Limited Food Access as an Equilibrium Outcome: An Empirical Analysis

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Abstract

Lack of access to nutritious and affordable food has become an important public policy issue in the U.S.: various interest groups are seeking to reverse a trend whereby certain areas lack larger, full-service grocery stores that provide “higher” quality foods. Based on game-theoretic findings suggesting that lack of food access can be an equilibrium outcome, we specify a model relating access to higher quality food stores to a vector of supply and demand factors, using seven years of county-level data for the contiguous U.S., and a constrained generalized ordered logit estimator. Our results suggest that demand side factors, especially market size (total income and SNAP funds) play an important role in determining food access, and that large food stores avoid areas with higher poverty. Some cost determinants, such as the ratio of building costs to the total site cost, home price index (for counties with higher poverty rates than the average) and ease of recruiting labor, affect the probability of observing areas with no access. A more favorable business tax regime has no impact on access, while better transportation infrastructure reduces rather than improves food access. Our results shed new light on the determinants of food access in addition to highlighting what policy can and cannot accomplish to improve food access.

JEL Codes: Q18; R3; L81

Key Words: Food Access, Equilibrium; Food-Store Density

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The relationship between consumer diets and characteristics of the "food environment"[1] has been widely investigated and is the object of considerable policy debate because of its profound implications for consumer well-being, especially those with low incomes (*inter alia* Hawkes 2008; Holsten 2007). Copious evidence suggests that areas inhabited predominantly by less-privileged individuals are characterized by fewer large (or "high quality") food stores (see, *inter alia*, Alwitt and Donley 1997; Ball, Timperio and Crawford 2008; Morland, Wing and Diez Roux 2002; King, Leibtag, and Behl 2004; Moore and Diez Roux 2006; Powell *et al*. 2007; Zenk *et al.* 2005), and that limited access to food stores can constitute a barrier to obtaining adequate amounts of nutritious food (Haering and Syed 2009; Ver Ploeg *et al.* 2009). A positive relationship exists between the quality of food choices available to low-income (food stamp recipient) households and access to food outlets (Rose and Richards 2004) and by the same token, empirical evidence suggests that richer food environments lead to lower levels of food insecurity (Bonanno and Li 2011). Also, a relationship between access to different types of food outlets and obesity has been argued to exist both in the U.S. and internationally (Morland, Diez Roux and Wing 2006; Hawkes 2008; White 2007).

The term "food desert" has been minted to describe the likely negative relationship between diminished food access and ability to maintain a healthy diet; in the 2008 Farm Bill the U.S. government defines these as areas "… with limited access to affordable and nutritious food, particularly […] composed of lower-income neighborhoods and communities" (for other definitions see Ver Ploeg *et al.* 2009). Identifying and measuring food deserts is complex and depends on which food stores should be considered, what the definition of "neighborhoods and

[1]The *food environment* comprises all factors influencing the availability of, or consumers' access to, food that can be consumed at home (food-at-home) and ready-to-eat pre-cooked food for consumption away from home (food-away-from-home) (Cummins and Macintyre 2006).

communities" is, and what "affordable" and "nutritious" food means (see Ver Ploeg *et al.* 2009 for further considerations).

The concept of food desert as illustrated above links the supply of nutritious food products (and by default, of food outlets providing them) to low-income consumers, and the cost they face in obtaining such products. Although larger stores[2] belonging to organized chains can achieve lower costs by using their efficiency along the supply chain and offer healthier food (i.e., fruit and vegetables) at lower price than smaller, unorganized stores (Hawkes 2008), empirical evidence on whether the presence of larger stores selling healthier products improves consumer diets is mixed. For example, while Rose and Richards (2004) found that ease of supermarket access is associated with increased daily consumption of fruits and vegetables among food stamp recipients, Cummins *et al.* (2005) found no significant changes in consumption habits after entry of a large-scale food retailer.

Although the interaction between the healthfulness of low-income consumer choices and the food environment is complex (Drewnowski and Darmon 2005) the drivers of the *supply-side* component of food deserts can be inferred using simple economic principles. Bitler and Haider (2011) point out that the existence of areas characterized by limited food access can be rationalized in an economic framework by referring to the interaction of demand and supply drivers. Assuming that nutritious food is a normal good, demand for it will increase with income; thus, demand for stores providing such food will be lower in low-income areas. Also differences in taste (which may be related to educational level, ethnicity, etc…) may lead to varying demand for "healthy" foods. The supply-side of the issue, on the other hand, instead

[2] In general terms, limited access to "large" food stores may result in higher search and transportation costs and lead to higher food prices because of monopoly power or cost inefficiencies characteristic of smaller stores (King, Leibtag, and Behl 2004). Limited access could cause further hardships for low-income consumers who may lack adequate transportation means and have limited ability to adopt cost-saving strategies (Leibtag and Kaufman 2003).

relates to the costs of investment and operation facing food outlets in terms of sourcing, sorting and distributing foods. Even under perfect competition (as Bitler and Haider argue), a shrinking demand curve could intersect the long-run average cost of retailing food in its downward-sloping portion, indicating long-run downward sloping supply, i.e., a reduction in the number of stores.

However, perfect competition does not apply to modern food retailers, who offer retailing services that cannot be separated from the physical products sold in the stores (Betancourt and Gautschi 1988, 1993; Bonanno and Lopez 2009); that is, retail food represents a bundle of differentiated products comprised of the physical product, services, ambience and assortments (Betancourt and Gautschi 1990, 1993; Betancourt 2006; Richards and Hamilton 2006; Bonanno and Lopez 2009). Some food retailers invest in fixed cost to increase their overall "quality" level, softening price competition to become more attractive to consumers who are less price-sensitive (Bonanno and Lopez 2009); thus fixed costs are endogenously determined (Sutton 1991).[3] The existence of high fixed costs and consumer heterogeneity across markets may lead both firms and consumers to sort according to their features – i.e., costs and preferences – which lead some goods not to be available in all markets (Waldfogel 2008). In sum, these factors, suggest that limited access to nutritious food for low-income consumers may simply be an equilibrium outcome of differentiated product firms (i.e., food retailers) selling their products (i.e., locating their stores) in markets where there is a sizable demand. Such firms will play a multi-stage game while facing consumers who are heterogeneous *across* markets (i.e., income levels and taste for "quality" change across areas but all consumers in the same market are assumed to be identical).

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[3] This rationale, which follows Sutton's (1991) endogenous cost model, is used by Ellickson (2006, 2007) to explain how the food retailing industry has become a two-tiered industry where a large firm of smaller (low-quality) stores coexists with a natural oligopoly of fewer, large (high-quality) firms.

In this paper we consider an empirical framework where both demand and supply-side factors determine access to large food outlets (grocery stores with more than 50 employees and Walmart Supercenters). We measure the extent of access via a *Limited Access Index* (LAI) obtained by dividing the number of large stores in a county by a number of partitions consistent with pre-specified potential area of influence for a store (10 miles radius in rural counties and 0.5 miles in urban ones). Our results suggest that although the role of demand-side factors outweighs supply-side forces in determining lack of access, policy seeking to improve access, especially in areas with more low-income households, needs to consider both aspects.

The Model

What follows describes the strategic game in Ellickson (2006, 2007), which uses the Endogenous Sunk Cost framework developed by Sutton (Shaked and Sutton 1987; Sutton 1991). Consumers in a given market *j* are identical and value retail quality (i.e., food retailers represent vertically differentiated goods). Food retailers play a three-stage game: in the first stage both potential entrants and incumbent stores decide whether or not to *enter* market *j* (incumbents playing "*Enter*" when they do not exit the market); in the second stage firms that have entered set the level of quality offered to consumers (i.e., assortment and level of service, as in Bonanno and Lopez 2009); in the third stage firms compete à la Cournot. Of the two types of stores considered in Ellickson (2006, 2007) we focus only on those offering "high quality," which are characterized by large assortments and food products likely to be of high quality.

Assume symmetric demand and cost, and let the observed number of firms in market *j* represent a possible equilibrium of this game (Bresnahan and Reiss 1991; Berry 1992); define this equilibrium number of firm as N_j^*.[4] If, in a given market, none of the potential entrants finds it optimal to play "*enter*" or, in other words "*do not enter*" represents the best response to any of the other players' actions, the equilibrium number of large food retail firms in j is $N_j^*=0$; in that case consumers in j will be deprived of access to large food outlets. Ellickson (2007) shows that, for high quality stores, N_j^* depend on market size, investment costs (in his paper price of land) and the relative costliness of investing in quality to satisfy quality-valuing consumers. He presents three possible scenarios: 1) the equilibrium number of firms increases with market size; 2) the equilibrium number of firms decrease as market size expands (i.e., a market can become saturated), an effect reinforced by increasing investment costs; and 3) if the market size is small, corner solutions are possible where $N_j^* \leq 1$. This last outcome explains the lack of large stores, at least in some markets.[5]

We observe the number of firms in geographic areas (indexed by $l = (1,...,L)$) which are aggregates of smaller local markets each representing a suitable location for a food retail store. In each area l the number of these markets represents the number of partitions into which l can be broken (i.e., each partition represents a potential market of interest). Let the number of markets in area l be indexed by j_l ($j=(1,\ldots,J_l)$), and the number of partition by Mkt_l. The average number of (equilibrium) retail firms in a market in l is given by $\bar{N}_l^* = \sum_{j \in l} N_{jl}^* \Big/ Mkt_l$ where $\sum_{j \in l} N_{jl}^*$ is the

[4] Entry games usually have multiple equilibria. Sorting firms (facing symmetric demand and cost) by decreasing profitability (i.e., the most profitable firms enter the market first, as in Bresnahan and Reiss 1991; and Berry 1992) the observed number of market participants is one Nash equilibrium of such a game. We abstract from the dynamic aspects of entry games as this is outside the scope of this work (see Jia (2008) for an example).

[5] In its empirical application, Ellickson (2006) shows that in the U.S. food retailing industry the second scenario (N_j^* decreasing with market size) is the most likely to be observed for large stores. He finds that while low-quality, smaller stores have an equilibrium number of firms increasing with market size, higher-quality stores, investing in fixed costs, organize in a natural oligopoly where the equilibrium number of firms does not grow indefinitely with market size. Similar notions apply to other industries where firms commit to a specific location (see for example Asplund and Sandin's (1999) application to Swedish regional markets for driving schools).

equilibrium number of large food retail firms in *l*. Assume the following relationship explains $\bar{N}_l^*$

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$$\bar{N}_l^* = \alpha \ln \bar{S}_l + g^D(\mathbf{X}_l; \boldsymbol{\alpha}^{\mathbf{D}}) + g^C(\mathbf{C}_l, \mathbf{K}_l; \boldsymbol{\alpha}^{\mathbf{C}}) + \varepsilon_l \qquad (1)$$

where $\bar{S}_l = \sum_{j \in l} S_{jl} / Mkt_l$, S_{jl} being the size of each market *j* in area *l* , measured by total income and ln() is the natural log operator (consistent with Ellickson (2006) who indicated that the equilibrium number of high quality firm declines with market size); $g^D(.)$ and $g^C(.)$ are functions qualifying, respectively, how demand (other than market size) and cost factors affect the equilibrium number of firms; $\mathbf{X}_l$ is a vector of demand shifters (including also an average measure of the composition of consumers across the *j* markets in *l* to account for heterogeneity across areas); $\mathbf{C}_l$ and $\mathbf{K}_l$ are vectors of variables capturing, respectively, variable and fixed cost; $\boldsymbol{\alpha}^{\mathbf{D}}$ and $\boldsymbol{\alpha}^{\mathbf{C}}$ are conformable vectors of parameter; and ε_j is a random term capturing other (unobserved) factors which could impact firm locations $\bar{N}_l^*$.

Under the assumptions of footnote 4, the observed average number of firms in each partition represents an equilibrium. $\bar{N}_l^*$ then serves as an indicator of consumers' access to large food retailers. First, outcome $\bar{N}_l^*$=0 represents a scenario where no firm finds it profitable to locate in any of the partitions of *l* (no access); second, $0 < \bar{N}_l^* < 1$ indicates that, on average, *at least* one of the markets in *l* will have no large food retailer (limited access); and last, if $\bar{N}_l^* \geq 1$ all markets in *l* have, on average, at least one large food store (adequate access). Using this categorization, we define the Limited Access Index (*LAI*) as

$$LAI_l = \begin{cases} 0 & \text{if } \bar{N}_l^* \geq 1; \\ 1 & \text{if } 0 < \bar{N}_l^* < 1; \\ 2 & \text{if } \bar{N}_l^* = 0; \end{cases} \qquad (2)$$

Let h = {0,1,2} be one of the three possible outcomes of *LAI*; assume that $g^D(.)$ and $g^C(.)$ are linear in variables and parameters and let $\mathbf{Z}_l = [\ln \bar{S}_l\ , \mathbf{X}_l, \mathbf{C}_l\ , \mathbf{K}_l\ ]$ contain the covariates in (1) and $\boldsymbol{\theta} = [\alpha, \boldsymbol{\alpha}^{\mathbf{D}}\ , \boldsymbol{\alpha}^{\mathbf{C}}\ ]$ represent its parameters. Then the probability that a given outcome of *LAI* conditional on both the demand and cost factors is observed is:

$$\Pr(LAI_l = h|\ \mathbf{Z}_l) = \Lambda\ (\delta_{h-1} - \mathbf{Z}_l`\boldsymbol{\theta}) - \Lambda\ (\delta_h - \mathbf{Z}_l`\boldsymbol{\theta}); \qquad (3)$$

where Λ is the logistic CDF, $\delta_0 = -\infty$, $\delta_3 = +\infty$ (δ_1 and δ_2 represent "cut-off" points) so that the vector of coefficients $\boldsymbol{\theta}$ can be estimated via maximum likelihood ordered logit. More details on the estimation method are provided in the next section.

Data and Estimation

We estimate equation (3) using seven years (2000-2006) of observations for 2,876 contiguous U.S. counties, comprised of 20,132 observations. For our definition of access to large food stores, we adopt an approach similar to that in Ver Ploeg *et al* (2009). The county-level number of large food retailers is the sum of grocery store establishments (NAICS 44511 > 50 employees) from the County Business Patterns, plus the number of Walmart Supercenters from T.J. Holmes' database (Holmes 2010, 2011). Dividing this number by the square miles of land in each county, obtained from the U.S. Bureau of Census Gazetteer of counties (2001) rescaled to account for the potential travel radius to reach a store (Ver Ploeg *et al.* 2009, box b1), i.e., 10 miles radius in rural counties and 0.5 miles in urban ones (identified via the USDA Rural-Urban continuum codes), we obtain a county-level Limited Access Index.

As noted above we include demand and supply side variables that could impact store location decisions. The demand-side variables capture market potential and heterogeneity in taste across areas. Among the first group of variables we include a proxy for total market size (log of total income, from the Bureau of Economic Analysis); population density, calculated in thousands of people per square mile (from the U.S. Census Bureau Population Estimates Program – PEP); poverty rate (from the Small Area Income and Poverty Estimates – SAIPE – by the U.S. Bureau of Census), to represent demand limitations; and a variable capturing the additional potential demand coming from low-income individuals who participate in the Supplemental Nutrition Assistance Program (SNAP) measured as SNAP participants/ population in poverty (both from SAIPE). Variables capturing consumers' heterogeneity across areas are the share of population that is black, Hispanic, and 14-25 years of age, 25-64 years of age, and over 65 (from the PEP).

Supply-side determinants aim to capture two types of costs: fixed investment (and location) costs and operating costs. Fixed cost variables are state-level variables measuring the ratio of the cost of the structure to the total value of a home, i.e. the "structure share" and a home price Index from the "Land Prices by State" database of the Lincoln Institute of Land Policy as described in Morris and Heathcote (2007); share of non-agricultural land from the USDA National Agricultural Statistical Service (to proxy for land availability). As for the sources of variable costs, we consider the following: large stores require more frequent delivery of goods and may operate their own truck fleet, and so we include the "on-highway" price of diesel (all types) in $/gal (from the U.S. Department of Energy); another common cost in retailing is electricity: we include monthly retail prices of electricity for commercial use ($/Kwh), also from the U.S. Department of Energy. Although labor is another major cost in retailing, we excluded proxies for retail wages as they are impacted by the composition of the local retail industry; instead we used county-level unemployment rates (from the Local Area Unemployment

Statistics, the U.S. Bureau of Labor Statistics) to capture the ease with which unskilled retail workers can be recruited.

Additional controls added to the model are: ease of distribution/capillarity of infrastructure, i.e., state-level miles of public roads/squared miles of land (U.S. Department of Transportation, Federal Highway Administration); the likelihood of benefiting from “short” channels, via the share of vegetables produced in each acre of agricultural land in a county (from the USDA National Agricultural Statistical Service); the presence of a “business friendly” tax regimes, via an indicator variable that identifies states with zero corporate income taxes (from the U.S. Tax Foundation), an indicator variable for Metropolitan areas (calculated from the USDA Rural-Urban continuum codes); and, lastly, as the LAI contains the number of Walmart Supercenters, the distance from Benton County, Arkansas, to capture part of the chain’s hub-&-spoke logistics system (Courtemanche and Carden 2011; Bonanno 2010). This is obtained by applying the Haversine formula to county centroid coordinates (U.S. Bureau of Census Gazetteer of Counties 2001). State-level fixed effects and year dummies are also included in the model.

A list of variables and their summary statistics is provided in Table 1, which also illustrates some of the differences across areas showing different values of LAI. From the data it emerges that 23.8% (4,791) of the counties considered had no large food store, while a slightly smaller proportion of counties showed LAI of 0 (full coverage by large food stores, 21.3%). One of the most striking features of the data is the difference across subsamples of counties characterized by “no access” (LAI=2) or “limited access” (LAI=1) and those with “adequate access”. In particular, counties characterized by LAI=2 show some an aging population (lower share of population between 15-24 years of age and higher share of over 65), larger shares of Hispanic population, higher poverty rates, but also higher rates of SNAP redemptions, lower population density, smaller market size (i.e. lower levels of ln(INC)). Also, as one can see from the values at the bottom of table 1, a disproportionally large share of counties LAI=2 are located in the South or Midwest.[6]

With respect to the proxies for fixed cost, the average value of the share of structure cost over the total cost of buildings is higher in "no access" areas than the average suggesting that, relatively speaking, building larger stores may be more expensive in these areas. However, the home price index does not show large variations across areas with different LAI. As for the variable costs, while electricity for commercial use is on average cheaper in areas characterized by LAI=2, the price of diesel shows little variation, while unemployment rates are lower. Not surprisingly the quality of the infrastructure is worse in areas characterized by less access (i.e., the number of miles of highways per square mile is lower) while the share of agricultural land is higher. Lastly, the average distance from Benton County in "no access" areas is lower, and there also are more areas without corporate income tax, consistent with the fact that 50% of these counties are located in the South.

Moving on to an illustration of the estimation method used, as mentioned above, equation (3) is estimated via ordered logit. However, the parameters of the ordered logit are constrained to satisfy the proportional odds assumption, which can be restrictive if the independent variables impact the different levels of *LAI* in a non-proportional way. To relax these restrictions, the model was re-estimated via a constrained generalized ordered-logit which allows, via a backward stepwise selection process, to impose sequential constraints on the estimated coefficients that do not violate the proportional odds property, leaving the other coefficients unconstrained (Long and Freese 2006; Williams 2006). Wald-tests on the estimated parameters did not support the

[6] Some of these features are similar to those characterizing food deserts in rural counties described in Morton and Blanchard (2007).

rejection of the null that the parameters jointly satisfy the proportional odds assumption. Data manipulation and estimation were performed in STATA version 11.

Empirical Results and Discussion

The estimated parameters of equation 3, reported in table 2, were obtained using different estimators: ordered logit (first column; OL) constrained generalized ordered logit (second and third columns; CGOL), and a generalized ordered logit (last two columns; GOL). The values of the pseudo R squared show CGOL and GOL outperforming OL; the use of either of the first two estimators leads to very little difference in goodness of fit with values of the pseudo R squared being, respectively, 0.5474 and 0.5478 while the OL has only limited explanatory power. Furthermore, the *p*-value of a Wald test for the validity of the parallel regression assumption (under the null of the regression curves' slopes being jointly the same) performed on the OL coefficients is 0.000, indicating that the parallel regression assumption is not satisfied. The step-wise sequential process of the CGOL shows that for 19 parameters the parallel regression assumption holds (for these parameters the null of the slopes being the same cannot be rejected: the *p*-value of the test is 0.8834). Among the variables for which the parallel regression assumption holds (besides fixed-effects parameters, which are excluded for brevity), and which are highlighted in table 2, one has the share of population 14-25 years of age, that of Hispanics, the home price index, the price of electricity for commercial use and the indicator for states without a corporate income tax. Of the coefficients associated with these variables, only one shows considerably differ behavior across CGOL and GOL (the home price index). In sum, we find that the CGOL and GOL outperform the OL and that they are statistically equivalent; therefore, only CGOL average marginal effects of the independent variables on the likelihood that a county shows increasing levels of limited access to large food stores are discussed (Table 3).

Before illustrating the average marginal effects, a brief summary of the estimated parameters follows, which overall suggests that demand factors appear to be stronger determinants of limited access than cost factors. In the first place, most of the demand side variables are statistically significant and show the expected sign, indicating that both the size of the market and its composition play a fundamental role in determining limited access. The impact of the fixed cost variables is weak across estimators – an increase in fixed cost increases the likelihood of observing areas with no access (the coefficient for Structure Share and Home Price Index are positive and significant in determining the probability of observing LAI=2; the latter, however, does not violate the proportional odds assumption and could therefore have no impact). Variable and distribution costs also show limited impact, and, in the case of electricity price a negative sign, indicating that as the price of electricity for commercial use increases the likelihood of a county showing limited access decreases (this could reflect the fact that areas without access are mostly non-metro, where utility costs may be lower). The same occurs with the distribution/logistic costs, although they seem to play a more relevant role in determining either the likelihood of observing counties with limited access areas (distance form BC) or no access (share of Ag land), while capillary of infrastructure (miles per highways per square mile) is related to higher likelihoods of observing limited access, which is a counterintuitive result. Absence of corporate income tax does not affect the probability of observing limited access, while the probability of observing no access seems to be lower in metro areas.

The average marginal effects obtained from the coefficients of the CGOL are reported in table 3. We remind the reader that the values in the column “LAI=0” represent the average marginal change in the probability of observing a county with adequate access for a marginal change in one of the estimated variables *with respect to* observing a county characterized by either LAI=1 or LAI =2. The same value, with an opposite sign, will represent a marginal effect on the probability of observing “no access” (LAI=2) with respect to that of observing “adequate access” (LAI=0). The values under the column “LAI=1” and “LAI=2” represent, respectively the marginal effects of each of the independent variables on the probability of observing incremental values of the LAI (i.e. the probability of observing LAI=1 instead of LAI=0 and that of observing LAI=2 instead of LAI=1, respectively).

Focusing on the demand factor first, one can notice that the natural log of total income has a large and negative average marginal effect on the likelihood of observing counties with some pockets of limited access (LAI=1: -4.5%) and counties with no access (LAI=2; -15.67% compared to LAI=1 and -20.2 % compared to LAI=0), showing that the average size of each local market is one of the strongest determinants of food stores location and, therefore of the probability of observing limited access. Also, a unitary increase in population density leads to very large decreases in the probability of observing counties with no large food stores, i.e. a -272% increase from LAI=1 to LAI=2. However, this effect is reasonable considering that a unitary increase in population density is a 430% increase of this variable. Proportionally, a population density increase of 1% would lead to a 0.63% decrease in the probability of observing a county without access to large food retailers. As this impact is still considerable, it should be noted, once again, from the sample averages in table 1 and from the marginal effect of the “metro” indicator below that counties characterized as no access (LAI=2) are mostly non-metro.

A unitary increase in SNAP redemption rate leads to an average decrease in the probability of having limited access of -1.55% and that of having a no access are by an additional

-1.04%, indicating that the additional demand generated by participation in SNAP can be seen positively by large food stores as a source of potential demand. Differently, a marginal increase in poverty rates increases the likelihood that a county has no access to larger food retailers (by 2.11%: 1.34 for limited access areas plus an additional 0.77% for moving from limited to no access).

The estimated average effects of population characteristics on the likelihood of observing areas with limited and no access show interesting patterns. With respect to the age groups, we find that while a unitary increase in the share of population in the 15-24 age group is associated with an a higher likelihood of observing limited access, it is also associated with a decrease in the likelihood of observing no access (-1.25%). Unitary increases in the share of population 25-64 years of age and 65 years of age have negative and statistically significant marginal effects on the probability of observing areas with limited access and with no access, the former showing smaller effects than the latter (share of population 25-64: -0.71% for LAI=1; -0.26% for LAI=2; share of population over 65: -0.8% for LAI=1; -0.67% for LAI=2). Also, we find little evidence that a marginal change in the share of population being black would impact in any substantial way the probability of observing areas with limited or no access; a similar effect, showing mall magnitude is found for the share of population being Hispanic although in these case the estimated marginal effects are statistically significant.

The impact of the cost factors on the probabilities of observing counties with limited/no access areas shows less clear patterns than the demand determinants; in some cases, these variables seem to impact negatively the probability of observing counties with *no access* to large food retailers. This indicates that while cost factors may contribute to observe areas where *no* firm finds it profitable to enter, they are less relevant in discouraging entry of at least *some* firms.

A unitary increase in the share of building cost coming from structures leads to an increase in the probability of observing an area with no access compared to that of observing limited access (+0.21%), suggesting that structure costs may have an impact but only in determining total deprivation form large stores, while the Home Price Index seems to play no role. Also, operating costs play a weak role in determining the likelihood of an area showing limited access. While price of diesel does not play any role in the likelihood of observing limited access, a unitary change in the price of electricity for commercial use is associated with a lower probability of observing no access areas. A marginal increase in the unemployment rate, used as a proxy for ease of recruiting workers, leads to a decrease in the probability of observing counties with pockets of limited access (i.e., LAI=1) in the amount of reason of -0.34% and, to a lesser extent, no access (-0.19%) compared to that of observing adequate access.

An improvement in the capillarity of the transportation system, indicated by an increase of one mile of highway system / square mile of land, leads to lower probabilities of observing both counties with adequate access and those with areas of limited access but an increase in the likelihood of observing no access by 11.8% (compared to limited access). Also, an increase in 1% of the share of land dedicated to agriculture lowers the probability of observing limited access, but increases that of having no access by 1.05%, suggesting that areas specialized in agricultural production are more likely to show total lack of access (holding constant population density). Distance from Benton County shows a positive and statistically significant relationship with the probability of observing LAI=1, indicating that areas that are more distant from Walmart's headquarters are more likely to have lower access – as our measure of access includes Walmart SCs, this can be explained by the hub-and-spoke logistic system. This means that more stores will be located closer to distribution systems which are more distant from BC both temporally and spatially. Lastly, absence of corporate taxes has no impact on the level of access, and metro counties appear to be 83% less likely to show no access than to contain areas with limited access (probably because of the higher population density attracting large food stores).

As the official definition of food deserts in the U.S. focuses on areas "[…] composed of lower-income neighborhoods", we re-estimated equation (3) including only counties with a poverty rate above the sample average (14.08). The CGOL estimates (N=8,279) show a similar behavior to the full sample (estimated parameters and average marginal effects are in table 4): the parallel regression assumption is not violated for 23 variables (*p*-value of the test for parallel slopes for these variables is 0.9912). Two of these 23 variables are the same as those in the full sample, the share of population 14-25 years of age, and the states without a corporate income tax. Further, the share of black population replaces the share of population that is Hispanic, and the distance from Benton County also satisfies the proportional odds assumption.

The pattern of the average marginal effects presented in table 4 are mostly consistent with those illustrated above, although in some cases their values show different magnitude than those in table 3; the most significant differences are discussed below. A unitary change in the log of total income (market size) shows no statistically significant effect on the likelihood of observing limited access areas, but it shows a negative impact on that of observing "no access", its magnitude being 50% larger than that measured in the full sample. Also, although the average marginal effect of the SNAP participation ratio is similar to that discussed above, its impact is larger on the likelihood of observing "LAI=1" than on observing areas with "no access" (30% smaller). A similar pattern is observed for the average marginal effect of poverty rate. These results indicate that one of the most important discouraging factor for store location, especially in low-income areas, is the lack of market potential, and that even if additional demand from SNAP participants may work as a stimulating factor, it is less relevant in areas where poverty rates are higher. Both ethnic and age composition of the population show similar or smaller average effects than those measured in the full sample (with the exclusion of the share of population between 15-64 years of age).

Also, the average marginal effects of the fixed cost variables are larger than those obtained using the full sample: in particular, the home price index shows a positive and significant impact on the likelihood of observing no access; this indicates that cost drivers may become more important for retailers once they consider the "riskier" decision of locating in areas with higher poverty rates. Similarly, higher price of diesel seems to result in a higher likelihood of observing counties characterized by limited access. The other variables show the same behavior they did in the full sample.

Summary and Conclusions

Using the result provided by Ellickson (2006, 2007) that modeling food retailers as players of a game where the cost of delivering quality is endogenous (Shaked and Sutton 1987; Sutton 1991) could lead to areas with limited number of large food stores, we offer an empirical framework to test the determinants of access to food stores in local markets inside counties. We assess the probability of local markets to have full, limited and no access to the "high quality" type of food stores, considering both supply and demand factors to show how limited access can be an equilibrium outcome of market forces.

We find a clear and consistent path for demand side factors as determining food access within local markets inside counties, where market size especially (both in terms of total income and the additional demand from low-income individuals accessing SNAP) explaining a portion of the location of large food stores. Also, we find that large food stores avoid areas with higher levels of poverty, and although age composition matters for the likelihood of observing limited access, ethnic composition matters less; this is important because it suggests that studies showing a particular ethnic profile in areas characterized by low food access may be observing spuriously correlated phenomena. However we do find that the share of Hispanic is related to lower levels of large store access, although the effect is very small; this is probably due to higher demand for ethnic foods in these communities, which tend to be supplied through smaller outlets. With respect to the cost factors our results are not as clear, although they show that some cost determinants, such as the share of the cost of buildings coming from structures, home price index (more for a sample of counties with high poverty rates), and ease of recruiting labor play a role in the probability of observing areas with no access. Surprisingly, we find that a favorable tax regime for businesses has no impact on easing lack of access.

Our analysis confirms that the problem of “food deserts” arises fundamentally due to a lack of consumer purchasing power and market demand. Simply, if the (fixed) costs of store operations are not covered by the demand that exists in a particular community, food stores will cease to operate. As for public policy intervention, it turns out that one federal program is already playing a key role in attenuating the problem of food access: the SNAP program, although its role is less marked if one restricts the analysis to counties with poverty rates above the average. Other potential policy levers (e.g., tax breaks on diesel fuel), and corporate taxes in particular, appear to play less of a role according to our results. Lowering the cost of capital investments (perhaps via grants or low-interest loans, though programs similar to the Fresh Food Financing Initiative in Pennsylvania), could result useful in areas with higher poverty rates, however, the results are mixed. Somewhat surprisingly, building more roads to enhance access would have exactly the opposite effect.

Perhaps most paradoxical is the finding with respect to agricultural land shares (associated with less access even after controlling for other factors). In part this shows the great disconnect that now exists between food production and consumption. An opportunity may exist for raising awareness among food system participants of this disconnect, and subsequently re-localizing or re-regionalizing the food system to assure greater food access. However, whether such a regionalization would result in a well-functioning food system with greater access, or not, is an empirical question yet to be answered.

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Table 1. Sample statistics

	Full		LAI=0		LAI=1		LAI=2	
	Mean	st.err	Mean	st.err	Mean	st err	Mean	st.err
LAI (N obs)	20,132		4,273		11,068		4,791	
Demand								
Ln(INC)	11.051	2.258	13.516	0.746	10.255	2.084	10.692	1.972
Pop density	0.230	1.733	0.192	2.780	0.336	1.565	0.018	0.017
SNAP ratio	13.729	5.451	13.865	5.048	12.998	5.262	15.297	5.871
Poverty Rate	14.084	5.706	14.226	5.214	13.310	5.509	15.745	6.191
Share pop15-24	13.887	3.445	14.264	4.315	14.201	3.460	12.823	2.030
Share pop25-64	51.030	3.519	50.952	3.332	51.431	3.464	50.176	3.649
Share pop >65	14.885	4.045	15.124	3.143	13.772	3.747	17.243	4.363
Share pop Black	8.822	14.068	9.590	14.248	8.952	13.002	7.838	16.081
Share pop Hisp	6.864	12.490	3.760	5.984	8.149	13.426	6.666	13.954
Fixed Cost								
Structure Share	81.269	16.147	82.413	14.458	79.403	17.505	84.557	13.468
Home Price Index	1.217	0.225	1.208	0.208	1.232	0.248	1.189	0.176
Variable Costs								
Price Diesel	1.797	0.502	1.792	0.498	1.805	0.505	1.781	0.497
Price Electricity	7.149	1.684	7.209	1.603	7.360	1.880	6.607	1.032
Unemploy Rate	9.104	3.117	9.785	2.712	9.132	2.881	8.430	3.772
Distribution / Logistic								
Highway	1.890	0.782	2.133	0.566	1.910	0.894	1.627	0.563
Share Ag Land	5.569	4.876	5.303	3.883	5.084	4.963	6.928	5.205
Distance from BC	655.887	348.012	638.043	304.459	699.205	377.614	571.730	291.851
Other Controls								
No Corp Tax	0.114	0.318	0.049	0.217	0.117	0.321	0.165	0.371
Metro	0.356	0.479	0.003	0.055	0.582	0.493	0.147	0.354
Geographic Area	N	%	N	%	N	%	N	%
North	1,470	7.30	1,048	9.47	40	0.83	382	8.94
Midwest	6,909	34.32	3,326	30.05	1,986	41.45	1,597	37.37
West	2,674	13.28	1,868	16.88	662	13.82	144	3.37
South	9,079	45.10	4,826	43.60	2,103	43.89	2,150	50.32

Table 2.		OL	CGOL		GOL	
			LAI=1	LAI=2	LAI=1	LAI=2
Demand	Ln(INC)	-1.2049 ***	-3.0983 ***	-1.8068 ***	-3.0922 ***	-1.8247 ***
		(0.0199)	(0.0684)	(0.0760)	(0.0689)	(0.0772)
	Pop_density	0.2050 ***	0.0336 **	-31.3856 ***	0.0323 *	-30.7042 ***
		(0.0146)	(0.0168)	(3.0893)	(0.0171)	(3.1200)
	SNAP ratio	-0.2103 ***	-0.3976 ***	-0.1195 ***	-0.4009 ***	-0.1169 ***
		(0.0269)	(0.0499)	(0.0325)	(0.0550)	(0.0343)
	Poverty Rate	0.2118 ***	0.3237 ***	0.0884 ***	0.3266 ***	0.0858 ***
		(0.0258)	(0.0485)	(0.0304)	(0.0534)	(0.0321)
	Share pop15-24	-0.0978 ***	-0.1440 ***	-0.1440 ***	-0.1456 ***	-0.1425 ***
		(0.0103)	(0.0167)	(0.0167)	(0.0230)	(0.0221)
	Share pop25-64	0.0170	-0.0393 **	0.0524 ***	-0.0425 **	0.0535 ***
		(0.0111)	(0.0196)	(0.0158)	(0.0253)	(0.0177)
	Share pop >65	0.0442 ***	-0.1029 ***	0.0146 ***	-0.1054 ***	0.0147 ***
		(0.0081)	(0.0152)	(0.0124)	(0.0187)	(0.0138)
	Share pop Black	0.0266 ***	-0.0033	0.0040	-0.0033	0.0040
		(0.0019)	(0.0032)	(0.0028)	(0.0034)	(0.0028)
	Share pop Hisp	0.0181 ***	0.0091 ***	0.0091 ***	0.0085 *	0.0091 ***
		(0.0021)	(0.0029)	(0.0029)	(0.0050)	(0.0034)
Fixed Cost	Structure Share	0.0031	0.0084	0.0236 ***	-0.0028	0.0408 ***
		(0.0036)	(0.0088)	(0.0090)	(0.0107)	(0.0132)
	Home Price Index	0.1941	0.3875	0.3875	-0.2920	1.2723 **
		(0.1900)	(0.3915)	(0.3915)	(0.4961)	(0.5729)
Variable Costs	Price Diesel	0.2235	0.4622	0.2969	0.7511 **	0.0191
		(0.2041)	(0.2839)	(0.2805)	(0.3749)	(0.3514)
	Price Electricity	-0.0807 ***	-0.1844 ***	-0.1844 ***	-0.1858 ***	-0.1941 ***
		(0.0303)	(0.0507)	(0.0507)	(0.0688)	(0.0707)
	Unemploy Rate	-0.0931 ***	-0.0234 *	0.0221 *	-0.0220	0.0209 *
		(0.0077)	(0.0142)	(0.0113)	(0.0145)	(0.0114)
Distribution / Logistic	Highway	0.4992 ***	0.3449 ***	1.3567 ***	0.2076	1.1524 ***
		(0.0384)	(0.1187)	(0.1490)	(0.1635)	(0.2529)
	Share Ag Land	-0.0041	0.0081	0.0635 ***	0.0078	0.0646 ***
		(0.0040)	(0.0094)	(0.0059)	(0.0096)	(0.0059)
	Distance from BC	0.0010 ***	0.0011 ***	-0.0003	0.0008 ***	-0.0002
		(0.0002)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Other Controls	No Corp Tax	0.3622 ***	0.1337	0.1337	0.2222	0.1484
		(0.1343)	(0.2033)	(0.2033)	(0.3306)	(0.2591)
	Metro	-4.0211 ***	0.6665	-9.5797 ***	0.7794	-9.6862 ***
		(0.1007)	(0.6074)	(0.4593)	(0.6242)	(0.4666)
	Cut-off 1	-14.1789	-44.9695 ***	-15.1547 ***	-46.9393 ***	-13.2825 ***
		(1.0600)	(2.0354)	(1.8383)	(2.6138)	(2.2794)
	Cut off 2	-10.3940				
		(1.0568)				
Pseudo R2		0.2666	0.5474		0.5478	
Log Likelihood (Max)		-14757.5	-9106.75		-9098.51	
Log Likelihood (0)		-20122.4	-20122.4		-20122.4	
Wald test joint sign		10729.90	5893.68		22047.8	
p-value PAR		0.0000	0.8334			

*Note: *, **, and *** represent 10, 5 and 1% significance levels*. Standard errors in parenthesis. Fixed-effects and year dummies' coefficients omitted for brevity; *Pseudo R2*: Maddala's Pseudo R Squared; *p-value PAR*: *p*-value test for parallel regression

Table 3. Average marginal Effects: Constrained Generalized Ordered logit (GCOL)

		CGOL		
		LAI=0	LAI=1	LAI=2
Demand	Ln(INC)	0.2021 ***	-0.0450 ***	-0.1570 ***
		(0.0026)	(0.0067)	(0.0061)
	Pop_DEN	-0.0022 **	2.7297 ***	-2.7276 ***
		(0.0011)	(0.2660)	(0.2660)
	SNAP ratio	0.0259 ***	-0.0155 ***	-0.0104 ***
		(0.0032)	(0.0035)	(0.0028)
	Poverty Rate	-0.0211 ***	0.0134 ***	0.0077 ***
		(0.0031)	(0.0033)	(0.0026)
	Share pop15-24	0.0094 ***	0.0031 ***	-0.0125 ***
		(0.0011)	(0.0004)	(0.0015)
	Share pop25-64	0.0026 **	-0.0071 ***	0.0046 ***
		(0.0013)	(0.0012)	(0.0014)
	Share pop >65	0.0067 ***	-0.0080 ***	0.0013
		(0.0010)	(0.0009)	(0.0011)
	Share pop Black	0.0002	-0.0006 **	0.0004
		(0.0002)	(0.0003)	(0.0002)
	Share pop Hisp	-0.0006 ***	-0.0002 ***	0.0008 ***
		(0.0002)	(0.0001)	(0.0003)
Fixed Cost	Structure Share	-0.0005	-0.0015 ***	0.0021 ***
		(0.0006)	(0.0005)	(0.0008)
	Home Price	-0.0253	-0.0084	0.0337
		(0.0255)	(0.0085)	(0.0340)
Variable Cost	Price Diesel	-0.0301	0.0043	0.0258
		(0.0185)	(0.0078)	(0.0244)
	Price Electricity	0.0120 ***	0.0040 ***	-0.0160 ***
		(0.0033)	(0.0011)	(0.0044)
	Unempl Rate	0.0015 *	-0.0034 ***	0.0019 *
		(0.0009)	(0.0012)	(0.0010)
Distribution / Logistic	Highway	-0.0225 ***	-0.0954 ***	0.1179 ***
		(0.0077)	(0.0139)	(0.0128)
	Share Ag Land	-0.0005	-0.0050 ***	0.0055 ***
		(0.0006)	(0.0007)	(0.0005)
	Distance BC	-0.0001 ***	0.0001 ***	0.0000
		(0.0000)	(0.0000)	(0.0000)
Other	No Corp Tax	-0.0087	-0.0029	0.0116
		(0.0133)	(0.0044)	(0.0177)
	Metro	-0.0435	0.8760 ***	-0.8325 ***
		(0.0396)	(0.0547)	(0.0375)

*Note: *, **, and *** represent 10, 5 and 1% significance levels*. Standard errors in parenthesis, obtained with the delta method . Fixed-effects coefficients and year dummies' coefficients omitted for brevity

Table 4. Estimated parameters, model performance and average marginal effects – counties with poverty rates above the average (N=8,279); Constrained Generalized Ordered Logit (CGOL)

		Estimated Coefficients		Average Marginal Effects		
		LAI=1	LAI=2	LAI=0	LAI=1	LAI=2
Demand	Ln(INC)	-3.0727 ***	-2.1692 ***	0.2531 ***	-0.0211	-0.2319 ***
		(0.0963)	(0.1255)	(0.0048)	(0.0135)	(0.0123)
	Pop_DEN	0.0332 *	-26.3038 ***	-0.0027 *	2.8152 ***	-2.8125 ***
		(0.0181)	(4.6324)	(0.0015)	(0.4916)	(0.4916)
	SNAP ratio	-0.3957 ***	-0.0683	0.0322 ***	-0.0249 ***	-0.0073
		(0.0593)	(0.0418)	(0.0048)	(0.0049)	(0.0045)
	Poverty Rate	0.3419 ***	0.0619 *	-0.0279 ***	0.0212 ***	0.0066 *
		(0.0576)	(0.0390)	(0.0047)	(0.0047)	(0.0042)
	Share pop15-24	-0.1376 ***	-0.1376 ***	0.0112 ***	0.0035 ***	-0.0147 ***
		(0.0255)	(0.0255)	(0.0021)	(0.0007)	(0.0027)
	Share pop25-64	0.0058	0.1030 ***	-0.0005	-0.0105 ***	0.0110 ***
		(0.0300)	(0.0255)	(0.0024)	(0.0023)	(0.0027)
	Share pop >65	-0.1125 ***	-0.0022	0.0092 ***	-0.0089 ***	-0.0002
		(0.0242)	(0.0188)	(0.0020)	(0.0019)	(0.0020)
	Share pop Black	0.0013	0.0013	-0.0001	0.0000	0.0001
		(0.0029)	(0.0029)	(0.0002)	(0.0001)	(0.0003)
	Share pop Hisp	0.0169 ***	0.0012	-0.0014 ***	0.0012 **	0.0001
		(0.0060)	(0.0042)	(0.0005)	(0.0006)	(0.0005)
Fixed Cost	Structure Share	-0.0316 *	0.0472 ***	0.0026 **	-0.0076 ***	0.0051 ***
		(0.0158)	(0.0178)	(0.0013)	(0.0018)	(0.0019)
	Home Price Index	-0.7012	1.8831 **	0.0571	-0.2585 ***	0.2014 **
		(0.6097)	(0.7734)	(0.0497)	(0.0814)	(0.0826)
Variable	Price Diesel	0.5657	-0.1128	-0.0461	0.0581 **	-0.0121
		(0.4038)	(0.4209)	(0.0329)	(0.0254)	(0.0450)
	Price Electricity	-0.0724	-0.3457 ***	0.0059	0.0311 ***	-0.0370 ***
		(0.0924)	(0.0089)	(0.0075)	(0.0088)	(0.0095)
	Unemploy Rate	-0.0251	0.0117	0.0020	-0.0033 *	0.0013
		(0.018)	(0.0149)	(0.0015)	(0.0017)	(0.0016)
Distribution	Highway	0.3599	2.6099 ***	-0.0293	-0.2497 ***	0.2791 ***
/ Logistic		(0.226)	(0.2885)	(0.0184)	(0.0277)	(0.0302)
	Share Ag Land	0.0009	0.0633 ***	-0.0001	-0.0067 ***	0.0068 ***
		(0.0088)	(0.0072)	(0.0007)	(0.0009)	(0.0008)
	Distance BC	0.0011 ***	0.0011 ***	-0.0001 ***	0.0000 ***	0.0001 ***
		(0.0003)	(0.0003)	(0.0000)	(0.0000)	(0.0000)
Other	No Corp Tax	-0.0836	-0.0836	0.0068	0.0021	-0.0089
		(0.2551)	(0.2551)	(0.0208)	(0.0065)	(0.0273)
	Metro	-1.3914 **	-11.8658 ***	0.1134 **	1.1553 ***	-1.2687 ***
		(0.6401)	(0.7569)	(0.0521)	(0.0916)	(0.0754)
	Constant	-46.0153 ***	-11.9287 ***			
		(3.1989)	(3.0809)			
Pseudo R2		0.4767				
Log Likelihood (Max)		-4525.26				
Log Likelihood (0)		-8648.36				
Wald test joint sign		2681.14				
p-vlaue PAR		0.9912				

*Note: *, **, and *** represent 10, 5 and 1% significance levels*. Standard errors in parenthesis (standard errors for marginal effects obtained via the delta method). Fixed-effects and year dummies' coefficients omitted for brevity; *Pseudo R2:* Maddala's Pseudo R Squared; *p-value PAR*: *p*-value test parallel regression.