Zwick Center for Food and Resource Policy

Working Paper Series

No. 34

A Longitudinal Analysis of Fast-Food Exposure On Child Weight Outcomes: Identifying Causality Through School Transitions

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September 2014

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Abstract

This paper employs a novel identification strategy based on changes in the route students would use to commute between their home and their school as they transition to higher grades housed in different schools to investigate the effect of fast-food availability on childhood weight outcomes by gender, race and location. Using a longitudinal census of height and weight for public school students in Arkansas, we find no evidence that changes in fast-food exposure are associated with changes in BMI z-score. Our findings suggest that laws restricting fast-food restaurants from areas near schools are neither effective nor efficient means of improving public health.

Keywords: fast-food, childhood obesity

Highlights:

- Introduces a new identification strategy based on commuting routes to school.
- Employs longitudinal data of measured BMI for Arkansas public school students.
- Results suggest that exposure to fast-food restaurants has no effect on body weight.
- There is no meaningful heterogeneity by race, gender, SES or length of commute.
- Policies restricting fast-food near schools are likely ineffectual and inefficient.

JEL Classifications: I10, R12, R40

1. Introduction

The rate of childhood obesity, 19.6% for those ages 6-11 and 18.1% for those ages 12-19 (Ogden et al., 2010), is a leading public health priority in the United States. The problem is particularly acute among minority groups. The childhood obesity rate among black females is 29.2% versus 14.5% for white females, while the rate among Hispanic males is 26.8% compared to 16.9% for white males (Ogden et al., 2010). Although a number of researchers have identified a positive association between childhood obesity risk and the accessibility of fast-food establishments, evidence for a causal relationship (rather than a simple correlation) is lacking. Because fast-food restaurants do not locate randomly with respect to characteristics associated with the obesity status of residents (Dunn, 2010; Dunn, Sharkey and Horel, 2012), studies that ignore the endogenous determination of fast-food accessibility may not yield consistent estimates of its true causal role, and thus misinform important policy debates, e.g., whether fast-food restaurants should be allowed to locate near schools.[1] While a recent paper by Alviola et al. (2014) addresses potential endogeneity using instruments for the spatial distribution of fast-food restaurants around schools, their data are limited to school-level aggregates. Therefore, this paper considers the causal influence of fast-food accessibility on individual childhood obesity outcomes using a panel of public-school students in Arkansas.

To do so, we measure the number of fast-food restaurants along the route from the child's home to her school. We argue that for practical purposes, fast-food exposure on the route between home and school is a similar treatment to—and hence informative about—fast-food exposure in the area surrounding school. Specifically, for students that walk or bike to school

[1] In 2013, the Austin City Council rejected a measure to explore the banning of fast-food restaurants near schools. In 2009, New York City Councilman Eric Giola proposed that no new fast-food restaurants could open within 0.1 miles of a New York City public school.

(and older students who drive themselves), where a restaurant is located along the commuting route—at the midpoint or one of the end nodes—should have at most a second order effect on total fast-food consumption, at least relative to the first order effect of the presence of the restaurant. For students that utilize school busses following dedicated routes who would not be able to access fast-food restaurants along their commuting route, there is simply not enough time between the end of the school day and bus departures to allow a fast-food purchase at restaurants located adjacent to the school. Further, most students, particularly in early grades, cannot leave campus during the day to eat at nearby restaurants.

Our identification strategy is based on the argument that changes in the route measure as a consequence of the child transitioning from elementary school to middle school, from middle school to junior high school, or from junior high to high school are exogenous even if locations of restaurants, residences, and schools are endogenously determined. Intuitively, although the change in fast-food exposure along commuting routes could be known to parents, it is exceedingly unlikely that residential location or commercial zoning decisions are affected by this knowledge.

There are reasons to expect that greater exposure to fast-food would increase consumption and lead to higher BMI measures. One mechanism is that greater densities of fast-food restaurants should lower the full cost of consuming fast food meals. In fact, Curry et al. (2010) appeal to travel costs as an explanation for their finding that the effect of fast-food proximity on weight was much smaller among a sample of pregnant women than among a sample of early adolescent schoolchildren. In general, adult populations have greater mobility than do schoolchildren. To the extent that travel costs are important, the effect of nearby fast-food establishments should be largest for middle and junior high schoolchildren. These children are not old enough to drive but are old enough to have pocket money and to move about neighborhoods without direct parental supervision.

Another potential mechanism is that greater environmental access to fast-foods amplifies promotional efforts by fast-food companies. Fast food is heavily advertised and advertising is often targeted to children (Linn and Novosat, 2008). Even if all children are equally impressed by an advertising message, those with greater access to fast-foods in the built environment will have more opportunities to act on the promotional suggestions contained therein. In particular, fast food restaurants in the neighborhood may serve as stimuli that remind children to request fast food from their parents or caregivers. On-premises signage and promotional materials are often coordinated with media campaigns. This may further increase the potency of messages children encounter through television, websites, or other sources. Finally, most school days end in the mid to late afternoon -- several hours after the child has last had a meal. Because many children will have developed an appetite by this time of day, the presence of fast-food restaurants on the route home may be an especially important stimulus that motivates purchases of or requests for fast food.

Despite these arguments, our findings do not support a causal link between fast-food exposure along the route to school and BMI. This conclusion holds across different ages of children and for subsamples by gender, race, and ethnicity. We also find no differences by income status as measured by whether the child qualifies for free or reduced price school lunches or between urban and rural children.

In what follows, we provide an overview of earlier findings about the impact of fast food restaurants around the home or around the school on the body weight of children. We then explain the Arkansas childhood BMI data, the routes-to-school measure of restaurant density we use in this study, and the natural experiments that comprise our empirical strategy. The final two sections of the paper present our results and conclusions.

2. Fast-food availability and childhood obesity

Studies on the relationship between exposure to fast-food and childhood obesity outcomes can be categorized by the measure of exposure employed. One group of papers considers the effect of proximity of fast-food restaurants to schools. In general, these studies often yield conflicting results, even when using comparable data. For example, Currie et al. (2010) report that for ninth-graders attending public schools in Los Angeles, CA, a fast food restaurant within 0.1 miles of a school results in a 5.2 percent increase in school-level obesity rates. Yet, another study of ninth-graders in California found no relationship between proximity of fast-food restaurants and school-level obesity rates (Howard, Fitzpatrick and Fulfrost, 2011). Using student-level data from California, Davis and Carpenter (2009) found that a fast-food restaurant located within one-half mile of a school increased obesity risk by 7%.

A second group of papers considers the effect of fast-food restaurants located near a child’s residence. As a whole, these studies also produce widely divergent results. Looking at elementary and middle-school students, Mellor, Dolan and Rapoport (2011) found statistically significant relationships between obesity and the number of fast-food restaurants located within one-tenth and one-quarter of a mile of the residence. In contrast, a study of children in Cincinnati, OH found no relationship between distance to the nearest fast-food restaurant and the probability of childhood obesity (Burdette and Whitaker, 2004). Further, a study using

Australian data actually found a large negative relationship between fast-food restaurants located within 2km of the residence and weight outcomes (Crawford, et al., 2008).

A third group considers a broader measure of overall exposure based on the number or density of restaurants within a defined geographic area. For example, Sturm and Datar (2005) link the student-level data from ECLS to the per capita number of restaurants in the child's home and school zip code for those residing in metropolitan areas, but find no statistically significant relationship between obesity and outlet density.

Given the clear lack of consensus in the published literature, the common assertion that greater fast-food accessibility is associated with childhood obesity outcomes is simply not tenable. Howard, Fitzpatrick and Fulfrost (2011) illustrate the point:

> "Residing near fast food restaurants (9) and convenience stores, for example (10,11), is associated with excess weight [*among children*], while residing near supermarkets is associated with lower weight (11,12). While not all studies have observed these types of associations (12-15), similar relationships have been reported for the majority of studies involving adults (16-20)."

In our opinion, this is a misreading of the existing results with respect to both children and adults. Rather, the over-arching theme that emerges from the literature is that context matters.

A second issue is the widespread failure to address the potential endogeneity of fast-food exposure. Fast-food restaurants, as profit maximizing firms, do not locate randomly. Rather, they will tend to open where consumer demand while be greatest. One argument is that individuals who choose to purchase fast-food will tend to engage in a variety of other obesogenic activities. Thus, correlational studies would tend to overstate the true causal effect of fast-food on weight outcomes. In contrast, Dunn (2010) argues that fast-food restaurants will tend to locate where the disposable income of residents is highest, since fast-food is a normal good (Park, et al., 1996).

Individuals with higher socio-economic status would tend to have better health status, and to the extent that the explanatory variables fail to fully capture this effect, a naïve covariance would understate the true effect of fast-food availability. Dunn (2010) does indeed find that markers of socio-economic status like income and educational attainment are positively associated with the number of fast-food restaurants in the county of residence and that OLS tends to understate the relationship between fast-food exposure and weight outcomes. Dunn, Sharkey and Horel (2011) and Alviola, et al., (2014) report similar results. Moreover, the selection of restaurant location based on socio-economic attributes appears to be more pronounced in communities with a greater proportion of minority resident, which is consistent with work on fast-food pricing (Graddy, 1997).

To overcome the endogenous determination of fast-food exposure, previous studies have tended to utilize characteristics of the highway system as instruments to generate exogenous variation and identify the causal effect on obesity outcomes (Anderson and Matsa, 2011; Dunn, 2009, 2010; Dunn, Sharkey and Horel, 2012; Alviola et al., 2014). Their findings on the relationship between fast-food availability and weight outcomes among adults using IV methods are instructive. Dunn (2010) estimates the relationship between fast-food availability and BMI by gender, race/ethnicity and residential location among respondents to the 2004-2006 BRFSS. He finds that the magnitude of the relationship depends greatly on each of these characteristics. Among rural whites, there is no statistically or economically significant relationship once individual and county-level attributes are included in the explanatory variables. His findings are corroborated by Anderson and Matsa (2011), who also use a predominantly white (93%) sample of rural respondents to BRFSS, and Dunn, Sharkey and Horel (2012), who look at whites in a rural region of Central Texas. In contrast, Dunn (2010) does find a statistically significant relationship among blacks and Hispanics, which is again corroborated when Dunn, Sharkey and Horel (2012) consider blacks and Hispanics in their sample.

Differences across school types are also reported in Alviola et al., (2014), who consider the effect of fast-food proximity on school-level obesity rates in Arkansas. Addressing the endogeneity of fast-food through IV estimation, they find that restaurants located within one-quarter mile of elementary schools have no statistically significant relationship with school-level obesity, but a strong, positive relationship at schools housing students in higher grade levels.

It becomes evident that sweeping statements regarding effect of greater fast-food availability on obesity outcomes is unsupported and potentially misleading. A more useful approach is to fully acknowledge that fast-food exposure may be more salient for some populations than for others and to generalize results drawn from one sample only to groups with similar characteristics, e.g. age, race/ethnicity, gender, socio-economic status, urbanicity, etc.

3. Data

Our data come from three sources. First, we use the Arkansas BMI dataset from 2004 to 2010. This is a unique panel dataset at the student level that includes child weight and height data collected by trained personnel in the public schools and maintained through legislative mandate at the Arkansas Center for Health Improvement (ACHI) (Justus et al. 2007). BMI is calculated as a ratio ([weight in pounds /(height in inches)^2] $\times$ 703) and then converted to age-gender specific z-scores according to the Centers for Disease Control and Prevention guidelines (CDC 2013).

From 2004 through 2007 all public school children were targeted for BMI screenings. However, only children in even-numbered grades, kindergarten through 10th grade, were measured beginning in 2008. While participation is not universal, response is very high. During the 2003-04 school year, 345,892 of 421,973 students (82.0%) generated valid measurements. The most likely reason students did not have height and weight reported was because of absence (7%), non-attendance (4%), parental refusal (4%) and child refusal (2%) (ACHI 2005). There was little difference in gender or race/ethnicity in the rate of non-reporting, but non-reporting did tend to increase in grade level: 13% in elementary school, 15% in middle school and 25% in high school (ACHI 2005). Participation was similar during the 2009-10 school year with 178,015 of 220,532 students (80.7%) in grades K, 2, 4, 6, 8, and 10 generating valid measurements. The most common reasons for exclusion were absence (7%), parental refusal (5%) and child refusal (2%) (ACHI 2010).

Student BMI was then matched to home and school address through annual school registration records that are also housed at ACHI. Home address was used to geocode the roof-top location of student residences. Records with less precise geo-coordinates (e.g., zip code centroids) were excluded. The address match-rate was relatively high, between 85 and 90 percent for each cohort. Using the GIS procedure in SAS 9.3 (SAS Institute Inc., Cary, NC, 2011), neighborhoods were defined using one-half mile (805m) Euclidian catchment areas centered on their residential and school address. The number of fast-food restaurants within that area was summed to generate exposure near home ("home exposure") and exposure near school ("school exposure"). The Euclidean distance between the residential address and the nearest fast-food restaurant was also calculated.

No information was available on the actual route taken by children between home and school, nor on the mode of transportation, e.g., bus, car, walking. Hence, the shortest street-network commuting distance between home and school was calculated, generating a poly-line for each student. For identification purposes, the food environment along the shortest route is actually preferred to the environment along the realized route, as the latter would clearly be endogenous. Indeed, the former would be the most obvious candidate to instrument for the latter. As in previous studies, a 100m buffer centered on the poly-line was constructed and the number of fast-food restaurants within the buffer area was summed to calculate exposure along the commuting route ("route exposure").

Second, geo-coded restaurant data were purchased from Dun and Bradstreet (D&B). To assure that our measures of fast-food exposure are reasonably synchronous with the BMI measurements, we used end-of-year business lists corresponding to each year for which BMI measurements are available. We started with all establishments with a standard industrial classification (SIC) code of 5812 "Eating Places" and then removed full-service restaurants based on six and eight-digit SIC codes, if available. Otherwise, we identified fast-food restaurants using the company name or, in the case of chain or franchise restaurants, the trade name. When the type of establishment remained in doubt, we used internet searches and identified fast food restaurants based on website information (e.g., menus), customer ratings, or street-view images in the Google search engine. Fast-food restaurants, as used in our study, include the major hamburger chains and drive-in restaurants (e.g. McDonalds, Burger King, Wendy's), dairy stores with large fast-food menus (e.g., Dairy Queen), take-out pizza establishments, quick-service taco places (e.g., Taco Bell), sandwich delicatessens (e.g., Subway, Quiznos), and fried chicken restaurants (e.g., KFC, Chick-Fil-A). Our definition of fast-food establishments excludes specialty stores such as ice-cream parlors not selling other fast foods (e.g., Baskin-Robbins), coffee shops (e.g. Starbucks), and donut shops (e.g. Krispy Kream). With the help of ACHI personnel, we geo-referenced and interfaced the BMI data with fast food store locations so that our final dataset provided measures of the fast food environment near home, near school and along the route between home and school

Finally, we used neighborhood-level information from the US Census Bureau to identify whether each child's residential address fell into an urban or rural census block based on census-defined places.

4. Fast-food exposure in Arkansas

This section briefly describes the relative importance of the different measures of fast-food exposure for children in Arkansas. Of particular importance is establishing that route exposure accounts for an economically meaningful proportion of total exposure. In addition, we explore how exposure varies by race and socio-economic status.

Table 1 summarizes the fast-food exposure measures for students during the 2009-2010 school year. The mean total exposure level is 3.34 restaurants and route exposure contributes a substantial share: 35.9%. The number of restaurants within 0.5 miles of the school attended is 65% larger than the number of restaurants within 0.5 miles of the residence ($p<0.01$). Exposure along the shortest commuting route between residence and school is also significantly larger than exposure near home, 49% ($p<0.01$). The majority of children in the sample have zero exposure within 0.5 miles of home (69.6%). In contrast, 45.2% of children have at least one fast-food restaurant located within 0.5 miles of their school.

Figure 1 plots the relative contribution of each exposure count measure to total fast-food exposure for each quintile of the fast-food exposure distribution. Exposure near school accounts for the greatest contributor in the 2nd- 4th quintiles, while exposure near home and along the shortest commuting route are roughly equal contributors. In the highest exposure quintile, however, exposure along the route is the largest contributor.

Table 2 reports Spearman correlation coefficients for the four exposure methods. Although each of the correlations is positive and statistically significant at the p<0.01, the magnitude of the correlations are relatively small. Only the correlation between exposure at near school and exposure along the shortest route between home and school is greater than 0.25. Together, these results demonstrate that route exposure accounts for a substantial share of total exposure and correlation between exposure measures was relatively weak, 20-30% and 0.21, respectively, consistent with previous analyses for adults in England (Burgoine and Monsivais, 2013)..

4.1. Differences in exposure by race

Table 3 reports the mean fast-food exposure by school-year, grade-level, and race/ethnicity. At all grade levels, residential exposure accounts for the smallest share of total exposure among white students. For white students in the 2nd grade, school exposure accounts for the largest share of total fast-food exposure (p<0.01). In 6th and 10th grade, however, exposure along the commuting route between home and school accounts for the largest share of fast-food exposure (p<0.01). Indeed, for these students, route exposure is more than twice as great as residential exposure. This is true in both 2004 and 2010.

Among black students, school exposure accounted for the largest share of total exposure at all grade levels during the 2003-04SY. During the 2009-10SY, however, the difference in school exposure and route exposure was no longer statistically significant for 6th and 10th graders. This reflected both a decrease in fast-food exposure near school and an increase in fast-food exposure along commuting routes.

For Hispanic students, the relative importance of school and route exposure has changed over time. During the 2003-04SY, school exposure accounts for the largest share of total exposure among Hispanic students in 2nd and 10th grade, while residential exposure accounts for the largest share among 6th graders. Six years later, school exposure is the largest contributor to total fast-food exposure only for 2nd graders, while route exposure accounts for the largest share among 6th and 10th graders. This reflects both a large increase in mean route exposure for Hispanic 10th graders, 1.83 to 2.39 ($p<0.01$), and an even larger decrease in the mean school exposure, 2.81 to 1.96 ($p<0.01$).

Residential exposure accounts for a greater share of total fast-food exposure among black and Hispanic students compared to white students. During the 2009-10SY, residential exposure accounted for 22.9% of total exposure for white 2nd graders, compared to 34.4% of black 2nd graders ($p<0.01$) and 35.7% for Hispanic 2nd graders ($p<0.01$). Among 6th graders, these figures were 19.5% for white students, 27.8% for black students ($p<0.01$), and 32.7% for Hispanic students.

Regardless of year or grade-level, white students tend to be less exposed to fast-food restaurants near their residence than black or Hispanic students. For example, mean residential exposure among white students in the 2nd grade during the 2009-10SY was 0.65 and 0.58 smaller than the mean residential exposure of their black and Hispanic counterparts, respectively ($p<0.01$). Similarly sized exposure differentials exist at other grade-levels and school years. White students also tend to be less exposed to fast-food near their school than black students.

The mean school exposure among white students in the 2nd grade during the 2003-04SY was 0.19 smaller ($p<0.01$) than the mean school exposure of black students in the 2nd grade, declining only slightly to 0.18 ($p<0.01$) during the 2009-10SY. The school exposure differential between white and black students becomes larger in higher grades. The mean school exposure for white students in the 6th and 10th grades during the 2003-04SY is 0.95 ($p<0.01$) and 0.85 ($p<0.01$) smaller, respectively, than the mean for their black counterparts. Unlike the exposure differential among 2nd graders, however, these differences have declined substantially over time. During the 2009-10SY, school exposure differential between white and black students fell to 0.48 ($p<0.01$) for students in 6th grade and 0.64 ($p<0.01$) for students in 10th grade. For 6th graders, this reflected both an increase in school exposure for white students and a decrease in school exposure for black students. More positively, for 10th graders this was entirely the result of a decrease in school exposure for black students.

White students in 2nd and 10th grade also tend to be less exposed to fast-food near their school than Hispanic students (the difference is mean fast-food exposure is not statistically significant for 6th graders). The mean school exposure for white students in the 2nd and 10th grades during the 2003-04SY is 0.62 ($p<0.01$) and 1.55 ($p<0.01$) smaller, respectively, than the mean for their Hispanic counterparts. While large, these differentials have decreased substantially over time. During the 2009-10SY, school exposure differential between white and blacks students fell to 0.22 ($p<0.01$) for students in 6th grade and 0.71 ($p<0.01$) for students in 10th grade. At both grade-levels, this almost entirely reflects a decrease in exposure among Hispanic students, rather than an increase in exposure among white students.

Differences in route exposure across race/ethnicity tend to be less pronounced than for residential and school exposure among students in 2nd and 6th grade. For example, during the

2009-2010 school year, route exposure for Hispanic 2nd graders was less than route exposure for white 2nd graders ($p<0.01$) and was not statistically different between white and Hispanic 6th graders. For 10th graders, however, the difference in white-Hispanic route exposure, 0.79, was larger than the difference in both white-Hispanic residential exposure, 0.46, and school exposure, 0.71.

4.2. Socio-economic disparities in exposure

Table 4 reports the mean fast-food exposure by school-year, grade-level, and free/reduced lunch status, a measure of student socio-economic status. Students who receive free lunch tend to be more exposed to fast-food near their residence than students who pay full price, a relationship that was consistent over time. During the 2003-04SY, mean residential exposure for 6th grade students who paid full price for lunch was 0.35 lower ($p<0.01$) than for students receiving free lunch, compared to 0.37 lower ($p<0.01$) during the 2009-10SY. For 10th graders, the differential in 2003-04SY is 0.28 ($p<0.01$) versus 0.30 ($p<0.01$) in 2009-10SY. There is a significant decline in residential exposure among students eligible for reduced lunch between the 2003-04SY and 2009-10SY. Mean residential exposure falls by 0.19 ($p<0.01$) for 2nd graders receiving reduced-price lunch, by 0.15 for 6th graders ($p<0.01$), and by 0.22 ($p<0.01$) for 10th graders.

The relationship between lunch status and school exposure is much weaker. There is no statistically significant difference between those receiving free lunch and those who pay full fare in mean school exposure for 2nd graders in either 2003-04SY or 2009-10SY. During the 2003-04SY, mean school exposure for 6th graders who paid full price for lunch was 0.27 lower ($p<0.01$) than for 6th graders who received free lunch. But, in the 2009-10SY, this relationship reversed: mean school exposure for sixth graders receiving free lunch was 0.18 lower ($p<0.01$) than for sixth graders who paid full price.

Students who paid full price for lunch tended to have greater route exposure than students who received free lunch. During the 2009-10SY, the mean route exposure for 2nd grade students paying full price was 0.24 higher ($p<0.01$) than students receiving free lunch, 0.40 higher ($p<0.01$) among 6th graders, and 0.37 ($p<0.01$) higher among 10th graders. These differential are larger than during the 2003-04SY, when there were 0.08 ($p<0.01$) for 2nd graders, 0.09 ($p<0.01$) for 6th graders, and 0.29 ($p<0.01$) for 10th graders.

It is worth noting two additional phenomena that are evidenced in the preceding results. First, there is a large increase in the proportion of Hispanic students attending schools in Arkansas from the 2003-04SY to 2009-10SY. Second, the proportion of students paying full price for lunch declined between the 2003-04SY and 2009-10SY and the proportion of students receiving free lunch increased, but the proportion receiving lunch at reduced price remained relatively stable. Further, mean fast-food exposure among students receiving reduced price lunch looks similar to students receiving free lunch during the 2003-04SY, but more closely resembles exposure among those paying full price during the 2009-10SY. This is likely a result of the Great Recession reducing household incomes, thereby affecting which households qualified for (or took advantage of) the Federal School Lunch Program.

5. Identification Method

To identify the causal role of fast-food exposure on student weight outcomes, we utilize the natural experiment that arises when students change the school they attend as they progress through the K-12 educational system. When students move from elementary school to an intermediate school (a middle school or junior high school) or from an intermediate school to high school their exposure to fast-food may change simply because the route between their home and their school has changed.

Figure 2 plots a hypothetical situation for two students, *A*, who is normal weight, and *B*, who is obese. They reside at homes, H_A and H_B, respectively. Student *A* lives in a neighborhood without nearby fast-food restaurants and the elementary school she attends, E_A, also does not have fast-food restaurants located nearby. It is possible that student *A* experiences a lack of fast-food exposure because of decisions made by her parents to choose to live in a healthy food environment and to restrict commercial zoning around elementary schools. In contrast, multiple fast-food restaurants are located near the residence, H_B, and elementary school, E_B, of Student *B*. This may arise because his parents are less concerned about the food environment. A regression analysis of weight status on fast-food exposure would generate a positive relationship, but we would not be able to determine whether this was causal or simply reflecting the underlying preferences for the food environment on the part of parents.

Our identification strategy is based on using the change in food environment that arises as students *A* and *B* progress to middle school and now each attend *M*. The parents of student *A* may choose where to live based on the food environment near their home and the schools their children attend, but are unlikely to do so based upon changes in fast-food exposure on the route taken to school. Moving to middle school, student *A* now passes two fast-food restaurants, so her exposure has increased. Student *B* now passes two fewer fast-food restaurants, so his exposure has decreased. We use these changes in exposure as independent variables to explain changes in BMI z-scores.

In our sample of public school students, we consider several transitions: from elementary school to an intermediate school (a middle school or junior high school), from one intermediate grade to another, and from an intermediate school to high school. For the elementary to intermediate school transition, we consider two general grade structures. First, there are students who attended an elementary school for 4th grade, and then made one and only one transition to an intermediate school within the same school district for 6th grade. That is, we would include students who attended a K-5th grade elementary school and a 6th-8th grade middle school, but would not include students who attended a K-6th grade elementary school (no transition) or attended a K-4th grade elementary school, a 5th grade intermediate school, and a 6th-8th grade junior high school (multiple transitions).

Second, there are students who attended an elementary school for 4th grade and made one and only one transition to an intermediate school within the same district for 8th grade. This sample would include students who attended a K-5th grade elementary school and a 6th-8th grade middle school as in the case above. It would not include students who attended a K-8th grade primary school (no transition) or attended a K-4th grade elementary school, a 5th-7th grade middle school, and a 8th-9th grade junior high school (multiple transitions).

We also consider the change between the 6th and 8th grades. Examples include a single transition from a K-6th grade elementary school into an intermediate school housing the 7th and 8th grades or the transition between intermediate schools of two different levels as would be the case of a student that attends a 5th to 6th grade middle school and then a 7th to 8th grade junior high school. Again, inclusion in this sample requires one and only one school transition between the 6th and 8th grades and that the student transitioned through schools within the same district.

For the intermediate school to high school transition, we consider students who attended one school for 8th grade, and afterwards made one transition to a high school in the same school district for 10th grade. That is, we would include students who attended a 6th-8th grade intermediate school and then attended a 9th-12th grade high school, but would not include students who attended a K-12th grade comprehensive school (no transition) or attended a 6th-8th grade middle school, a 9th grade junior high school and a 10th-12th grade high school (multiple transitions).

There is considerable diversity in how Arkansas public schools house the different grades, especially the intermediate grades. This is potentially important in light of recent findings that 6th graders in middle schools are placed at an academic disadvantage relative to those in elementary schools (Rockoff and Lockwood 2010; Schwerdt and West 2013). While our focus is not on academic achievement, it is possible that intermediate school environments differ in ways that make them more or less obesogenic. Thus, one advantage to examining transitions across schools, as we do here, is that it tends to homogenize students by requiring similar grade configurations within the different samples.[2]

We restrict all samples to only include students who have the same residence for each of those grades so that changes in exposure are not driven by the decision to change residence. Further, students are only included in the sample if they advance one grade for each year they are in the sample.

For all students who meet the sample restrictions for a particular transition, we calculate the change in measured BMI z-score, the change in the number of fast-food restaurants located

[2] One exception is the 6th to 8th grade transition. This sample would combine students that spent the 6th grade in an elementary school with those spending 6th grade in an intermediate school. Given the results below, it is unlikely that this is a problem in our context.

along the shortest-distance route between home and school, and the change in the route distance during that transition. The following linear regression specification is then estimated:

$$(1)\ \Delta BMIZ_{i,t} = \beta_0 + \beta_1 \Delta FF_{i,t} + \beta_2 \Delta DIST_{i,t} + X_i\gamma + Z_i\theta + \delta_i + \varepsilon_{i,t}$$

where $\Delta BMIZ_{i,t}$ is the change in BMI z-score for student *i* making grade transition $t \in \{4 \rightarrow 6; 4 \rightarrow 8; 6 \rightarrow 8; 8 \rightarrow 10\}$; $\Delta FF_{i,t}$ is the change in fast-food exposure for student *i* making grade transition *t*; $\Delta DIST_{i,t}$ is the change in route distance between home and school for student *i* making grade transition *t*; X_i is a vector of individual specific attributes including gender, race, meal status, urban-rural indicator; Z_i is a vector of attributes for the Census Block Group in which student *i* resides including median household income, % living under the poverty line; median gross rent; and educational attainment; δ_i is a school-district fixed-effect; and $\varepsilon_{i,t}$ captures unobservable attributes.

Given the variety of grade structures observed in the data, for any particular school transition, different students will experience more or less time in the school they are transitioning to. For example, a student who transitions from a K-6th grade elementary school to a 7th-9th grade middle school experiences 2 years of the food environment associated with the second school between 4th and 8th grade. In contrast, a student who transitions from a K-4th grade elementary school to a 5th-8th grade middle school experiences 3 years of the food environment associated with the second school between 4th and 8th grade. One might therefore expect a dose-response relationship between changes in fast-food exposure and weight outcomes. Therefore, the following specification is also estimated:

$$(2)\ \Delta BMIZ_{i,t} = \beta_0 + \beta_1 \Delta FF_{i,t} + \beta_2 \Delta DIST_{i,t} + \beta_3 \Delta FF_{i,t} * EX_{i,t} + X_i\gamma + Z_i\theta + \delta_i + \varepsilon_{i,t}$$

where $EX_{i,t}$ is the number of years that student *i* experiences the food environment in the school to which they are transitioning during transition *t*. Thus, the coefficient β_3 provides the linear dose-response function.

The identification approach described in the preceding section should address the possible bias created by the location selection processes of both households and fast-food establishments. However, it is still possible that other attributes of the food environment experienced by adolescents also change when students move between schools. For example, suppose that fast-food restaurants tend to locate near other potentially obesegenic establishments, such as convenience stores and ice cream shops, for which we do not have information on route exposure. In this instance, an increase in fast-food exposure would capture both the causal influence of greater fast-food availability on weight outcomes, as well as the spurious influence of greater access to convenience stores. We would then expect the estimated coefficients to be upper-bounds on the true causal effect of fast-food exposure on weight outcomes. As will become clear in the next section, the estimated upper bound is still highly informative.

6. Results

6.1. Association between changes in obesity and fast-food exposure

To establish a baseline correlation between measures of fast-food exposure and adolescent weight outcomes, we conduct a preliminary analysis using both the youngest and oldest students for whom we have BMI measurements. Table 5 reports descriptive statistics for two groups of students during the 2007-2008SY: those in 4^{th} grade and those in 12^{th} grade (we use this particular school year because it is the last in which 12^{th} graders were routinely screened for height and weight). For the former, we calculate the change in BMI between kindergarten and 4^{th}

grade using data collected during the 2003-2004SY. For the latter, we calculation the change in BMI between 9th grade and 12th grade using data collected during the 2004-2005SY. Fast-food exposure is calculated as the mean exposure over the period and then discretized to allow for non-linear response functions.

Table 6 reveals that changes in BMI z-score for students in elementary school are not associated with fast-food exposure when initial BMI, race/ethnicity, gender, socio-economic status and neighborhood characteristics are controlled for. In contrast, the change in BMI z-score for students in high school is 0.1 larger for students who have 5 or more fast-food restaurants near their school (8 percent of the sample) compared to students with no fast-food restaurants. Students in high school with 2-4 fast-food restaurants (15.1 percent of the sample) along the commuting route also tend to have a change in BMI z-score that is 0.1 points higher compared to students without fast-food along their commuting route. This provides some evidence that at higher exposure levels, fast-food near school or along the commuting route is positively associated with weight outcomes and 0.1 standard deviations would be considered a fairly sizeable effect if causal. It is also reassuring that the estimated associations are similar in magnitude for both school and route exposure, as the goal is ultimately to use route exposure, over which policy makers may have little influence, to inform possible interventions in the food environment around schools.

6.2. Changes in obesity and changes in route exposure

Table 7 reports descriptive statistics for the each of the four grade transitions we consider in the regression analysis. The mean BMI z-score ranges from 0.71 to 0.76, indicative of a serious obesity and overweight problem among students. Although the mean change in BMI z-score as students transition is relatively small, its variation is quite large: the standard deviation of the change in BMI z-score ranges from 62% to 73% of the mean BMI z-score.

As students transition to schools that house higher grade levels, they tend to commute farther from home, particularly when moving between elementary and middle school. As a result, they tend to pass slightly more fast-food restaurants. More importantly, the standard deviation in the change in the number of fast-food restaurants is relatively large--between 2.5 and 3 restaurant—suggesting that there will be sufficient variation in fast-food exposure to generate precise estimates of the treatment effect.

Table 8 reports coefficient estimates from equations (1) and (2) for each grade transition. It is clear that changes in exposure have no effect on changes in BMI z-score. For example, increasing fast-food exposure by three restaurants moving from 8^{th} to 10^{th} grade (roughly one standard deviation) would increase mean change in BMI z-score by .003, less than one percent (0.7%) of the standard deviation for the observed change in BMI z-score. The coefficient estimates on change in fast-food exposure for the other grade transitions, as well as the coefficient estimates on the interaction term for years of exposure, are similarly small.

There are notable differences across gender and race/ethnicity in how BMI z-score changes over time. For example, the BMI z-score of female students in early grades tends to increase more rapidly than the BMI z-score of male students. During the transition from 8^{th} to 10^{th} grade, however, the BMI z-score of male students tends to increase by a greater amount. It is also interesting that relative to students who receive free school lunch, students who pay full price for lunch tend to exhibit smaller increases in BMI z-score during early grade transitions.

Given these results, we also examine whether the effect of changes in fast-food exposure varies across gender, race/ethnicity, or urban/rural residence.

6.3. Results by gender, race/ethnicity and location

Table 9 reports coefficient estimates from equation (1) by student gender for each grade transition. Again, estimate generates a collection of well-estimated zeros. Each of the coefficient estimates is small in magnitude. Half of the estimates are greater than zero, while half are less than zero. One estimate (females moving from 4th to 8th grade) is negative and statistically significant at the 5% level, but that should not be an unexpected outcome of hypothesis testing.

Table 10 reports the coefficient on the change in fast-food exposure from estimation of equation (1) across race/ethnicity, residential location and lunch status.[3] These results also indicate that there is no economically meaningful relationship between changes in fast-food exposure and changes in BMI z-score. Of the 32 coefficient estimates, only one is statistically significant at the 5% level.[4]

7. Conclusion

The food environment in general and fast food in particular has received considerable attention as factors contributing to high rates of childhood obesity. In this paper, we explored the link between fast-food exposure along the route to school and childhood BMI z-scores. Our empirical strategy was based on what can reasonably be considered exogenous changes that occur along the route between home and school as children follow the natural progression from elementary school through high school. Descriptive statistics indicate that these natural changes

[3] Full regression results are available upon request.

[4] In 40 randomly chosen, independent samples, one would expect two coefficient estimates to be statistically significant at the 5% level purely by chance. Although not independent samples, it is nonetheless worth pointing out that over the 40 subgroup analyses, two coefficient estimates were statistically significant at the 5% level.

to the route induce a good deal of variation in the number of restaurants to which children are exposed as they progress through the school system.

Although naïve OLS regressions of route and school exposure show similar, positive association between fast-food availability and BMI z–score, we find no evidence for a causal relationship. Moreover, we find no effect across any of the age ranges or across subsamples by gender, race, ethnicity, income, or urbanity. Finally, while it could be possible that fast food restaurants matter but their effects on BMI are longer-term, we found no evidence that longer exposures as in the 4th to 8th grade transition differ meaningfully from the 4th to 6th or 6th to 8th grade transitions.

Beyond the lack of statistically significant point estimates, even if we allow for potential omitted variables bias from failing to include all potentially relevant aspects of the food environment and interpret the coefficients as upper bounds on the true causal effect of fast-food exposure, there is no economically meaningful relationship between fast-food availability along commuting routes and childhood weight outcomes.

A key variable to which we do not have access is the mode of transportation utilized by students. Although the average treatment effect of restricting fast-food restaurants from areas near schools may be zero, there could be a subset of students who walk, bike or drive themselves to school that would be affected by such a policy. Yet, when we repeat the analysis splitting the sample according to distance between home and school (not reported), we do not find that students who live within one mile of school respond more strongly to changes in exposure than children who live more than two miles from school. As route exposure and school exposure are similar treatments from a practical standpoint given the time and transportation constraints faced by school children, these results suggest that policies that restrict fast-food restaurants from locating near schools will not reduce average childhood obesity rates.

Acknowledgements: This research was funded by the Agriculture and Food Research Initiative of the USDA National Institute of Food and Agriculture, grant number 2011-68001-30014. This work was also partly supported by the National Research Foundation of Korea (NRF-2011-330-B00074). The authors would like to thank seminar participants at the University of Connecticut, the University of Milwaukee-Wisconsin, Bryn Mawr College, and the 2014 ECHE/IHEA Joint Meetings. This work is covered by University of Arkansas at Fayetteville IRB Protocol Number 10-11-235.

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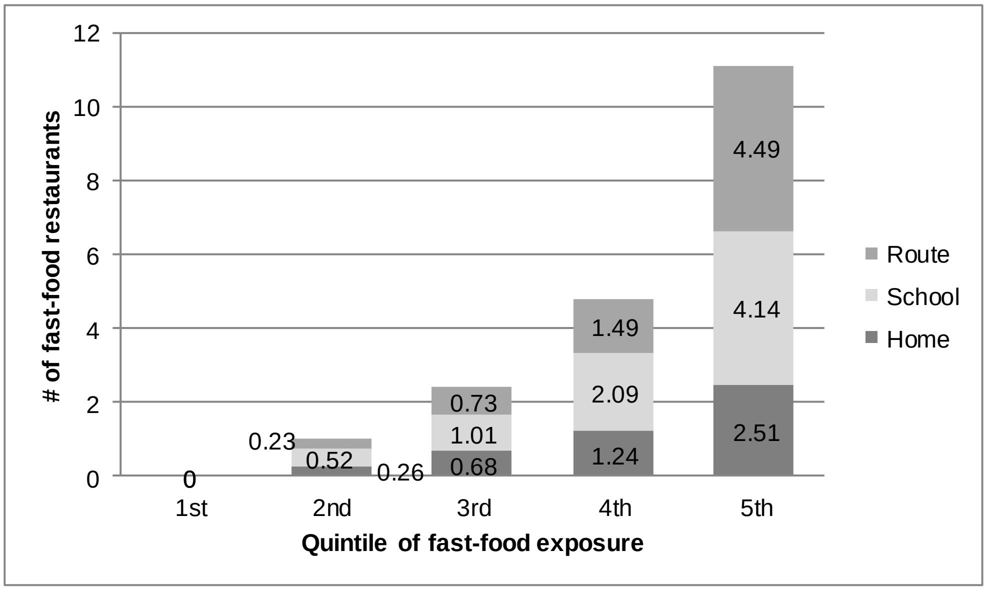
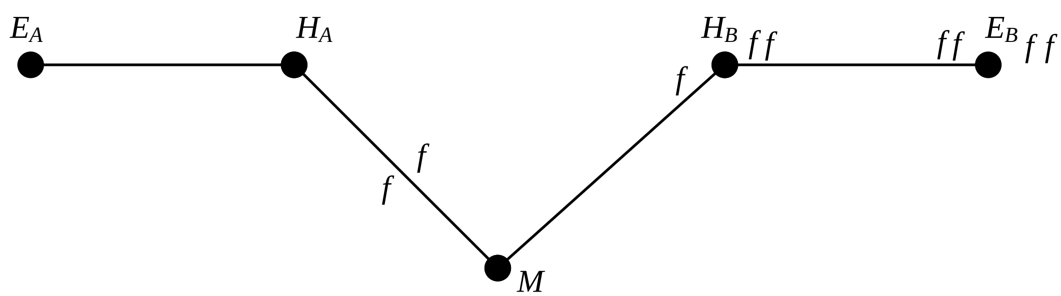
Figure 1



Notes: *N*=155510. *Home* exposure is the number of fast-food restaurants within ½ mile radius of residence. *School* exposure is the number of fast-food restaurants within ½ mile radius of residence. *Route* exposure is the number of fast-food restaurants within 100m buffer along shortest network distance between school and residence.

Figure 2: Heuristic of Identification Strategy



H_i denotes the residence of student i in school district D.
E_i denotes the elementary school of student i in school district D.
M denotes the middle school in school district D.
f denotes the location of a fast-food restaurant.
Solid lines indicate commute routes.

Table 1: Summary statistics of fast-food exposure measures

Fast-food exposure measure	Mean	Minimum	Maximum
Total exposure (# of restaurants)	3.34±4.45	0	58
# within 1/2 mile of residence	0.81±1.76	0	20
# within 1/2 mile of school	1.33±2.27	0	16
# within 50m of route between school and home	1.20±2.64	0	46
Distance to nearest restaurant from residence (miles)	1.933±2.508	0.002	20.976
Proportion with no exposure			
within 1/2 mile of residence	69.6%		
within 1/2 mile of school	54.8%		
within 50m of route between school and home	64.6%		

Notes: *N*=155510. Mean reported with standard deviation. Route between school and home calculated as shortest network distance.

Table 2: Spearman correlation coefficients between exposure count measures

	# within 1/2 mile of residence	# within 1/2 mile of school
# within 1/2 mile of school	0.181*	
# within 50m of route between school and home	0.152*	0.252*

Notes: *N*=155510. Route between school and home calculated as shortest network distance. * denotes statistical significance at $p<0.01$.

Table 3: Means of fast-food exposure by race and school year

# fast-food restaurants within:	White	Black	Hispanic
		2004	
2nd graders	*14954*	*5260*	*1437*
1/2 mile of residence	0.58 ±0.01	1.25 ±0.03	1.21 ±0.06
1/2 mile of school	1.27 ±0.02	1.46 ±0.03	1.90 ±0.08
50m of route between school and home	0.82 ±0.02	0.96 ±0.03	0.77 ±0.05
6th graders	*15265*	*4997*	*1111*
1/2 mile of residence	0.51 ±0.01	1.19 ±0.03	1.04 ±0.06
1/2 mile of school	0.88 ±0.01	1.83 ±0.04	0.78 ±0.06
50m of route between school and home	1.04 ±0.02	1.34 ±0.04	0.87 ±0.05
10th graders	*13539*	*3796*	*780*
1/2 mile of residence	0.52 ±0.01	1.14 ±0.03	1.03 ±0.07
1/2 mile of school	1.26 ±0.02	2.11 ±0.04	2.81 ±0.08
50m of route between school and home	1.41 ±0.03	1.33 ±0.04	1.83 ±0.12
		2010	
2nd graders	*16238*	*5507*	*2864*
1/2 mile of residence	0.64 ±0.01	1.29 ±0.03	1.22 ±0.04
1/2 mile of school	1.18 ±0.02	1.37 ±0.03	1.40 ±0.05
50m of route between school and home	0.96 ±0.02	1.08 ±0.03	0.79 ±0.04
6th graders	*15280*	*5376*	*2348*
1/2 mile of residence	0.57 ±0.01	1.17 ±0.03	1.14 ±0.04
1/2 mile of school	1.08 ±0.02	1.56 ±0.04	1.02 ±0.04
50m of route between school and home	1.27 ±0.02	1.48 ±0.04	1.32 ±0.05
10th graders	*12334*	*4072*	*1293*
1/2 mile of residence	0.56 ±0.01	1.19 ±0.03	1.02 ±0.06
1/2 mile of school	1.25 ±0.02	1.89 ±0.03	1.96 ±0.07
50m of route between school and home	1.60 ±0.03	1.97 ±0.05	2.39 ±0.11

Notes: Number of observations in italics. Mean reported with standard deviation. Route between school and home calculated as shortest network distance.

Table 4: Means of fast-food exposure by lunch status eligibility and school year

# fast-food restaurants within:	Full	Free	Reduced
		2004	
2nd graders	*9114*	*10141*	*2396*
1/2 mile of residence	0.57 ±0.02	0.96 ±0.02	0.85 ±0.04
1/2 mile of school	1.37 ±0.02	1.32 ±0.02	1.45 ±0.05
50m of route between school and home	0.86 ±0.02	0.78 ±0.02	1.12 ±0.06
6th graders	*9827*	*9147*	*2399*
1/2 mile of residence	0.51 ±0.01	0.86 ±0.02	0.81 ±0.04
1/2 mile of school	0.95 ±0.02	1.22 ±0.02	1.23 ±0.04
50m of route between school and home	1.08 ±0.02	0.99 ±0.02	1.64 ±0.07
10th graders	*11282*	*5218*	*1615*
1/2 mile of residence	0.56 ±0.01	0.84 ±0.02	0.88 ±0.05
1/2 mile of school	1.50 ±0.02	1.59 ±0.03	1.27 ±0.05
50m of route between school and home	1.45 ±0.03	1.14 ±0.03	2.02 ±0.10
		2010	
2nd graders	*9175*	*13094*	*2340*
1/2 mile of residence	0.63 ±0.02	1.04 ±0.02	0.66 ±0.03
1/2 mile of school	1.28 ±0.02	1.24 ±0.02	1.15 ±0.04
50m of route between school and home	1.12 ±0.03	0.88 ±0.02	0.86 ±0.05
6th graders	*9280*	*11399*	*2325*
1/2 mile of residence	0.57 ±0.02	0.94 ±0.02	0.69 ±0.04
1/2 mile of school	1.30 ±0.02	1.12 ±0.02	1.06 ±0.04
50m of route between school and home	1.55 ±0.03	1.15 ±0.02	1.27 ±0.06
10th graders	*9166*	*6959*	*1574*
1/2 mile of residence	0.62 ±0.02	0.92 ±0.02	0.66 ±0.04
1/2 mile of school	1.39 ±0.02	1.56 ±0.03	1.26 ±0.05
50m of route between school and home	1.92 ±0.04	1.55 ±0.04	1.57 ±0.08

Notes: Number of observations in italics. Mean reported with standard deviation. Route between school and home calculated as shortest network distance.

Table 5: Descriptive Statistics for 2007-2008SY

	K to 4th grade (N=4,129)	9th to 12th grade (N=2,576)
Restaurants along route		
1	0.123 (0.329)	0.160 (0.366)
2-4	0.087 (0.281)	0.134 (0.341)
5 or more	0.040 (0.197)	0.056 (0.229)
Restaurants within 1/2 mile of school		
1	0.204 (0.403)	0.212 (0.409)
2-4	0.181 (0.385)	0.167 (0.373)
5 or more	0.071 (0.257)	0.064 (0.246)
Restaurants within 1/2 mile of residence		
1	0.124 (0.329)	0.106 (0.308)
2-4	0.106 (0.308)	0.080 (0.271)
5 or more	0.041 (0.198)	0.023 (0.150)
ΔBMI z-score	0.096 (0.710)	-0.140 (0.528)
Lagged BMI	0.618 (1.033)	0.763 (1.004)
Route distance	2.674 (3.086)	3.741 (4.250)
Black	0.178 (0.382)	0.205 (0.404)
Hispanic	0.075 (0.263)	0.017 (0.128)
Female	1.492 (0.500)	1.480 (0.500)
Free lunch	0.340 (0.474)	0.256 (0.436)
Reduced lunch	0.103 (0.305)	0.077 (0.266)
Urban	0.574 (0.495)	0.397 (0.489)
Median household income	43.439 (17.803)	38.188 (13.528)

Note: The 2007-2008 school year was the last time that 12th grade students were measured for height and weight as part of Arkansas's statewide BMI data collection program. The change in BMI z-score is calculated based on the BMI z-score during the 2003-2004SY for children in 4th grade. The change in BMI z-score is calculated based on the BMI z-score during the 2004-2005SY for children in 12th grade.

Table 6: Multivariate Regression Results for 2009-2010SY

	K to 4th grade (N=4,129)				9th to 12th grade (N=2,576)			
Restaurants along route								
1	0.018			0.015	0.004			0.008
	(0.033)			(0.034)	(0.029)			(0.030)
2-4	-0.010			-0.007	0.103**			0.100**
	(0.039)			(0.040)	(0.032)			(0.033)
5 or more	0.093			0.094	0.056			0.039
	(0.059)			(0.059)	(0.051)			(0.052)
Restaurants within 1/2 mile of school								
1		0.043		0.039		0.014		0.012
		(0.028)		(0.028)		(0.028)		(0.028)
2-4		0.022		0.015		0.047		0.030
		(0.030)		(0.031)		(0.030)		(0.031)
5 or more		-0.043		-0.047		0.109*		0.102*
		(0.044)		(0.045)		(0.048)		(0.049)
Restaurants within 1/2 mile of residence								
1			0.021	0.010			-0.045	-0.048
			(0.035)	(0.035)			(0.036)	(0.037)
2-4			0.016	0.010			-0.004	-0.024
			(0.037)	(0.038)			(0.042)	(0.043)
5 or more			-0.020	-0.011			-0.070	-0.103
			(0.057)	(0.058)			(0.072)	(0.073)
Lagged BMI	-0.175**	-0.176**	-0.176**	-0.175**	-0.046**	-0.045**	-0.046**	-0.046**
	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)
Route distance	-0.006	-0.004	-0.003	-0.006	-0.001	-0.002	-0.002	-0.001
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)	(0.004)
Black	0.146**	0.143**	0.145**	0.142**	0.052	0.067*	0.060	0.058
	(0.035)	(0.035)	(0.035)	(0.036)	(0.033)	(0.033)	(0.033)	(0.034)
Hispanic	0.130**	0.129**	0.128**	0.129**	0.064	0.060	0.065	0.066
	(0.047)	(0.047)	(0.047)	(0.047)	(0.082)	(0.082)	(0.082)	(0.082)
Female	-0.030	-0.029	-0.031	-0.029	0.008	0.008	0.009	0.006
	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)
Free lunch	0.010	0.010	0.009	0.010	0.016	0.010	0.012	0.017
	(0.027)	(0.027)	(0.027)	(0.027)	(0.027)	(0.027)	(0.027)	(0.027)
Reduced lunch	0.046	0.045	0.045	0.045	-0.037	-0.039	-0.035	-0.036
	(0.037)	(0.037)	(0.037)	(0.037)	(0.040)	(0.040)	(0.040)	(0.040)
Urban	-0.061*	-0.053	-0.057*	-0.061*	-0.055*	-0.061*	-0.033	-0.052
	(0.029)	(0.028)	(0.029)	(0.030)	(0.027)	(0.026)	(0.028)	(0.029)
Median household income	-0.001	-0.001	-0.001	-0.001	0.000	0.000	0.000	0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)

Note: The 2007-2008 school year was the last time that 12^{th} grade students were measured for height and weight as part of Arkansas's statewide BMI data collection program. The change in BMI z-score is calculated based on the BMI z-score during the 2003-2004SY for children in 4^{th} grade. The change in BMI z-score is calculated based on the BMI z-score during the 2004-2005SY for children in 12^{th} grade. Standard errors are clustered at the school-grade level. **, * denotes statistical significance at 1% and 5%, respectively.

Table 7: Descriptive statistics by grade transition

	4th to 6th grade	4th to 8th grade	6th to 8th grade	8th to 10th grade
BMI z-score	0.709	0.763	0.725	0.709
	(1.093)	(1.032)	(1.030)	(1.030)
Change in BMI z-score	0.030	0.053	0.030	-0.011
	(0.439)	(0.554)	(0.460)	(0.442)
Change in fast-food exposure	0.626	0.459	0.261	0.419
	(2.923)	(2.487)	(2.444)	(3.095)
Change in route distance	0.628	0.480	0.062	0.197
	(1.936)	(2.225)	(1.569)	(1.445)
Female	0.493	0.484	0.485	0.482
	(0.500)	(0.500)	(0.500)	(0.500)
Black	0.191	0.196	0.155	0.222
	(0.393)	(0.397)	(0.362)	(0.415)
Hispanic	0.088	0.064	0.074	0.063
	(0.283)	(0.244)	(0.262)	(0.243)
Asian	0.006	0.006	0.006	0.006
	(0.078)	(0.080)	(0.076)	(0.080)
Pacific Islander	0.016	0.013	0.015	0.016
	(0.126)	(0.114)	(0.121)	(0.124)
Other	0.002	0.003	0.002	0.002
	(0.046)	(0.051)	(0.049)	(0.045)
Unknown	0.000	0.000	0.000	0.001
	(0.009)	(0.009)	(0.009)	(0.027)
Reduced Lunch	0.099	0.111	0.095	0.081
	(0.298)	(0.314)	(0.293)	(0.273)
Full Pay	0.551	0.542	0.577	0.624
	(0.497)	(0.498)	(0.494)	(0.484)
Unknown Lunch Status	0.002	0.002	0.002	0.003
	(0.040)	(0.047)	(0.039)	(0.054)
N	33308	10597	33130	34758

Table 8: Effect of changes in fast-food exposure by grade transition

	4th to 6th grade		4th to 8th grade		6th to 8th grade		8th to 10th grade	
Change in fast-food exposure	-0.001	0.001	-0.004	0.010	0.001	0.004	0.001	0.001
	(0.001)	(0.004)	(0.003)	(0.023)	(0.001)	(0.003)	(0.001)	(0.003)
X years of exposure		-0.002		-0.005		-0.002		0.000
		(0.002)		(0.008)		(0.002)		(0.002)
Change in route distance	-0.002	-0.002	0.003	0.003	-0.001	-0.001	0.000	0.000
	(0.002)	(0.002)	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)
Female	0.042 **	0.042 **	0.087 **	0.087 **	0.048 **	0.048 **	-0.090 **	-0.090 **
	(0.006)	(0.006)	(0.012)	(0.012)	(0.006)	(0.006)	(0.007)	(0.007)
Black	0.029 **	0.029 **	-0.014	-0.015	-0.048 **	-0.048 **	0.016 *	0.016 *
	(0.008)	(0.008)	(0.017)	(0.017)	(0.011)	(0.011)	(0.008)	(0.008)
Hispanic	-0.027 *	-0.027 *	-0.061 *	-0.061 *	-0.094 **	-0.094 **	-0.047 **	-0.047 **
	(0.011)	(0.011)	(0.026)	(0.026)	(0.012)	(0.012)	(0.012)	(0.012)
Asian	0.048	0.048	-0.051	-0.050	0.008	0.008	0.001	0.001
	(0.048)	(0.048)	(0.073)	(0.073)	(0.034)	(0.034)	(0.033)	(0.033)
Pacific Islander	-0.003	-0.003	0.019	0.019	-0.023	-0.023	-0.039	-0.039
	(0.019)	(0.019)	(0.053)	(0.053)	(0.024)	(0.024)	(0.022)	(0.022)
Other	0.017	0.017	0.128	0.127	0.114	0.114	-0.031	-0.031
	(0.060)	(0.060)	(0.124)	(0.123)	(0.063)	(0.063)	(0.034)	(0.034)
Reduced Lunch	-0.013	-0.013	-0.024	-0.024	-0.013	-0.013	-0.004	-0.004
	(0.010)	(0.010)	(0.021)	(0.021)	(0.010)	(0.010)	(0.010)	(0.010)
Full Pay Lunch	-0.048 **	-0.048 **	-0.077 **	-0.077 **	-0.041 **	-0.041 **	0.003	0.003
	(0.007)	(0.007)	(0.013)	(0.013)	(0.007)	(0.007)	(0.007)	(0.007)
Unknown Lunch Status	0.092	0.092	-0.009	-0.011	0.003	0.003	-0.022	-0.022
	(0.078)	(0.078)	(0.113)	(0.114)	(0.04)	(0.040)	(0.037)	(0.036)
N	33,308		10,597		33,130		34,758	

Notes: Each regression includes median household income, % population living in poverty, median gross rent, and educational attainment for Census block group in which student resides. School district fixed-effects also included. Standard errors clustered at school-district level in parentheses. (**,*) denotes statistical significance at 1% and 5% level respectively.

Table 9: Effect of changes in fast-food exposure by grade transition and gender

	4th to 6th grade		4th to 8th grade		6th to 8th grade		8th to 10th grade	
	Male	Female	Male	Female	Male	Female	Male	Female
Change in fast-food exposure	-0.001	-0.002	-0.001	-0.007 **	0.001	0.000	0.000	0.002
	(0.002)	(0.002)	(0.005)	(0.003)	(0.002)	(0.002)	(0.002)	(0.001)
Change in route distance	0.001	-0.005	0.002	0.004	-0.003	0.001	-0.003	0.002
	(0.002)	(0.003)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)	(0.002)
Black	-0.006	0.065 **	0.018	-0.045	-0.010	-0.086 **	0.049 **	-0.021
	(0.011)	(0.011)	(0.026)	(0.028)	(0.013)	(0.014)	(0.011)	(0.011)
Hispanic	-0.038 *	-0.017	-0.056	-0.060	-0.087 **	-0.105 **	-0.057 **	-0.037 *
	(0.017)	(0.013)	(0.039)	(0.037)	(0.017)	(0.017)	(0.015)	(0.016)
Asian	0.048	0.059	-0.129	0.037	0.072 *	-0.050	-0.061	0.057
	(0.051)	(0.063)	(0.08)	(0.097)	(0.031)	(0.055)	(0.037)	(0.035)
Pacific Islander	-0.003	0.000	-0.112	0.132 *	-0.080 **	0.036	-0.044	-0.031
	(0.026)	(0.027)	(0.08)	(0.059)	(0.026)	(0.035)	(0.030)	(0.032)
Other	-0.154 *	0.158	0.050	0.239	0.164	0.051	-0.009	-0.042
	(0.073)	(0.089)	(0.176)	(0.171)	(0.088)	(0.120)	(0.052)	(0.058)
Reduced Lunch	-0.005	-0.023	-0.006	-0.048	0.003	-0.030 *	-0.006	-0.001
	(0.013)	(0.013)	(0.032)	(0.028)	(0.014)	(0.014)	(0.012)	(0.015)
Full Pay Lunch	-0.025 **	-0.073 **	-0.035	-0.119 **	-0.028 **	-0.055 **	0.009	-0.004
	(0.008)	(0.010)	(0.019)	(0.022)	(0.010)	(0.011)	(0.009)	(0.010)
Unknown Lunch Status	0.091	0.093	-0.059	0.030	0.079	-0.053	0.007	-0.055
	(0.100)	(0.116)	(0.137)	(0.159)	(0.082)	(0.058)	(0.055)	(0.076)
N	16,871	16,437	5,457	5,140	17,083	16,047	18,005	16,753

Notes: Each regression includes median household income, % population living in poverty, median gross rent, and educational attainment for Census block group in which student resides. School district fixed-effects also included. Standard errors clustered at school-district level in parentheses. (**,*) denotes statistical significance at 1% and 5% level respectively.

Table 10: Effect of changes in fast-food exposure by grade transition, race/ethnicity, urbanicity and lunch status

	4th to 6th grade	4th to 8th grade	6th to 8th grade	8th to 10th grade
By race/ethnicity				
White	-0.001	-0.005	0.000	0.002
	(0.002)	(0.005)	(0.001)	(0.001)
Black	-0.001	-0.002	0.002	-0.002
	(0.002)	(0.003)	(0.002)	(0.002)
Hispanic	-0.006	0.002	0.001	0.002
	(0.005)	(0.012)	(0.004)	(0.002)
By urbanicity				
Urban	-0.001	-0.003	0.000	0.001
	(0.001)	(0.004)	(0.001)	(0.001)
Rural	-0.004	-0.007	0.002	0.002
	(0.002)	(0.007)	(0.002)	(0.002)
By lunch status				
Free	-0.002	-0.003	0.002	-0.002
	(0.002)	(0.004)	(0.002)	(0.001)
Reduced	0.005	0.003	0.000	-0.003
	(0.004)	(0.010)	(0.004)	(0.004)
Full	-0.002	-0.006	0.001	0.003 *
	(0.002)	(0.004)	(0.002)	(0.001)

Notes: Each entry is the coefficient on the change in the number of fast-food restaurants within one-half mile of the route between student's residence and school from a separate regression. Each regression includes a full set of explanatory controls (see Table 2). Standard errors clustered at school-district level in parentheses. (**,*) denotes statistical significance at 1% and 5% level respectively.