

Discussion and conclusion

The empirical results of our discrete choice models are largely consistent with prior research but provide additional, more subtle distinctions regarding how urban residents interact with their activity spaces in choosing where to shop for food. As in a number of recent studies (Drewnowski et al, 2012; Hillier et al, 2011; Hirsch and Hillier 2013; Laska et al, 2010; Thompson et al, 2011), participants showed a willingness to travel beyond the closest supermarket, in part due to a preference for lower prices (DiSantis et al, 2013; Zenk et al, 2011b). But the choice of supermarkets that required travel beyond the closest food stores was also explained by the greater availability of healthful foods at those more distant stores (Cannuscio et al, 2013). Consistent with Handy and Clifton (2001) and Zenk et al (2011b; 2014), women were more likely than men to travel further to do their food shopping.

While none of the findings relating to specific significant main or interaction effects contradicted findings from prior research, together they add nuance to what is known about food store choice. They show that distance from home is an important consideration but exerts a different influence on people according to their individual and household characteristics. In other words, even participants living on the same block experienced store accessibility differently. This is explained, in part, because people who live on the same block do not necessarily spend time at the same places. Even though the location of the place where participants spent the most time when they were not at home is a very rough approximation of their activity space, model 1 showed that this a significant factor, with participants choosing food stores closer to where they spend most time other than at home. This supports the concept of trip chaining, although trip chaining would involve combining errands and visits to friends or relatives with food shopping, which is beyond our simple measure of one place where people spend much of their time when they are not at home. For people who traveled 3 miles or more from home to the place where they spend time, the location of that place was less important. This may be because they are as likely to choose stores along the way as these near their other destinations and because once you have traveled several miles from home,

(8) Other standard measures are discussed in section 3.8.1 of Train (2009).

(9) To compute this rate for a series of choice situations, $i = 1, \ldots, N$, where the number of alternatives in each situation i is given by $n_i = \#S_i$, the expected success fraction in each situation i under random predictions is simply $1/n_i$. So, the overall expected *random success rate* is given (in percentage terms) by

$$\frac{100}{N}\sum_{i=1}^{N} 1/n_i .$$

In the present case, with $N = 451$ choice situations, this yields the value 14.197.

traveling extra distances to certain stores may not take on the same burden as for those who generally stay closer to home.

Mode of travel turned out to contribute more to predicting food store access than car ownership. As expected, people who used public transportation for their food shopping chose stores close to public transit stops. On the other hand, people who traveled by car to do their food shopping—whether they owned the car or received a ride from friend or relative—behaved similarly. Even in low- and middle-income communities with relatively low levels of car ownership, most people drive or get a ride to do their food shopping (Hillier et al, 2011; 2012). Within this study population, only 11% of participants used transit as their primary mode of transportation for food shopping.

Compared with non-Black participants, Black participants tended to choose stores closer to home. While Black and non-Black participants chose the largest and closest full-service supermarkets in nearly equal proportions, there was clear racial sorting among limited assortment and specialty stores. Nearly all the participants who chose chain discount stores were Black. On the other hand, only one of the twelve participants who chose Trader Joe's, a chain specialty grocer, was Black. None of the participants who shopped primarily at a co-op or farmers' market were Black and only a third of those shopping at the high-end supermarkets (Wegman's and Whole Foods) were Black. Most of the study area is characterized by high levels of racial segregation, and the blocks with white residents were clustered on the eastern side of the study area. But the racial sorting across food stores is not explained only by residential segregation or patterns in food store location. Zenk et al (2014) described Black food shoppers' experiences with racial discrimination. Experience or fear of racial discrimination may lead Black shoppers to patronize stores closer to home and where other shoppers are also Black. This is clearly an area for further examination that could, potentially, help to address racial disparities in obesity and chronic disease.

While race was a significant factor in store choice as it interacted with store characteristics, receipt of public assistance was not significant in either model. Being Black was collinear with receipt of public assistance, but even when race was removed from the model, public assistance was not significantly associated with store choice. Car ownership, another proxy for socioeconomic status, was not significant when it was included in model 1. Similarly, employment status was not significant. For the study population, then, race seems to influence store choice more than socioeconomic status.

Strengths and limitations

The primary strength of this study is that it shows the value of discrete choice models for understanding food store choice in the context of the ongoing scholarly and popular debate about equity in food access. Our research contributes to reframing the important question from 'what food stores are nearby?' to 'what factors other than distance influence where people shop?' This study provides additional evidence that how people access food varies according to their individual and household attributes, suggesting that individuals perceive the food landscape differently based on sex, race, and mode of transportation, and that a single 'food dessert' map cannot assess food access for all residents. An important strength of this study was the combination of food shopping behavior data, collected through a resident survey, with detailed data about food stores, collected through field visits. While primary data collection is more time consuming and costly than reliance on administrative data, we demonstrated in this project that it was feasible to collect such data for a relatively large area and that such data contribute to a more nuanced understanding regarding how and why people choose to shop at certain food stores.

The primary limitation of this study relates to the lack of information about certain potentially relevant individual and store characteristics. The survey was kept short to minimize respondent burden and optimize participation. However, additional information about food stores could also improve the predictive success of the statistical models. This might include the availability, cost, and type of parking, and pedestrian infrastructure (Handy and Clifton, 2001), check-out options (express lines and self-checkout), the availability and type of grocery bags, membership fees (such as those required for wholesale stores) in-store amenities (such as a bank, ATM, or pharmacy) and customer service (Hillier et al, 2012; Zenk et al, 2011b). The marketing literature identifies store advertising practices, including weekly circulars (Bodapati and Srinivasan, 2006), and the number and types of brands (Briesch et al, 2009) as factors in store choice. Coupon policies, special sales and promotional policies, and authorization to accept federal WIC (Special Supplemental Nutrition Program for Women, Infants, and Children) and SNAP/food stamp benefits might also be incorporated into future models.

Refining other variables could also help to improve the predictive value of the conditional logit models. More robust measures of price, alternative measures of activity space, and detailed data on the routes by which individuals travel would be useful. A food store located along the way home from work might be just as convenient as a store located near work. Our measure of store proximity to transit did not incorporate bus access even though some transit users within the study may take the bus to do their food shopping. Activity spaces have been measured using travel diaries and GPS (Kerr et al, 2012; Zenk et al, 2011c), but less-expensive and time-consuming approaches might involve asking participants to identify all the places where they spend time and shop as well as the major routes they travel.

The predictive value of discrete choice models of shopper behavior might also be improved by refining the set of stores identified as alternatives. Most shoppers perceive far fewer choices than are actually available (Fotheringham, 1988; Robinson and Vickerman, 1976) and 'choice set specification' may have significant impact on parameter estimates as well as goodness-of-fit measures (Pelligrini et al, 1997). Future studies should try to identify these perceived options, either by asking residents which stores they *ever* shop at or the stores from which they choose. The way in which we operationalized the choice sets may in some ways be too restrictive. For example, if all residents on certain blocks only shop at local stores, then such choice sets would tend to constrain the full effect that 'distance from home' has in the model.(10)

Ultimately, we modeled only the choice of primary food shopping destination. The marketing literature supports the concept of habitual behavior and shopper loyalty to a primary store (Bell et al, 1998; Rhee and Bell, 2002), but individuals and households shop at different outlets for different types of shopping (Hirsch and Hillier, 2013). Finally, this study takes the first step in modeling food store choice, but it does not connect food store choice with the foods residents purchase and eat or with the health outcomes. Future research must take the next steps in identifying causal pathways between food shopping, food purchases, consumption, weight status, and health outcomes (Rose et al, 2010; USDA, 2009). A limited number of studies have analyzed data about food shopping behavior collected automatically through store loyalty cards (Ball et al, 2011), SNAP and WIC program participation (Caster and Henke, 2011), food store receipts (French et al, 2009; Holsten 2010), and Nielsen Homescan data (Volpe and Okrent, 2012). These types of data on food purchases could prove critical to making links between store choice, food choice, and health outcomes.

So what does understanding food choice do to improve food access in low-income communities? We still have much to learn about the relationship between food shopping behavior and health outcomes, but we do know that even when constrained by lack of personal and environmental resources people make choices about food stores. Current local, state, and

(10) We are grateful to an anonymous referee for this observation.

federal policies that direct subsidies to new supermarkets focus primarily on questions about the location of the new store ('is this an area of need?') and its business model ('can this store succeed?'). The supermarket industry already takes advantage of extensive commercial market research to understand how to attract and retain customers. Research on food store choice focused on improving food access, however, may be used to inform public policy in regard to the type and location of stores that receive tax credits in order to maximize their potential to change food shopping behavior and improve the health of the population. This behavior approach to planning and evaluating place-based interventions provides another example of the value of combining planning and public health approaches to the broader set of problems that Paez et al (2010) call 'accessibility deprivation' or 'patterns of social exclusion'.

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