# A Multidimensional View of Food Environment Impact on Consumption and Food Security

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# 1 Introduction

Since the 1990's the rapidly growing body of research on food deserts has sought to test the hypothesis that location matters (Walker et al, 2010; Larson et al, 2009; Charreire et al, 2010). Location refers to the relationship between distance between a household and food stores (including supermarkets, grocery stores, and restaurants), and what affect increasing distance has on consumption patterns (mainly fruits and vegetables) and health outcomes (Aggarwal et al, 2014, Dunn et al, 2012; Michimi and Wimberly, 2010). Previous research can be divided between into two major categories: those that try to identify neighborhoods with disproportionately low access to food stores and those that try to identify a relationship between location and consumption or health outcomes (Beaulac et al, 2009; Charreire et al, 2010).

Although there is strong evidence to suggest that there exists neighborhoods in the United States, with low access to grocery stores and supermarkets, identifying what, if any, effect this has on household consumption and health outcomes has been more difficult (Beaulac et al, 2009; Aggarwal et al, 2014, Dunn et al, 2012; Michimi and Wimberly, 2010). The results of these studies seems to be contradictory at times, which may be a result of the lack of theoretical framework from which to derive empirical models, and the failure to utilize approbate empirical methods that can model spatial relationships (Beaulac et al, 2009).

The purpose of this paper is to show how the household production model can supply a much needed framework to this body of literature. Secondly, it will address two empirical weakness in previous studies which treated all stores and locations as equals. The first weakness will be addressed by using a unique dataset collected in the Dan River region (DRR) , which includes three counties in south central Virginia and north central North Carolina (Hill et al, 2012; Chau et al, 2013). The project utilized the Nutrition Environment Measures Surveys (NEMS) to evaluate the quality of restaurants and stores, with a particular interest in assessing the availability of healthy foods (Glanz et al, 2007; Saelens et al, 2007). Each food outlet received a score which reflects several attribute important to food choice, which can be used to differentiate stores based on availability, quality and price of healthy foods.

The second weakness resulting from of treating all locations equally, occurs when inappropriate methods are used to analyze data with a potential spatial relationship. Previously, studies have relied upon methods commonly applied to cross sectional datasets, including logistic and linear regressions, however, these methods rely upon the assumption of independent and identically distributed (i.i.d.) observations which will be violated in spatial data (Aggarwel et al, 2014; Blitstein et al, 2012; Dunn et al, 2012; Michimi and Wimberly, 2010; Pearson et al, 2005). In the case that data expresses a spatial relationship observations nearer to each other will act more similar, inducing correlation in the data set that violates the i.i.d. assumption. Using spatially explicit methods can address this correlation and incorporate the information into the analysis.

## 2 Access and Consumption

Food deserts, which refer to an area where residents to not have access to a supermarket, first became a popular research phenomena in the early 1990's (Cummins and Macintre, 2002; Walker et al, 2010). Researchers focused on identifying areas with limited access, and found considerable evidence for disparities in access in low income and African American communities in the United States (Beaulac et al, 2009; Walker et al, 2010; Larons et al, 2009; Cummins and Macintyre, 2005). These findings may reflect significant changes in the retail food environment since the 1960's, which has resulted in the rapid growth of chain supermarkets, and the movement of store locations to the edges of town (White, 2007; Walker et al, 2010).

This change in the retail environment has not been without its benefits. The increased prevalence of the supermarket has also lead to an expansion of the variety and quality of foods available, as well as a decline in prices (White, 2007). Yet, early research on food deserts focused only the presence of a store as an indicator of access. Later, when studies began to compare access based on the relative cost of a basket of food, the evidence for disparities became more mixed (Beaulac et al, 2009; White, 2007). While some papers have shown that healthier diets are more expensive than unhealthy diets in low-income areas, others have found no difference, and still others only found a gradient once quality was taken into consideration (White, 2007)

Then in the early 2000's research on food access turned towards the relationship between access and consumer behavior, with a particular interest in fruit and vegetable consumption (White, 2007; Capsi et al, 2012). While there is some evidence of a difference in the nutritional quality of diets across socio-economic classes, there was a question as to whether or not the disparities found in food access had an influence on consumer behavior (White, 2007). Research has also expanded to include the effects of access to alternative food outlets, such a fast food restaurants and corner stores (Walker et al, 2010; Larson et al, 2009). There is some evidence that fast food restaurants serve lower quality foods, and that access to full service restaurants (as compared to fast food) can improve dietary intake (Larson et al, 2009). Access to fast food and full service restaurants also displays some disparities based on socioeconomic status, with a greater density of fast food restaurants in lower income areas and more full service restaurants in higher income areas (Larson et al, 2009). A more limited number of studies have used a definition of the food environment that combines retail stores with restaurants (Papas et al, 2007).

Studies on the relationship between access and consumption are complicated by the definition of access, and level of spatial aggregation. Access has been conceptualized to include five dimension: availability which describes the adequacy of supply; accessibility which describes the geographic component of access; affordability and particularly perceptions of the value relative to costs; acceptability which describes attitudes about the local food environment; accommodation which describes how well local food sources meet local needs (Capsi et al, 2012; Charreire et al, 2010). Availability and accessibility are two of the most commonly researched dimensions of access. Food deserts would be classified as an expression of availability (Capsi et al, 2012). However, food deserts are often defined at an aggregate level by comparing availability at the census tract or block (Capsi et al, 2012).

Density is an alternative measures for availability that is defined at the household level by using geographic system information (GIS) to draw a buffer around a household, and then count the number of various food stores within that boundary (Capsi et al, 2012). In the case that availability is measure by density, the findings on the relationship between access and a healthy diet are mixed (Capsi et al, 2012). While there are many indicators of a healthy diet fruit and vegetable intake is the most popular, yet, studies considering fruit and vegetables have conflicting results and even when there was a significant result the magnitude of the finding is small (Capsi et al, 2012; Larson et al, 2009; Thornton et al, 2012).

Accessibility is another dimension of access that indicates the geographic ease of accessing food outlets. This is often measured at the household level, using the distance from home to the nearest supermarket, or grocery store as the measure for accessibility (Aggarwal et al, 2014; Dunn et al, 2014; Capsi et al, 2012; Inagami et al, 2006). Although some studies use the centroid of a census unit to proxy for the location of a household (Capsi et al, 2012; Inagami et al, 2006). One weakness of this method, is that it is generally unknown whether or not the household actually shops at the nearest store (Aggarwal et al, 2014). Accessibility is often used when trying to asses the relationship between household level access and fruit and vegetable consumption, however, this dimension produces even more inconsistent findings than availability, and very often no relationship can be established (Capsi et al, 2012; Dunn et al, 2012; Ball et al, 2009). In one review, of the thirteen papers that looked at accessibility and fruit and vegetable consumption 7 found no relationship, and one found increase consumption when living further from a grocery store (Capsi et al, 2012).

Being able to identify what, if any, effect access, either to supermarkets or restaurants, has on household consumption, and diet composition is an important step in understanding what interventions are necessary to help improve dietary outcomes. This is particularly true for low-income neighborhoods which are disproportionately affected by disparities in access, and may have lower consumption rates of healthy foods. Using the current body of literature has resulted in the justification of building of new grocery stores to improve fruit and vegetable consumption, but with very limited success (Cummins and Macintyre, 2002; Wang et al, 2007; Sadler et al, 2013). This may suggest that the relationship between access and consumption is more complicated than currently theorized.

There are many challenges in identifying the relationship between access and consumption, previous literature has focused on the potential confounding effects that perception of the food environment, and level of spatial aggregation utilized in defining availability and access (Thornton et al, 2012; Blitstein et al, 2012). There has also been concern that the empirical models utilized to analyze this relationship are not spatially explicitly, and this point will be addressed later in the paper (Papas et al, 2007; Day and Pearce, 2011; Sadler et al, 2011). First, this paper will address the basic theoretical framework used to investigate the relationship between access and consumption of fruits and vegetables.

In the past, the interest between access and fruit and vegetable consumption has come from a body of literature that identified disparities in access to heathy foods, consumption of healthy food, and health outcomes (such as obesity). Since consumption of healthy foods such as fruit and vegetables are related to health outcomes, the question of whether access was tied to lower fruit and vegetable consumption and thus health outcomes arose. However, in practice the definition of access has been limited to physical proximity to a food store and the choice of fruit and vegetables as an outcomes ignores the decision making process of the household which may be affected by many factors, including preferences, income, and access.

A first step in further detangling the relationship would be to introduce a theoretical model that can be used to incorporate multiple dimensions of access, model their interactions, and motivate an empirical model. This paper purposes the use of the household production model to better incorporate multiple dimensions of access, and to potentially identify reasons as to why previous literature has been unable to find a relationship between access and fruit and vegetable consumption and identify the potential greatest barriers to healthy eating.

# 3 Household Production Model

The discussion of the effect of access on fruit and vegetable consumption is indirectly addressing the determinants of fruit and vegetable demand. However, since fruits and vegetables are often consumed as part of meals rather than purchased, using fruits and vegetables alone as an outcome my be inadequate when considering the effects of the food environment (i.e. access to grocery stores to restaurants).

Traditional models of demand would consider the demand for a goods, such as fruits and vegetables, where demand is determined by a utility function, $V(X)$, which represents a household preferences, and income constraint $PX = Y$, where $Y$ represents household income, and $P = (p_1, ..p_k)$ the price of good $X = (x_1, .., x_k)$. The traditional model has two potential weaknesses when analyzing the relationship between access and consumption. First, it does not consider the cost of time, and second, it does not acknowledge that households may not derive their utility directly from the good, but rather indirectly through the commodity the good is used to produce (Becker, 1965; Pollak and Wachter, 1975).

These weakness of the traditional demand model was recognized in the household production model developed by Becker (1965). The purpose of his paper was to develop a model that could incorporate the cost of time as a constraint, in much the same way as was traditional done with income. So in the household production model, there are two resource constraints: time and income:

$$\sum_{i=1}^{m} p_i q_i = wT_w + Y \tag{1}$$

$$T_w + \sum_{i=1}^{m} T_i = T \tag{2}$$

Equation 1 contains the income constraint, where $w$ refers to the wage rate, $T_w$ refers to the amount of time spent working, and Y refers to unearned income. Equation 2 contains the the time constraint, which contains the time spent working and $T_i$ is the time spent on each commodity. T represents the total amount of time in the time frame of interest, which could be a day ($T = 24$ hours) or a week ($T = 7$ days). These constraints can capture several dimensions of access including affordability in the income constraint, and accessibility in the time constraint. While accessibility is generally measured in terms of distance, this distance also carries with it a time cost, which is a function of both distance and mode of transportation. Clearly longer distances will have relatively higher time cost, but this cost may be mitigated by the mode of transportation. For the same distance, walking will have the highest time cost, and driving the lowest time cost. Mode of transportation is an often over looked component of accessibility, but will be important as it implies the same distance could have a different time cost, and thus different measure of accessibility, for different individuals. This variation could be related to socioeconomic status, as wealthier individuals are more likely to own cars and thus have lower time costs.

Time cost will also be affected by the destination, whether it's a restaurant or grocery store. But to further expand on this point we need to introduce the concept of commodities, $Z = (z_1, ...z_{,m})$, which are produced from goods, $X = (x_1, .., x_k)$, and time in a household production function, $Z = f(X, T)$. Where the production function also represents a technology constraint, since households cannot consume more commodities than they can produce. Instead of households deriving utility from goods, they derive utility from commodities, $U(Z) = [z_1(x_1), z_2(x_2), ..z_m(x_m)]$. In the context of food consumption and access, the goods would be fruits, vegetables, protein, pasta, etc. and the commodities are meals. The advantage of using commodities is that it can reflect the effect changes in demand that are a result of changes in technology (Becker, 1965). Prior to the Becker model changes in demand could only be explained with changes in preferences. Incorporating technology into demand will be important in the investigation of changes in consumer demand for meals.

There are two important categories for meals which could be affect by technology and time costs: food at home (FAH) and food away from (FAFH). As technology has decreased the time it has taken to produce meals by increasing the availability of ready made meals, it may have lead individuals to shift their demand away from raw inputs such as fruits and vegetables and towards less healthy ready made meals. On the other hand, increasing demands for time may have lead individuals to increase their consumption of food away from home meals, as meals at restaurants and fast food establishments have a much lower time cost relative to cooking at home. Households determine their optimal levels of consumption by maximizing their utility subject to the production function, time and income constraints. Thus, optimal levels of consumption are a function of prices, time costs, as well as other attributes of preferences.

Using a model that captures a more complete picture of the household decisions process in regards to consumption may show why empirical models that only use fruit and vegetable consumption fail to find any relationship between access and consumption. Utilizing food security and obesity as outcomes to the model may help to better identify the negative effects of limited access since it is affected by changes in FAFH, FAH, as well as the various goods related to consumption: fruits, vegetables, protein etc.

# 4 Data

The data for this study comes from the Dan River Partnership for a Healthy Community (DRPHC), a community academic partnership in the Dan River Region (DRR) and consists of an audit of grocery stores, supermarkets, and restaurants using the Nutrition Environment Measures Survey (NEMS) as well as household survey data. For both, physical addresses were collected making it possible to geocode their location, and create a point referenced dataset. The DRR consists of three counties in the south central Virginia and north central North Carolina. While all three counties are classified as rural by the USDA Rural Urban Community Area Codes (RUCA), the area also contains one mid-size regional city of approximately 43,000 residents and another smaller town of approximately 10,000 residents (Hill et al., 2014). The area is predominately white, low-income, and is federally designated as a medically under-served area/population (MUA/MUP) (Hill et al., 2014).

The household level data was collected via a telephone survey, which sampled listed and unlisted numbers, and both landlines and cellphones (Hill et al., 2014). The survey utilized random proportional sampling based on the population of the three counties and two cities, which resulted in a final sample size of 784(Hill et al., 2014). The survey was modeled after the Virginia and National Behavioral Risk Factor Surveillance System (BRFSS) surveys for 2011(Hill et al., 2014). It included modules to assess, demographics, socioeconomic status, assess physical activity, fruit and vegetable consumption and self reported weight and height which can be used to calculate body mass index (BMI). The survey also included the six item short form of the U.S. Household Food Security Survey Module.

The store level data was collected two stages, and is described in greater detail in Chau et al (2013). In the first stage, food outlets in the DRR were identified using a database of active permits to sell food, which is provided by the Virginia Department of Health. Those outlets that served a worksite or school, or did not serve the public were excluded. This list was divided into stores and restaurant, and then categorized by the NEMS classifications, which included two main category for stores and three main categories for restaurants. A fourth category was created for this study which included restaurants that served hot extras as a secondary function (ex. coffee houses) (Chau et al, 2013).

In the second stage, food outlets were evaluated using the NEMS surveys (Glanz, et al., 2007; Saelens et al., 2007). The purpose of the NEMS study is to assess the food environment as it relates to factors that would affect food choice: price, availability, and cues related to healthy food purchase (Saelens et al., 2007). There are two NEMS surveys: NEMS-S for food stores (i.e. grocery stores, convince stores) and NEMS-R for restaurants (i.e. fast food, full service), for both, higher scores indicate higher quality. NEMS-R classifies restaurants based on North American Industry Classification Systems (NAICS) standards into two categories: fast food restaurants and sit down restaurants (Saelens et al., 2007). Fast food restaurants are defined by limited service, and paying prior to eating while sit down restaurants are defined by table ordering and full service. The survey considers the availability of multiple menu items (including entrees, main dishes, side dishes etc), and their healthfulness (based on government standards); facilitators of healthy eating (availability of nutrition information on menus, labeling, reduced portion sizes etc); barriers to healthy eating (larger portions, all you can eat options, etc); as well as comparative prices for healthy versus unhealthy options (Saelens et al., 2007).

The focus of the NEMS-S survey is to asses the availability of more healthful or recommend choices; the quality of produce; and relative prices (Glanz, et al., 2007). The survey includes ten indicator food categories: fruits, vegetables, milk, ground beef, hot dogs, frozen dinners, baked goods, beverages, whole grain and baked chips. Fruits and vegetables were chosen based on national food sales and food consumption data to identify the top ten most commonly consumed fruits and vegetables, excluding potatoes (Glanz, et al., 2007). They also included an assessment of quality in the form of a binary acceptable variable, which was based on a visual inspection for bruising looking old, over ripened or spotted. The cost variable included the non sale price per pound of fruits and vegetables, as well as price for healthier and their regular food options.

Previously, the dataset was utilized in two papers, one which consider rural urban health disparities and another that considered disparities in the availability of healthy food by census block (Hill et al., 2014; Chau et al, 2013). Hill et al (2014) utilized the household survey data and found that when compare urban and rural residents based on race and BMI, severe obesity is worse for black and urban residents (Hill et al., 2014). They also found some differences in likelihood of meeting fruit and vegetal or physical activity recommendation by gender and and education level, with females and individuals with a college degree being more likely to meeting both recommendations (Hill et al., 2014). Chau et al (2013) describes the audit of the retail stores and restaurants, and utilizes the the store level information to assess disparities in access by block group race. They found a significant difference in the availability of health food by restaurant type. There was also a low availability of healthy foods in low-income and predominately black block groups, while middle to high income white block groups had the highest availability, although these difference were not statistically significant (Chau et al, 2013). This paper will build on these previous papers by combining the household level survey data with the data on food retailers to investigate the effects of access on household level outcomes.

# 5 Methods

Table 1 contains the summary statistics for the dataset. From this we can see that for most individuals in the sample, the nearest store to their home is a convince store,42.44%, followed by a sit down restaurant, 22.02%, and then fast-food restaurant, 18.33%. For only 7.38% of the sample was a grocery store the closest food retailer. Given the potentially lower quality of food associated with restaurants and convince stores, and the lower time cost associated with these stores types, it could have potential implications for consumption and health outcomes. Unfortunately, one weakness of this dataset, like many others, is that we do not have information on where individuals make food purchases, thus our investigation will focus on the effects of the food environment on consumption and health outcomes.

In this preliminary analysis we focus on the effects of the food environment, and access on obesity, and utilize the household production model to help specify our models. In this first model, we limit the definition of access to accessibility, and consider grocery store accessibility, which is measured by the distance from the home to the nearest grocery store. Poor accessibility would be represented by longer distances, so we would hypothesize that a significant positive effect for distance to the nearest grocery. In the second model, we address a previous weakness of accessibility papers which treats all grocery stores as equal by including the NEMS score of the nearest grocery store. NEMS score capture both the quality of the food available in the grocery store, as well as prices, both of which are important attributes in the household production model which theorizes that consumption decision are affected by preferences (which may be related to the quality of food available) as well as the prices of food. Finally, we expand the definition of access to try to capture availability, another dimension of access. In this preliminary model, we utilize dummies variables to indicate the store type closet to the household. These stores will have a relatively lower time cost since they require less travel, and if they are restaurants, this may further lower their time cost for meal production. They also begin to capture the effect the larger food environment has on individual level outcomes.

In all three models of accessibility, we also consider two empirical forms of the model. The first is a simple linear regression model, which would be biased in the presence of spatial clustering. The second empirical form is a hierarchical model, is a first attempt at address potential clustering in the model, since the hierarchical models is a linear regression with two levels (Cameron and Trivedi, 2005). In this model, a second level is specified at the county level which controls for the effect of clustering which occurs when individuals who live in the same county act more alike, then those across countries.

Additionally, in all three models we control for a variety of covariates that previous research, and the household production model would indicate are important determinants of consumption choices and health outcomes. These variables include race, age, sex, as well as employment status, income, and level of education.

# 6 Results

Table 1 provides the preliminary results for the effects of access on BMI. The three previously discussed models are presented, however, only the results for linear regression are included as they were no different from the results for the mixed models. The results from this table show that regardless of how access was defined, it had no effect on BMI. This could indicate that BMI may be a distal outcome for access, since it is also affected by physical activity. Thus, it will be necessary to next consider alternative outcomes, such as fruit and vegetable consumptions, as well as food security, which may be more sensitive to the effects of access. Additionally, we will work to better identify variables, such as density, that can better capture the availability dimension of access.

# 7 Tables

Table 1: Summary Statistics

| | Mean(SD) |
|---|---|
| BMI | 29.01 |
| | (6.43) |
| *BMI Categories* | |
| Under Weight(%) | 1.02 |
| | (10.03) |
| Normal(%) | 27.28 |
| | (44.57) |
| Overweight(%) | 33.63 |
| | (47.27) |
| Obese(%) | 31.35 |
| | (46.42) |
| Morbidly Obese(%) | 6.73 |
| | (25.06) |
| *Demographics* | |
| Male(%) | 23.86 |
| | (42.65) |
| Female(%) | 76.14 |
| | (42.65) |
| Age | 55.95 |

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**Table 1–continued from previous page**

| | Mean(SD) |
|---|---|
| | (17.18) |
| Caucasian | 60.52 |
| | (48.91) |
| African American | 34.81 |
| | (47.67) |
| Other or Multiracial | 2.71 |
| | (16.24) |
| *Employment Status* | |
| Employed(%) | 29.77 |
| | (45.75) |
| Unemployed(%) | 7.01 |
| | (25.55) |
| Retired(%) | 32.10 |
| | 46.72 |
| *Highest Level of Education* | |
| Less than Highschool(%) | 17.36 |
| | (37.90) |
| Highschool or GED(%) | 35.96 |
| | (48.02) |
| Some College(%) | 30.79 |
| | (46.19) |
| College(%) | 15.89 |
| | (36.58) |
| *Income Leve* | l |
| Less than \$20,000(%) | 45.36 |
| | (49.82) |
| Between \$20,000 and \$50,000(%) | 33.67 |
| | (47.29) |
| Greater than \$50,000(%) | 20.97 |
| | (40.74) |
| *Nearest Store Type* | |
| Grocery Store(%) | 7.38 |
| | (26.16) |
| Convenience Store(%) | 42.44 |
| | (49.45) |
| Other(%) | 3.44 |
| | (18.25) |
| Fast Casual Restaurant(%) | 6.40 |
| | (24.48) |

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**Table 1–continued from previous page**

| | Mean(SD) |
|---|---|
| Fast Food Restaurant(%) | 18.33 |
| | (38.71) |
| Sit Down Restaurant(%) | 22.02 |
| | (41.46) |
| *Distances in miles, to nearest retailer by type* | |
| Any Type | 1.55 |
| | (1.67) |
| Grocery Store | 3.67 |
| | (3.82) |
| Fast Food | 2.81 |
| | (2.91) |
| Any Restaurant | 1.85 |
| | (1.85) |
| NEMS score of nearest grocery store | 21.45 |
| | (7.84) |

Table 2: Effects of Access on Obesity

| | |
|---|---|
| *Model 1: Grocery Store Accessibility Only* | |
| | Coef(SE) |
| Distance (in miles) to nearest grocery store | -0.084 |
| | (0.066) |
| *Model 2: NEMS* | |
| Distance (in miles) to nearest grocery store | -0.049 |
| | (0.208) |
| NEMS score of nearest grocery store | 0.043 |
| | (0.044) |
| Distance X NEMS | -0.002 |
| | (0.009) |
| *Model 3: Grocery Store Accessibility + Availability* | |
| Distance (in miles) to nearest grocery store | -0.103 |
| | (0.069) |
| Nearst food retailer is a store | 1.184 |
| | (0.982) |
| Nearest food retailer is a restaurant | 1.051 |
| | (0.970) |
| *= $p$ <.05 **= $p$ <.01 ***= $p$ <.001 | |
| *Note the following variables were controlled for: gender, race, education, income, employment status* | |

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