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Featured Article

Measuring Food Access and Food Deserts for Policy Purposes†

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Abstract *Policymakers have dedicated increasing attention to whether Americans have access to healthful food. As a result, various methods for measuring food store access at the national level have been developed to identify areas that lack access. However, these methods face definitional, data, and methodological limitations. The focus on neighborhoods instead of individuals underestimates the barriers that some individuals face in accessing healthy food, and overestimates the problem in other neighborhoods. This paper reviews and critiques currently available national-level measures of food access. While multiple measures of food access are needed to understand the problem, we recommend greater attention be paid to individual measures of food store access.*

Key words: Policy targeting, food deserts, food access, poverty.

JEL codes: I14, I18, Q18.

Some low-income neighborhoods in the United States have been dubbed "food deserts" because of a dearth of supermarkets or other food retailers that offer a full range of affordable and nutritious foods. H.R. 2419 (ENR) - An Act to Provide for the Continuation of Agricultural Programs Through Fiscal Year 2012, and for Other Purposes. May 20, 2008. https://www.govtrack.us/congress/bills/110/hr2419/text. Residents of these neighborhoods, especially those who lack transportation or are poor, may be more reliant on smaller neighborhood stores that do not carry a full range of groceries or may offer items at higher prices. As a result, some residents of food deserts may face substantial barriers to eating a healthy diet; these barriers may be related to higher rates of obesity, diabetes, and other diet-related diseases in these communities.

†*The views in this paper are those of the authors and do not necessarily reflect the views or policies of the U.S. Department of Agriculture.*

There is evidence that food access limitations exist, at least for a small percentage of the population (USDA 2009). However, neither the concept of food deserts nor how they are measured has been well-established (Bitler and Haider 2010; USDA 2009). No consensus exists regarding what it means to lack access to healthy food. Much of the focus has been placed on the proximity of sources of healthy food and the resources (income, vehicles) that consumers use to travel to stores. Others have focused on the balance of healthy food sources relative to less healthy food sources, or the relative ease and price of choosing healthy food compared with unhealthy foods. Policy interventions and research have focused on *areas* that lack access, while little attention has been paid to *individuals* who lack access and whether they are concentrated in neighborhoods or are dispersed. The focus on areas has almost entirely been on low-income areas (see Larson et al. 2009 for a summary of the literature), but not everyone in low-income areas has low-income; some may have adequate resources (e.g., sufficient income or a vehicle) to easily overcome any access barriers. Further, some low-income individuals and households without vehicles may live in higher income areas, which are usually ignored in measuring food access.

Despite these measurement concerns, policymakers are moving forward with programs to reduce barriers to access. For example, the Pennsylvania Fresh Food Financing Initiative uses funds provided by the state, leveraged with funds from private organizations, to provide grants and loans to develop grocery stores in underserved areas throughout the state (TRF 2014). This program has been underway since 2004 and has served as a model for other programs in New York City, New Orleans, and California. As part of the First Lady's *Let's Move!* Initiative, three federal agencies—The Department of Agriculture, the Department of Health and Human Services, and the Department of Treasury—have developed programs to fund the development of healthy food retail outlets in food desert communities (http://www.letsmove.gov/healthy-communities). Moreover, President Obama's proposed 2015 budget includes almost $50 million to promote the development of healthy food outlets (U.S. Office of Management and Budget 2014).

These policy initiatives rely on measures of food access to describe how many people are affected, target policy interventions, and monitor whether food access is improving over time. A number of researchers and organizations have developed measures that have been used by policymakers, but these measures have different motivations that may be more appropriate for some policy purposes than others (FRAC 2011; Social Compact 2011; TRF 2011; USDA 2009; USDA 2013; Ver Ploeg et al. 2012). As a result, key gaps exist in assessing the scope and nature of the problem of food access, particularly to support policy initiatives.

This paper identifies and discusses some of these gaps, with a focus on implementing food desert and food access measures on the national level. The first section of the paper briefly describes the types of food access measures that have been implemented nationally, and presents estimates of how many Americans may face barriers to accessing healthy foods. The second section critiques these measures. The final section of the paper outlines new directions and enhancements to food access measurement to support and inform policy.

Types of Food Access Measures

The primary concern over food access and food deserts is that some populations may not be able to regularly obtain healthy foods because the foods are not available where they live, or they do not have other means to travel to places that sell healthy foods.[1] Most food access measures combine a population characteristic with a food retailer characteristic to create a measure of food access. Box 1 shows examples of how population characteristics (first column) are combined with food retail characteristics (second column) to create food access measures (examples in the third column). For example, one food access measure uses the population characteristic of households without vehicles and combines it with the presence or location of a supermarket to measure the number of households without a vehicle that are some distance from a supermarket (Ver Ploeg et al. 2012). Another measure uses the population density of an area and combines it with the square footage devoted to grocery retail in an area to produce a per capita measure of grocery retail space (Social Compact 2011). Population characteristics roughly correspond to factors that may be considered demand side. Retailer characteristics, on the other hand, correspond to supply side factors, while the interaction of these two creates food access measures that have both demand- and supply-side aspects. It should be noted that the demand- and supply-side factors are not exogenous—retailers consider population characteristics in choices about location, products, and store types, while individual households consider retail amenities in decisions about where to live.

As box 1 shows, food store access measures can be estimated at the individual level or for areas. An individual measure considers access by an individual (e.g., vehicle availability, how long it takes to get to a healthy food source, or perception of food access limitations). An area-based measure considers the access of a neighborhood or specific geographic boundary. A "food desert" is an area-based measure. A second distinction is whether the measure is relative or absolute. A relative measure of access examines the distribution of access for the population of interest, and designates individuals (or areas) as having "inadequate" access if they have relatively worse access than the rest of the population of interest. For example, a relative measure of access could designate anyone who lives farther than the median distance to a supermarket as having inadequate access. An absolute measure, on the other hand, considers a fixed standard of access and designates anything below that standard as "inadequate." For example, an absolute measure of access could designate anyone more than 1 mile from a store as having inadequate access. Both relative and absolute measures can be applied to individual- or area-based measures.

Individual Measures of Access

A number of individual measures have been used to examine access to healthy food on the national level, including direct questions that ask individuals about their food access. For example, the National Food Stamp

[1] *This concept is different from food insecurity, which does not focus on accessing healthy foods specifically, but rather focuses on whether a family can afford to obtain enough food for an active, healthy life. A food insecure household that lives next door to a store selling affordable, high quality foods would not have trouble accessing healthy foods, but may have trouble affording enough food. Lack of access to a healthy food source could contribute to food insecurity.*

Box 1 Components of Food Access Measures and Examples of Food Access Measures

	Population Characteristic	+ Store Characteristic	= Food Access Measure
Individual level	Residence and work location; travel patterns Resources – income, vehicles Preferences – race/ethnicity; education Other factors – disability, age Perception (perceived access)	Store location Type Size Prices Competition	1) Households without vehicles that are > .05 miles from a supermarket. 2) Survey question to individuals about whether getting to a store is difficult.
Area-level (for given geographic level)	Population density Poverty rate – average/median income Percentage without vehicles Percentage minority or elderly	Square footage Store counts Average prices Ratio of healthy to unhealthy food	1) Low-income areas where residents are more than 1 mile from a supermarket. 2) Low-income areas where the square footage of supermarkets /capita are relatively low compared with other low-income areas.

Participant Survey of 1996–1997 (NFSPS) asked survey respondents questions about how far they were from the nearest supermarket, where they typically did their food shopping, how often they shopped for food, and what travel modes they used to get to the stores (Ohls et al. 1999). The 2001 Food Security Supplement of the Current Population Survey (CPS) also asked households whether they had enough food, or enough of the kinds of foods they wanted and, if not, whether access to a store or lack of food in a store were the underlying reasons.[2] More recently, a Gallup survey asked a national sample of households a question about the ease of obtaining affordable fresh fruits and vegetables (Food Research and Action Center 2011). Perceptions of food availability have also been measured using direct survey questions (Moore et al. 2008). Finally, time-use data have been used to measure how much time is spent travelling to grocery stores. The NFSPS directly asked sample members how long it took them to get to the store in which they did their usual grocery shopping, while American Time Use Survey data, which collects time diaries from a large, nationally representative sample, have also been used to examine the time spent traveling to grocery stores, the chain of travel (from home, work, or other places), mode of transportation, and other characteristics of grocery shopping trips (USDA 2009).

Other individual-level measures of food access are indirect. These include measures of how close an individual is to food retailers, whether a vehicle is available for regular use at the household, and a combination of both factors. The 2012 report by the USDA Economic Research Service (ERS) provides estimates for such measures (Ver Ploeg et al. 2012).[3]

Area-based Measures of Food Access

Area-based measures of food access are the most widely-implemented measures of food access. Much of the literature has focused on area-based measures to assess how the food environment affects diet and related health outcomes (Larson et al. 2009). But area-based measures have also been used to assess the extent of limited access and the degree to which the problem of limited access is concentrated, as well as where it is concentrated (TRF 2011, 2012; USDA 2009; Ver Ploeg et al. 2012).

Commonly-used area-based measures include neighborhood-level measures of the distance to a store, the number of stores, availability of shelf space devoted to specific food items, and square footage of grocery retail. Some measures also include vehicle availability rates for an area (TRF 2011, 2012). Estimates of the amount of leakage for an area—that is, estimates of grocery sales in an area subtracted from the estimated expenditures on groceries by residents in the same area—have also been used (Social Compact 2011; TRF 2011, 2012). Finally, some studies have used the ratio of healthy to unhealthy food sources as a measure of food access (Gallagher 2007).

Food prices are likely to be a major determinant of food shopping behavior, especially for low-income consumers. The price of food is an important part of food access because it is likely that prices will be more competitive

[2]*These questions were part of the Food Security Supplement and were asked in previous years, but have not been asked since 2001.*

[3]*In practice, these measures are quasi-individual measures since the precise locations of individuals without vehicles are not known and thus, their distance to the nearest supermarket are estimated based on the area in which they live.*

with higher concentrations of food stores. Price measures for a basket of goods, or specific goods offered at different store types in a neighborhood have been used as indicators of affordability. These studies have mixed findings on the extent to which food prices in some neighborhoods vary (Block and Kouba 2006; Hayes 2000). Many of these studies use offered prices, not prices paid. For example, Broda et al. (2009) examine differences in prices paid for the same food items across income levels and find that many, but not all, low-income consumers pay less for the same food items than higher-income consumers. There may be time, travel, and other search costs for low-income consumers to find these low prices, which may pose additional barriers to accessing food.[4]

Box 2 Summary of National-level Measures of Food Access Used to Guide Public Policy

USDA 2009 and Ver Ploeg et al. (2012)

Relative and absolute measures of food access based on distance to sources of healthy food and vehicle availability. Supermarkets, supercenters, and large grocery stores used as proxies of sources of healthy and affordable food. Directory of stores developed by USDA using two lists of stores from 2010 for the 2012 analysis, and 2006 for the 2009 analysis. Population data for 2012 come from the 2010 Decennial Census and 2006 to 2010 American Community Survey; for 2009, population data come from the 2000 Decennial Census. Population data aerially allocated to .05-km square grids for entire United States for 2012 and 1-km square grids for continental United States for 2009. Distance measured from the geographic center of each grid to the nearest supermarket used to approximate access for people who live in that grid. Estimates presented for the entire United States and for population subgroups based on vehicle access, individual income, and area income.

Food Desert Locator (ERS 2011)

Absolute measure identifying low-income census tracts with substantial numbers or shares of individuals far from a supermarket as food deserts. Uses same data as USDA 2009. Also uses USDA grid-based measures of distance. Tracts qualify as low-income tracts if they meet the NMTC program eligibility criteria. Low-access is defined as more than 1 mile from a supermarket or large grocery store in urban areas and as more than 10 miles from a supermarket or large grocery store in rural areas. To be considered a food desert tract, at least 33 percent of the tract population or at least 500 people in the tract must have low access to a supermarket or large grocery store.

Food Access Research Atlas (ERS 2013)

Maps for absolute measures of food access for both low- and high-income census tracts. Three measures use different benchmarks for distance to the nearest supermarket, supercenter, or large grocery store to measure low-access census tracts, with separate distance benchmarks for rural and urban tracts. One of these three defines low access as a census tract where a substantial number (at least 500 people) or share of residents (at least 33%) is more than 1 mile from the nearest store (urban) or more than 10 miles in rural areas—a measure that is consistent with the measure in the Food Desert Locator. The other two distance measures use a .05 miles demarcation in urban areas and 10 miles in rural areas, or 1 mile in urban areas and 20 miles in rural areas. A fourth measure directly considers household vehicle availability. Under this measure, a tract is considered low access if a significant number of households without vehicles are more than .05 miles from a supermarket or a significant number or share of people are more than 20 miles from a supermarket. All 4 measures use the same data as

Ver Ploeg et al., 2012, and the same .05 km-square grid population estimates. Tracts are considered low-income if they meet the New Markets Tax Credit (NMTC) program eligibility criteria.

The Reinvestment Fund (TRF) Low Supermarket Access areas (TRF 2012)

This is a relative measure of areas with low access to supermarkets (LSA's) and a tool for mapping these areas. The LSAs are clusters of low- and moderate income (median income at or below 120 percent of the metropolitan area's median income level) census block groups whose residents are farther from supermarkets than residents in higher-income block groups that are otherwise similar in terms of population density and car ownership rates (with block groups classified into one of 8 density categories, and for some of these density categories, subcategorizations by car-ownership rates). 2000 Census data on population characteristics and 2011 Trade Dimensions data on supermarkets are used. The difference between the distance to a supermarket for the high income block group and low-moderate income block group, within one of the 13 density/car ownership categories, is used to assign each low-moderate income block group an access score based on the difference between the block group's distance to the nearest supermarket and the benchmark for that category. Block groups clustered around other block groups with similar scores are classified as Low Supermarket Access areas (LSAs). To measure which LSAs may support a supermarket, estimates of the amount of grocery leakage are estimated, which is the difference between estimates of grocery demand in the LSA (estimated using Consumer Expenditures survey data) and the amount of grocery sales in the area.

CDC's Healthy Tracts

A census tract-based approach published in the 2009 State Indicator Report on Fruit and Vegetables (USDHHS, 2011). The Healthy Tracts measure considers a census tract healthy if there is a healthy food retailer within .05 miless of the tract boundary. A healthy food retailer is one that typically carries fruits and vegetables—supermarkets, large grocery stores, warehouse clubs, and fruit and vegetable markets. The state-level indicator is the percentage of state census tracts containing healthy food retailers. Data are taken from a U.S. Department of Homeland Security Database, which is derived from Dun and Bradstreet commercial data (USDHHS, 2011).

Most area-based measures of access have been implemented at the local level, although a few have now been implemented nationally. These measures include those based on the 2009 USDA Report to Congress and its 2012 update (Ver Ploeg et al. 2012), related methods developed for the ERS Food Access Research Atlas (a web-based mapping tool for food access data (USDA-ERS 2013)), a "Healthy Tracts" designation developed by the Centers for Disease Control and Prevention (CDC), and a measure developed by the community investment group The Reinvestment Fund (TRF 2011). Each of these measures is described in box 2.

Table 1 provides estimates from these different national-level measures of the number and percentage of people and areas with limited food store access. The table shows a wide range of estimates; the TRF methods estimate that about 25 million people (8.8% of the population) live in areas with limited access to supermarkets. The ERS estimates vary widely across the measure used. Not surprisingly, the shorter the distance used as a benchmark for access, the greater the number and percentage of people who fall

[4] *See Rose et al. 2009 for estimates of the time/travel costs for different modes of transportation.*

Table 1 Estimates of the Number of People and Households with Limited Access to Healthy Food Options Using Different Methods.

	Food Access Measure	Number of people (p)/ households (hh) with limited food access	Percentage of total population (p) or of total households (hh)	Year of data for estimate
Area measures	TRF's Limited Supermarket Access areas[1]	24.6 million (p)	8.8 (p)	2000 population 2005–09 income 2011 store data
	USDA's Food Access Research Atlas			
	.05 and 10 mile measure	52.4 million (p)	17.0 (p)	2010 population
	1 and 10 mile measure	18.3 million (p)	5.9 (p)	2006–10 income & vehicle data
	1 and 20 mile measure	16.4 million (p)	5.3 (p)	
	No vehicle > .05 miles or > 20 mile measure	2.1 million (hh) 0.3 million (p)[2]	1.8% (hh) 0.1% (p)	2010 store data
	USDA's Food Desert Locator[1]	13.6 million	4.9 (p)	2000 population 2006 store data
	CDC's Healthy Tracts[3]	18,340 (tracts)	38.0 (of all census tracts)	2000 census tracts 2007 store data
Individual measures	Households with self-reported store access limitations to obtaining the food they need/want (USDA 2009)	NA	5.7 (hh)	2001 Current Population Survey Food Security Supplement
	FRAC/Gallup 2011 survey on the ease of obtaining affordable fresh fruits and vegetables	NA	8.2 (hh)	Gallup Survey covering 2008–2010

Notes: [1]*Excludes Alaska and Hawaii;*
[2]*Vehicle statistics refer to households, > 20 mile statistics refer to people;*
[3]*Number or percentage of census tracts without a healthy food retailer.*

outside of that benchmark. Using the half-mile and 10-mile benchmarks results in 52.4 million people (about 17% of the population) having limited access, in contrast to 16.4 million people when the 1-mile and 20-mile mile benchmarks are used (about 5.3%). When vehicle availability and distance to the nearest supermarket are considered, however, the estimates are much lower. Almost 2% of all households do not have a vehicle and live in low-income areas more than one-half mile from a supermarket; using the same measure, 0.1% of people live in low-income areas more than 20 miles from a supermarket. These wide differences reflect the general finding that accounting for vehicle availability makes a huge difference in estimates of the number of people who may be affected by limited food access (Ver Ploeg et al. 2012; USDA 2009). The CDC's Healthy Tracts measure, which is broad in that it considers all census tracts, not just low-income ones, estimates that almost 40% of all census tracts do not contain a healthy food retailer (estimates of the number of people in these tracts is not provided) (USDHHS, 2011).

These numbers contrast with estimates from direct individual-level measures described above. An estimated 5.7% of U.S. households reported that they did not always have enough food, or enough of the kinds of foods they wanted because of store access or store offerings, according to 2001 CPS data. The FRAC/Gallup survey data estimated that 8.2% of households reported that it was not easy to purchase affordable fresh fruits and vegetables (FRAC 2011).

Critique of Food Access Measures for Policy Purposes

This section presents a critique of currently-available measures of food access. We first critique individual measures of food access, followed by area-based measures of food access. Our critique is specifically oriented around issues that result from the use of these measures in national policy monitoring and targeting purposes. Policy monitoring entails describing and tracking over time the number of people and neighborhoods with limited access to healthful foods. Descriptive and monitoring measures help us understand the nature of the problem of limited food access, as well as detect changes in food access for populations or neighborhoods that may need to be addressed and, more broadly, provide part of the many statistics the federal government produces to monitor the nation's well-being. Measures are also needed for targeting purposes—to assess for whom and where policies to reduce barriers to food access should be targeted and how they should be evaluated—that is, assessing which individuals or areas are most in need and measuring how well the policies meet that need. We do not specifically examine access measures used to understand the relationship between the food environment and food spending, diet, and health.

Food Access Measures Focus Too Much on Area-based Measures Instead of Individual-level Measures of Food Access

A major weakness of current food access measures is that they are almost exclusively area-based measures. Such measures often infer that everyone in the same area has the same access to healthy food, usually by focusing only on low-income areas or because measures of proximity are made for neighborhoods. In reality, individual access varies within areas. Individuals

have different resources (income, access to a vehicle, social and family networks, and time), and these differences are likely to translate into differences in access. For example, while two neighbors may be about the same distance to a supermarket, their ability to access that supermarket is likely more affected by whether they have access to a vehicle.

Two individual-level measures that directly measure food store access have been implemented nation-wide: the now-dated CPS questions about food sufficiency, and the Gallup Poll questions about the ease of access to affordable fruits and vegetables. These two questions are a step in the right direction, but neither is an ideal measure of food access limitations. Gallup's FRAC question considers fresh fruits and vegetables, but no other healthy foods. Further, it does not separately measure access limitations from food insecurity (e.g., some very poor individuals may not be able to afford as much healthy food as they would like regardless of their level of access to healthy foods). The CPS measure, while better, is also not ideal because respondents are asked about the kinds of foods they want, for which respondents may include both healthy foods and less healthy foods, or foods that are more of a luxury.

Area-based measures require defining the area unit of analysis—the neighborhoods or geographical areas on which to focus (e.g., census blocks/block groups/tracts, zip codes). This choice matters because of the Modified Areal Unit Problem (MAUP): there is an infinite number of ways to aggregate data over areas, and different aggregations will likely yield different results in how the characteristics of areas are correlated with the outcomes of interest (Openshaw 1984). Measures of the presence of a healthy food store, or the amount of store retail space within a geographic area are subject to MAUP because the choice over which areas to aggregate can greatly affect estimates of access; if the area of aggregation is large enough, there is a greater probability that at least one source of healthy food is available. On the other hand, if the area unit used is small enough, it may seem like very few areas contain adequate sources of healthful food. The grid-based approach used by the USDA (2009) and Ver Ploeg et al. (2012) reduces MAUP problems because the grids provide greater precision in estimating how far people and households are from stores than does using larger geographic areas such as census tracts. The process of allocating census data to 1-square-kilometer grid cells (in 2009) or .05-square-kilometer cells (in 2012) also transforms the irregular shapes and sizes of census geographies into regularized grid cells. Errors could, however, be introduced when allocating block group-level census data to the 1-kilometer grids because block group boundaries do not match grid boundaries, and exact locations of populations inside block-groups based on census-aggregated totals are not precisely allocated to grid levels because their exact locations are not known (Ver Ploeg 2012).

Food Access Measures Should Not Focus Solely on Low-income Areas

A critique of area-based measures is that most consider only low-income, or low- and moderate-income neighborhoods as potential areas where food access is limited. This is often done to target place-based policies to areas that may have high concentrations of individuals who face food access barriers. Wilde et al. (2014) illustrate that poverty levels are not always predictive of supermarket proximity because low-income neighborhoods are, on average, closer to supermarkets. It is possible that higher income block

groups are more sparsely populated and thus farther than average from sources of healthy foods, and that higher-income block groups face less price competition than lower-income block groups (but more competition on specialty foods or other store characteristics besides access). For this reason, the practice of comparing food access in lower-income neighborhoods to higher-income neighborhoods, as is done in TRF's methodology, may not yield expected results.

Focusing on food access only in low-income neighborhoods will overlook some people with food access barriers who live in higher-income areas. Ver Ploeg et al. (2012) estimates that in urban areas, about 6.9 million low-income individuals live in areas with high concentrations of poverty that are more than 1 mile from a supermarket or large grocery store.[5] However, a greater number of low-income individuals live in moderate- and higher-income areas that are more than 1 mile from a supermarket—8.5 million, according to ERS estimates (Ver Ploeg et al. 2012). It is possible that many of these 8.5 million people have vehicles and can access stores farther away. But even measures of vehicle availability indicate that access problems may be just as important in moderate- and higher- income areas as in lower-income areas. Of the estimated 2.3 million households that are located more than one mile from a supermarket and do not have a vehicle, 1.4 million are in moderate- and higher-income areas, while 900,000 are in low-income areas (Ver Ploeg et al. 2012). Focusing only on low-income areas instead of low-income or vehicle-less individuals may overestimate the access problem in these areas, while underestimating the access problems in higher-income areas.

Purely Relative Measures of Access May Be More Problematic for Policy-making Purposes

A purely relative measure of access is unlikely to be viable for policy purposes when potential designs and implementations are considered. The major conceptual criticism such a measure would face is convincing people that relatively poor access to healthy food sources translates into inadequate access. For example, one relative measure of poor food access is based on the relative square footage of grocery retail space per capita in a neighborhood compared with the median square footage of grocery retail space per capita in the whole city. This measure would highlight areas of inequality in access, but it says nothing about whether the square footage of retail space is adequate to meet the guidelines for what constitutes an adequately healthy diet. If residents can still purchase an adequate diet with this amount of retail space, policymakers and the public are likely to wonder what the problem is. If the concern about poor access is that it affects diet and health, then to justify a relative measure of access, one must believe that having relatively unequal access to healthy food matters—that is, one's diet is poor because of relatively poorer access to healthy food, not because of an absolute deprivation of access to healthy foods.

Such a relative measure may also not reflect real improvements in access unless improvements at the bottom of the distribution outpaced the improvements in the rest of the distribution. For example, consider an intervention to

[5]*Low-income individuals are defined as those with family income at or below 200% of Federal Poverty Thresholds for family size. Low income areas are census tracts where more than 40% of the population is low-income.*

increase the square footage of grocery retail in targeted neighborhoods based on the relative measure of square footage per capita. Assume the intervention was very successful so that the square footage of grocery retail per capita increased in the underserved areas. However, if grocery retail per capita also improved in higher-income areas enough to increase the entire distribution of square footage per capita, the median will rise. The relative square footage measure will show that the underserved areas were relatively worse off than they were before the intervention; but in reality, access in these areas improved, just not at the same rate as access in higher-income areas.

National-level Measures of Food Access Have Weak and Inconsistent Methods to Account for Differences in Population Densities, Vehicle Ownership and Infrastructure

A related complication in determining what constitutes inadequate access, especially for area-based measures, lies in accounting for the vast differences in population density, vehicle availability, infrastructure (roads, sidewalks, public transportation), and both natural and man-made barriers across the country. Different methods have been used to allow for differences in population density and vehicle availability. For example, the USDA (2009) and Ver Ploeg et al. (2012) used vehicle availability and distance from a store to measure access overall and separately for urban and rural areas. The TRF's method divides the country into 13 different groups based on block-group population density and vehicle availability rates, and compares distance to supermarkets in low- to moderate-income areas to those of higher-income areas (TRF 2012).

It may be impossible to treat every area of the country the same, but using different definitions of low access based on population density or other methods raises issues of fairness for devising a national-level measure of need to target a policy intervention. For example, under ERS's original food desert measure (ERS 2011) people in rural areas must be 10 miles from a store before they are considered low access, while in urban areas the distance is only 1 mile. Rural populations have greater access to vehicles, but the measure does not consider vehicle availability. Any household in a rural area that does not have a vehicle and is located more than one mile from a store is likely to have access problems as well. The separate rural and urban distances used to distinguish food deserts by this definition can also create a situation where a small town that qualifies as an urban area (population of at least 2,500) can be designated a food desert, but the surrounding rural areas are not, even though the rural areas may be farther from a store than the town. For example, the urban tract is deemed a food desert because there is no store within 1 mile of that tract, but the adjacent rural census tract is not a food desert because it is within 10 miles of a supermarket, even though the rural tract is farther away from the nearest store.

Another criticism of the original ERS measure is that the definition does not characterize low-access areas in very dense urban cities such as New York or Chicago, because very few people are further than 1 mile from a supermarket or large grocery store in these cities. This criticism implies that 1 mile is "too far" and that a shorter distance should be applied to mark areas that have poor access (e.g., .05 miles). If a shorter distance is used for urban areas, the number of low-access areas grows significantly (see table 1) and

would grow more significantly in less-dense urban areas than in the very dense urban areas where people are still relatively close to supermarkets.[6]

In contrast, the TRF approach treats these very dense urban areas differently than less-dense urban areas (TRF 2012). This approach combines area-based distance to a store with area-based vehicle availability rates, but it does so using 13 different relative measures of low access. This approach is more tailored to estimate access across different types of areas of the United States (e.g., very dense cities vs. suburban area vs. less–dense cities) and is particularly well-suited to finding areas with relatively low access in dense areas compared with the absolute distance measures. However, the use of various definitions raises questions of fairness for a national-level policy because there are 13 different standards for how far is "too far" from a grocery store. For example, the benchmark distance for determining limited supermarket access areas (LSA) in the densest cities is 0.15 miles. Thus, a block group that is 0.2 miles from a supermarket could be considered an LSA. In comparison, residents of less-dense cities or less dense areas of the same city may not be considered low-access unless they are more than 1.22 miles from a supermarket (TRF's zone 6MC). As a result, a household without a vehicle in the less-dense city would be considered low-access only if it is more than 1.22 miles to a store, whereas a household without a vehicle in the very dense city would be considered low-access if it is more than 0.15 miles from a store (the 13 different areas consider area-level measures of vehicle availability, but not individual vehicle availability).

The Food Access Research Atlas (FARA) includes a low-income and low-access measure that is applied consistently across the entire United States, regardless of urban or rural status (ERS 2013). This measure considers census tracts where a significant number of households are without a vehicle and more than one-half mile to a store (outside of a walking distance to a store), and tracts where a significant number or share of residents are more than 20 miles from a store (outside a reasonable driving distance to a store) as low access tracts.

Other factors that vary significantly across areas and cities and may affect access include the extent of public transit, walkable and safe sidewalks, man-made and physical barriers, traffic congestion, and climate. We note that walkability and public transportation are likely to be more problematic in less-dense cities. For example, holding income and vehicle availability constant, residents of sprawling cities are likely to face greater walkability and public transportation barriers than residents of densely-populated cities where a greater share of residents walk and take public transit. There have been improvements in measuring these consistently on a national level, but they are still far from being incorporated into measures of access.

Measures of Access Based on Square Footage of Retail Space in an Area Have Limitations

Absolute measures of the square footage of grocery per capita in an area have also been used as a standard for adequate food access, often as an alternative to distance-based measures (Social Compact 2011; AECOM 2010). The concept behind these measures is that areas should have a certain

[6]*Analysis of the ERS data shows that in fact, few neighborhoods in New York are more than a half mile from a supermarket or large grocery store.*

square footage of grocery retail and that those areas with less than the standard are underserved, indicating that either there is too little competition among grocery stores or that there is overcrowding in stores. These methods have designated areas as underserved if they have less than 3 square feet of grocery retail per capita (Social Compact 2008).

A problem with this measure, however, is that it is unclear how the square footage of retail per capita relates to the availability of healthy and affordable foods. This measure presumes that the square footage of healthy food increases (decreases) at a rate that is consistent with increases (decreases) in the square footage of all grocery items. As stores grow, it is possible that the square footage of healthy food does not increase as fast, for example, if more store space is devoted to non-grocery goods or larger-sized products. For example, according to one study, the average square footage of grocery retail for the entire city of New York is 1.5 square feet per capita (AECOM 2010), which would translate into most of NYC being underserved by grocery retail using the 3-square feet benchmark.

Another problem with the grocery retail space per capita is that it is less conceptually straightforward than a measure of distance to the nearest supermarket; few people will have any idea how much food retail square footage per capita is normal, and thus little sense of what level is inadequate.[7]

Measures of Need Do Not Necessarily Consider Viability, and Vice Versa

The TRF LSA methodology explicitly identifies areas where new supermarkets may be viable. This technique may be useful for determining which underserved areas can support a supermarket, but it is problematic for determining which areas are underserved. The TRF method separately distinguishes low-access areas from viable areas, but components of the methods used to characterize low-access areas already include viability. First, the TRF measure considers only those low access block groups that are adjacent to other low-access block groups as LSAs, which excludes block groups that are far from a store but which are surrounded by block groups that are not low-access. Second, the measure considers low- and moderate-income areas as potentially low-access areas. As noted above, this includes many moderate-income areas that are likely included as potentially low-access areas in order to make a supermarket a more viable option (since there are residents with relatively higher incomes).

Measuring need based on whether a supermarket is viable is likely to underestimate need in some areas and overestimate need in others. Further, the set of areas that lack supermarkets is likely to be much larger than the set of areas where a supermarket has market viability. Focusing on supermarket viability will miss those that are underserved but not viable.

Distinctions Between "Adequate" and "Inadequate" Access is Difficult and Requires Making Empirical Judgments

Food access measures, whether they are relative or absolute, classify some areas as having inadequate access. Using empirical judgment to make this distinction is inevitable; however, how such a distinction should be made is not always obvious and can affect estimates of poor food access (see Wilde et al. 2014).

[7]*Here, a relative measure of grocery retail per capita is likely to be more understandable to the public.*

The most commonly-used criteria in classifying access as inadequate is distance—how far people are from stores. While there is no standard definition of what constitutes an inadequate distance to a store, there is some precedent. One study estimated the median distance of the population to a supermarket as 0.9 miles (Ver Ploeg et al. 2012). Median distances were shorter for people with low incomes (0.79 miles compared with 0.94 for higher-income people), and much shorter for households without vehicles (0.41 miles compared with 0.9 for households with vehicles;) see table 6 in Ver Ploeg et al. 2012). The USDA (2009) and the Food Access Research Atlas (ERS 2013) have used a range of distance to the nearest supermarket to characterize access for populations, starting with .05 miles and going to 20 miles. The CDC's Healthy Tracts definition uses the .05 miles buffer around a tract to designate stores that are "near" a tract. These distinctions may be reasonable from an empirical standpoint, may have precedent in literature, and may be conceptually straightforward; but they are, ultimately, judgments.

General Methodological Limitations

Each of these measures of healthy food access assumes that supermarkets and other large food stores are consistent sources of healthy and affordable food, and that accurate lists of these stores exist. There are problems with this assumption, but no practical solutions to it. Previous studies have shown that lists of stores are not perfect in terms of completeness or accuracy (Fan et al. 2009; Liese et al. 2010). Supermarkets and sometimes large grocery stores are used as proxies of sources of healthy and affordable foods, but not all of these stores have great selections, quality, or price. Supermarkets are not the only sources of healthy and affordable foods. Some smaller stores or ethnic food markets sell healthy options. Non-traditional food retailers such as dollar stores and pharmacies are increasingly offering groceries that can be found in traditional supermarkets, although some studies have found minimal healthy options there (Rose et al. 2009; Sharkey et al. 2009).

Finally, consumers—especially low-income ones—are price-sensitive and shop where prices are lower, which may not necessarily be supermarkets or may not be the nearest supermarket. These data limitations and methodological caveats present difficulties for a national-level assessments because conducting a complete and up-to-date census of the location, inventory, and prices of food stores would be prohibitively expensive.

Improving Food Access Measures

This paper has highlighted some of the ambiguity around the concept of food access limitations and discussed weaknesses of measures of food access and food deserts. Until there is greater clarity, multiple measures of food access limitations, including both individual and area-based, may be needed.

Improvements for Individual Measures of Access

Measures of an individual's food access should be used to understand the extent of food access problems, monitor changes in food access, and target policy. Individual measures should also be used to guide which

types of policy interventions are considered. Thus far, policy has almost exclusively focused on areas, even though evidence suggests that individuals with access barriers are dispersed throughout a range of areas, not just low-income areas (USDA 2009; Ver Ploeg et al. 2012). The focus on areas has resulted in a narrow view of potential policy instruments. For example, if individuals with access barriers are dispersed, then policies such as providing a voucher to offset the cost of transportation to a store, or providing stores with funds to deliver groceries to those with access problems may be better than a policy that encourages the construction of new stores or modifications to existing stores.

Both direct and indirect measures of individual access are useful. A direct measure of access, similar to the one asked in the 2001 CPS about how food access affected food insufficiency, could be developed to more specifically capture store access limitations. These questions may need to be redesigned to specifically distinguish between those lacking access to healthy food (as opposed to other types of foods) and those who lack money to purchase food or those who are food insecure. Such a measure could be a key marker of the success of a policy intervention aimed at reducing access limitations because it has the advantage of measuring individual access, not area access, and thus will track individuals regardless of the neighborhoods in which they live.

Similarly, an indirect individual measure that combines income, vehicle availability and distance to the nearest supermarket—for example, an estimate of the number of low-income households without vehicles that are a specific distance from a supermarket or a number of supermarkets—is likely to be a very credible indicator of individual access limitations. Such a measure would be based on what is considered outside of a reasonable walking distance. Ver Ploeg et al. (2012), for example, estimate the number of households without a vehicle outside of .05 and 1 mile from the nearest supermarket. This measure is applied evenly to the entire United States without adjusting for rural and urban distinctions.[8] Such a measure provides estimates of those with limited food store access, regardless of whether they live in low-income areas or moderate and higher income areas, which would provide a more accurate picture of the extent of food access problems than measures that only focus on low-income neighborhoods.

It may be possible to assess which households without vehicles also have low incomes to distinguish between those who may have enough resources to afford other means of obtaining groceries. A barrier to doing so, however, is obtaining estimates of the combination of those with low income and without vehicles at geographic levels that are small enough to estimate their locations, since the American Community Survey does not release this combination of income and vehicle availability at small geographic levels.

Together, a food access measure based on self-reported access and a measure combining income and vehicle availability status with distance to the nearest supermarket are likely to be very good indicators of individual access. These measures are relatively straightforward to understand and

[8]*More sophisticated methods could account for walking distance instead of straight-line distance to consider barriers such as bodies of water, highways, etc., that cannot directly be crossed on foot. The ESRI, a GIS mapping and consulting company, have also implemented network distance measures of food retail access (Richardson 2010; TRF 2012), but at a national level, the computing resources needed for doing so are substantial.*

would be credible to the general public; they could also be relatively inexpensive to compute on a regular basis. Direct questions added to a survey like the Food Security Supplement of the CPS could be added every other year, or even every 5 years since changes in population and store locations are not that dynamic. The American Community Survey annual collects information on vehicle availability and income, although for small areas like block groups, these data are only released as 5-year moving averages.

Improvements for Area Measures of Access

Our study has highlighted the problems with area-based measures. However, because policy interest will likely continue to be place-based, improvements to area-based measures of limited access are needed. As discussed above, there are particular challenges in area-based measurement for a national-level policy intervention that must consider the many diverse communities throughout the United States.

One potentially simple solution is to measure the number and percentage of households that do not have access to vehicles and are more than a walkable distance to a store, as well as the number that are so far from a store that even driving is burdensome. The Food Access Research Atlas uses such a measure (USDA 2013). The concept behind such a measure is that there is some distance for which it is a burden to walk to a store (.05 miles) and some distance for which it is a burden to drive to a store (20 miles). This metric is applied evenly to the entire United States without separate distinctions for rural and urban areas, since any household without a vehicle outside of the walking distance or beyond a reasonable traveling distance could be considered to have low access. Further, this measure need not focus only on low-income areas, since there could be moderate- and higher-income areas that have sizable populations that are either without a vehicle and far from a supermarket or just far from a supermarket. If data on the combination of income and vehicle availability status can be released at small geographic levels, then this could be a separate measure that provides more context to the hardship that both poor and car-less people face in accessing a store.

A more complicated approach to measuring the food store access in an area is to create an access index that uses multiple measures of access in an area to derive an overall "access score" for that area. One example of such an index is the Index of Medical Underservice (IMU), which is used by the Health Resources and Services Administration (HRSA) to determine Medically Underserved Areas (MUAs), which are areas where residents have a shortage of personal health services, a distinction that is used to determine eligibility for several federally-funded programs.[9] The IMU is based on four variables—primary care physicians per 1,000 residents, infant mortality rates, the percentage of the population with income below poverty levels, and the percentage of the population over age 65—from which an index score (which includes different weights for each of these 4 variables) is created. If the index score meets a threshold, the area is designated as medically underserved, although an area that does not meet this definition can still apply for the designation if it has exceptionally poor circumstances.

[9] *See http://bhpr.hrsa.gov/shortage/.*

A similarly-constructed index applied to food access could consider factors such as an area's income, distance to a supermarket or large grocery store, vehicle availability (the number or percentage of vehicle-less people far from a store), a measure of square footage of grocery retail per capita, and could possibly include a measure of walkability in the neighborhood.[10] Index scoring could be weighted by the severity of different components of the measure, depending on the policy goals. For example, poverty rates could be weighted more heavily if policymakers are more concerned about the poorest people lacking access.

Index components could be selected to balance features of different types of areas. Policymakers may want to design programs to alleviate food access to a variety of areas—rural, very dense urban, and all areas in between. An index measure may make that easier by considering a wider range of access indicators. For example, very densely-populated areas may have very few people who live outside of a specific distance from a store, but they may also be more likely to have low retail space per capita. Use of an index could mean that a poor area that does not meet the distance criteria may still be considered a food desert if its retail space per capita is low.

This type of index, however, has some severe drawbacks. First, determining which food access components should be included, how each is weighted and scored, and where to impose a threshold for determining underserved areas will involve more judgments. While judgment is necessary in any measure of adequacy, an index with multiple measures would require more judgments that, given the lack of consensus on how to measure food access, may be made with little empirical support. The index measure and how each component is weighted will also be less transparent to the general public, and will probably be more susceptible to influence by policymakers focusing on their own constituencies.

Further Analysis of the Consequences of Definitions of Adequate and Inadequate Food Access Is Needed

Making judgments about thresholds for adequate and inadequate food access, regardless of the measure, is inevitable. But further work is needed to understand how these thresholds affect the estimates of limited food access. Estimates should be accompanied by justifications for why different thresholds were chosen.

Enhancements to Other Measures of Food Access

There are several aspects of food access for which measures are underdeveloped. One concerns how prices paid for food correspond to individual and neighborhood food access limitations. Are prices paid by individuals and neighborhoods different for those who face access barriers than for those who do not? This concept of "realized access" presumes that an individual's access can be measured by observing where they shop and the prices they pay (including the transportation and time costs) as opposed to observing where they live and assuming their access is determined by that. Feather (2003) used data from the evaluation of a SNAP demonstration project in Dayton, Ohio to estimate the benefits to SNAP participants of

[10]*Need could also be assessed by including measures of diet-related health in the area, such as obesity rates, but these measures are generally not available below the state or county level.*

being closer to supermarkets. The data was based on a sample of SNAP participants' observed shopping behavior—where they shop, what distance they travel, and how they travel. This kind of study has not been replicated in other areas or on a national scale, but it could be useful for understanding the price, time and travel cost tradeoffs of shopping at different food stores. The USDA's National Food Acquisition and Purchase Survey (FoodAPS), which follows the food acquisition and purchases of SNAP, low-income, and other households for a week, and includes geographic data about food store access and food prices, may be an ideal data set with which to address these questions (Kirlin and Denbaly 2013).

Future efforts should also include a plan to test and validate measures of food access. Such efforts, which may only be most feasible on a local level, could include better characterizations of the food environment (in addition to just measuring where supermarkets are), or survey individuals to ask direct questions of food access (similar to the 2001 CPS measures), as well as use self-reported access to compare with other indirect measures of food access.

Conclusion

Advancements in measuring food access limitations have given us a better understanding of the extent of the population that faces barriers to accessing healthy and affordable food. As policies to improve food access for underserved populations are implemented, it is important to improve measures of food access limitations and to extend the types of measures that are considered for policy targeting, monitoring and evaluation. First, it is important to continue to estimate direct and indirect measures of individual access, because these measures provide information about need—how many people lack access, who they are, and where the live—as well as changes in need over time. These measures are also useful in evaluating area-based policies that may mask or ignore individual-level barriers to access. Relatedly, the emphasis on low-income areas overlooks many who have food store access barriers and live outside of low-income areas. Individual measures are important because they do not focus solely on low-income areas and can help estimate the full extent of those who face access barriers. Third, it is important to improve the way in which the diverse geography and population density of the United States is accounted for in food access measures. But in doing so, these improved measures should still represent fair and credible estimates of access, and minimize the inconsistencies that arise when different measures are applied to adjacent areas. Finally, because of the conceptual and methodological problems with measuring food access limitations, it is important to estimate a broad set of measures so that we can better target, monitor, and evaluate policy interventions to improve food access for underserved populations.

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