QOpen, 2021, **1**, 1–22
DOI: 10.1093/qopen/qoaa007
Advance access publication date: 14 January 2021
Article

A longitudinal analysis of fast-food exposure on child weight outcomes: Identifying causality through school transitions

Richard A. Dunn[1], Rodolfo M. Nayga, Jr[2], Michael R. Thomsen[2,*] and Heather L. Rouse[3]

[1]Department of Agricultural and Resource Economics, University of Connecticut, Storrs, CT 06269-4021, USA
[2]Department of Agricultural Economics and Agribusiness, University of Arkansas, Fayetteville, AR 72701, USA
[3]Department of Human Development and Family Studies, Iowa State University, Ames, IA 50011, USA
[*]Corresponding author: Department of Agricultural Economics and Agribusiness, University of Arkansas, 217 Agriculture Building, 1 University of Arkansas, Fayetteville, AR 72701, USA. E-mail: mthomsen@uark.edu

Received: June 30, 2020. **Accepted:** November 20, 2020

Abstract

This article investigates the effect of fast-food availability on childhood weight outcomes by gender, race, and location. We use a novel identification strategy based on changes in fast-food exposure along the route between the home and school that occur as students progress through the public school system and transition to different types of schools, e.g. from elementary school to intermediate school or from intermediate school to high school. 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 body mass index *z*-score for any student subpopulation.

Keywords: Fast food, Childhood obesity, Food environment

JEL codes: I12 Health Behavior, I14 Health and Inequality

1 Introduction

Reducing the rate of childhood obesity is a leading public health priority in the USA, where obesity rates are 18.4 per cent for those ages 6–11 and 20.6 per cent for those ages 12–19 (Hales *et al.* 2018). Childhood obesity is a documented risk factor for negative physical and mental health outcomes during adolescence, as well as poor educational performance (Carey *et al.* 2015; Kelly *et al.* 2019; Patalay and Hardman 2019). These costs persist throughout adulthood as obese children are more likely to be obese adults and thereby suffer from higher rates of morbidity and premature mortality (Serdula *et al.* 1993). Further, worse health outcomes coupled with outright discrimination can ultimately disadvantage obese adults in the labor market (Cawley 2015; Olesen, Cleal, and Willaing 2020; Rubino *et al.* 2020). A pernicious consequence is that obesity tends to perpetuate intergenerationally (Heslehurst *et al.* 2019).

The food environment—the availability of affordable healthful food options relative to unhealthful ones—has been hypothesized as an important determinant of childhood obesity outcomes. Of particular concern has been the role of fast-food restaurants in food consumption and the resulting obesity outcomes of children (Congdon 2019; Jia *et al.* 2019; Costa Peres *et al.* 2020). Local governments in the USA have fairly wide latitude to directly influence the food environment through the zoning process and have considered banning fast-food restaurants near schools, e.g. Austin, TX, and New York City, in an attempt to reduce the prevalence of childhood obesity.

Identifying the causal role of particular elements of the food environment in obesity outcomes faces two notable challenges. First, individual food environments are not randomly assigned. Rather, they are the observed outcome of households choosing where to live and businesses choosing where to operate (Dunn 2010). Second, the food environment is multidimensional. Researchers have largely focused on the food environment where children live or where they attend school, but these locations, while undoubtedly important, do not exhaust where children may encounter food consumption opportunities. Attempts to improve the food environment around schools may not be efficacious if other sources of exposure lead children to change where they purchase rather than what they purchase.

In this article, we contribute to the literature by addressing both of these issues. Specifically, we investigate the role of fast-food exposure along the route between home and school using transitions between schools as a plausibly exogeneous source of variation. Recent work has recognized that fast-food restaurants along the route from home to school are a significant source of exposure (Harrison *et al.* 2011; Burgoine and Monsivais 2013; Velazquez *et al.* 2015). Moreover, there is a growing awareness of the need to consider travel patterns to better understand the role of food environment in health outcomes (Widener 2018; Zhang and Mao 2019). Using a unique longitudinal dataset of public school children in Arkansas that includes measured body mass index (BMI), we are able to observe both where students live and where they attend school, and thereby construct the shortest route between these two locations using GPS software. We then link these data to proprietary commercial data that include the location of fast-food restaurants to calculate exposure at home, at school, and along the route.

Our identification strategy is based on the argument that changes in exposure to fast-food restaurants along routes as a consequence of a child transitioning from elementary school to middle school, from middle school to junior high school, or from junior high school to high school are plausibly exogenous even if locations of restaurants, residences, and schools are endogenously determined. Intuitively, although the change in fast-food exposure along routes could be known to parents, it is exceedingly unlikely that residential location or commercial zoning decisions are affected by this knowledge. This intuition is strongly supported by results from a set of falsification tests that demonstrate current BMI has no association with future changes in exposure along routes to school.

A notable feature of our student data is the inclusion of information on both socioeconomic status (proxied by receipt of free or reduced lunch) and race/ethnicity allowing us to evaluate whether subpopulations are affected differently by fast-food exposure. Childhood obesity is particularly acute among communities of color. Nationwide, obesity rates among Black and Hispanic youth are 20.4 and 23.6 per cent, respectively, compared to 14.7 per cent among Non-Hispanic White youth (Ogden *et al.* 2018). Communities of color also tend to experience less healthful food environments (Larson, Story, and Nelson 2009; Bower *et al.* 2014; Singleton, Affuso, and Sen 2016).

The economics profession has tended to focus on inefficiency as the primary reason for government intervention. There is certainly a valid argument that because children may not be fully rational or decision-makers and their caregivers may not adequately value the future costs of childhood obesity, a market failure exists. Nevertheless, in his plenary address at the International Health Economics Association Biennial Congress on the economics of obesity, Dunn (2015) argues that economists are equally responsible for identifying potential interventions that policymakers could implement to reduce inequity. As both a consequence and cause of poverty, developing interventions that break the intergenerational transmission of obesity in communities of color should be considered as part of a broader portfolio seeking to address the cycle of persistent inequality in the USA and improving the food environment may be one policy lever available to do so.

In a preview of our results, we reject any association between fast-food exposure along the route to school and BMI—our coefficient estimates are all very close to zero with exceptionally narrow confidence intervals. 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. Further, these results are robust to restricting the sample to those students who reside within one mile of their school and thus are least likely to commute via bus. These findings suggest that reducing fast-food exposure near school will not cause students to substitute toward fast food from establishments they would otherwise pass between school and home.

2 Fast-food availability and childhood obesity

There are several mechanisms through which exposure to fast food along the route to school could influence obesity outcomes. First, greater availability of fast-food restaurants should lower the full cost of consuming fast-food meals. Currie *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, arguing the latter are less mobile than the former and thus more responsive to increases in local access. To the extent that travel costs are important, the effect of nearby fast-food establishments should be largest for middle school and junior high school children. 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 access to fast food amplifies promotional efforts by fast-food companies. Fast food is heavily advertised and advertising is often targeted to children and adolescents (Linn and Novosat 2008; Pinto *et al.* 2020). 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.

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 (Costa Peres *et al.* 2020). This is true 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 mile of a school results in a 5.2 per cent 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 per cent. Earlier work focusing specifically on Arkansas public school children suggests that fast-food restaurants around schools resulted in small increases in BMI *z*-scores, but this finding was sensitive to the empirical strategy employed (Asirvatham *et al.* 2019).

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 (Jia *et al.* 2019). 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 2 km of the residence and weight outcomes (Crawford *et al.* 2008). Qian *et al.* (2017) found that density of fast-food restaurants in the residential environment was associated with increased childhood BMI *z*-scores among Arkansas children who changed residences, especially among rural children, non-minority children, and girls.

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 early childhood longitudinal study 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.

An important issue in much of the existing literature 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 will 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 socioeconomic 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 socioeconomic status like income and educational attainment are positively associated with the number of fast-food restaurants in the county of residence and that ordinary least squares (OLS) tends to understate the relationship between fast-food exposure and weight outcomes. Dunn, Sharkey, and Horel (2012) and Alviola *et al.* (2014) report similar results. Moreover, the selection of restaurant location based on socioeconomic attributes appears to be more pronounced in communities with a greater proportion of minority residents, 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 (Dunn 2010; Anderson and Matsa 2011; Dunn, Sharkey, and Horel 2012; Alviola *et al.* 2014; Qian et al. 2017; Asirvatham *et al.* 2019). 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 2004–6 behavioral risk factor surveillance system (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 per cent) 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 instrumental variable 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.

A notable recent contribution to the literature applies an entirely different identification strategy, using the random assignment of families to units within public housing in New York City to generate exogenous variation in residential fast-food exposure (Han, Schwartz, and Elbel 2020). These authors found that reducing the distance to fast-food restaurants increases obesity risk, most strongly for young children.

Together, these findings suggest it is important to account for the endogenous determination of fast-food availability and allow for potential heterogeneity in the response to fast-food exposure across sociodemographic characteristics, such as race/ethnicity, gender, age, and economic status.

3 Data

Our data come from three sources. The first is 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 2018).

From 2004 through 2007, all public school children were targeted for BMI screenings. However, only children in even-numbered grades, kindergarten (K) through tenth grade, were measured beginning in 2008. While participation is not universal, response is very high. During the 2003–4 school year (SY), 345,892 of 421,973 students (82.0 per cent) generated valid measurements. The most likely reason students did not have height and weight reported was because of absence (7 per cent), non-attendance (4 per cent), parental refusal (4 per cent), and child refusal (2 per cent) (ACHI 2004). 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 per cent in elementary school, 15 per cent in middle school, and 25 per cent in high school (ACHI 2004). Participation was similar during the 2009–10SY with 178,015 of 220,532 students (80.7 per cent) in grades K, 2, 4, 6, 8, and 10 generating valid measurements. The most common reasons for exclusion were absence (7 per cent), parental refusal (5 per cent), and child refusal (2 per cent) (ACHI 2010).

Student BMI was then matched to home and school addresses through annual school registration records. Home address was used to geocode the rooftop 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 per cent for each cohort. Using the GIS procedure in SAS 9.3 (SAS Institute Inc., Cary, NC), neighborhoods were defined using one-half mile (805 m) Euclidian catchment areas centered on their residential and school addresses. The number of fast-food restaurants within that area was summed to generate exposure near home ('home exposure') and exposure near school ('school exposure'). Alternative catchment areas were also defined using radii of one-quarter mile and one mile.

Because each student record includes both residential and school addresses, we are also able to calculate the shortest street-network commuting distance between home and school, generating a polyline for each student. A 100 m buffer centered on the polyline was constructed and the number of fast-food restaurants within the buffer area was summed to calculate exposure along the route ('route exposure').

Although we are able to construct the shortest potential commuting route for students, none of our data sources include information on the typical route taken by children between home and school. Yet, this particular data limitation is—perhaps counterintuitively—unimportant for the specific policy question under consideration. First, from a purely measurement error perspective, recent work suggests that using the food environment along routes calculated by GIS procedures, rather than the food environment along actual commuting routes based on GPS tracking, does not introduce a meaningful source of bias in the study of student weight outcomes (Burgoine *et al.* 2015). Indeed, the results reported subsequently could not reasonably be explained by attenuation bias, requiring signal-to-noise ratios that were an order of magnitude smaller than those reported in previous studies of route exposure.

Second, from the standpoint of analyzing the potential efficacy of policy interventions, a measure of route exposure that is not endogenously determined by student choices is obviously preferable. If students are willing and able to alter their commuting route to access fast-food establishments, then policies that propose fast-food exclusion zones around schools are unlikely to be effective unless these zones are much larger than currently proposed. Therefore, while we would strongly prefer to have both measures of route exposure (along the endogenously determined actual route and along the exogenously determined shortest route) to compare results and determine the importance of endogeneity, restricting our analysis to the latter measure still provides valuable information for policymakers.

Another data limitation is the lack of information on the mode of transportation utilized by students, e.g. bus, car, and walking, because of heterogeneity in the response to fast-food exposure. For example, students with greater freedom of movement (those who own a car or can walk between home and school) may respond more strongly to the availability of fast food. We address this concern in several ways. First, we examine different grade transitions separately. Older students have greater freedom and thus would be expected to have a stronger response. Second, we examine students in rural and urban areas separately. Previous research has demonstrated that students are more likely to live near their school in urban settings, increasing the likelihood that they walk between home and school (Pabayo, Gauvin, and Barnett 2011; Reimers *et al.* 2013; Su *et al.* 2013). Third, we examine students who live close to school (less than one mile) separately from those who live far from school (more than five miles). As will be reported subsequently, we do not find different responses across these subgroups, suggesting to us that while heterogeneity across mode of transportation may exist, it is likely not of empirical importance.

The second data source is geocoded restaurant data purchased from Dun & 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. We identified fast-food restaurants using the company name or, in the case of chain or franchise restaurants, the trade name. Because concerns have been raised about potential errors in D&B data, we also validated and supplemented the list and locations of fast-food restaurants using internet searches. Specifically, we 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. McDonald's, Burger King, Wendy's), dairy stores with large fast-food menus (e.g.

Table 1. Summary of fast-food exposure measures.

Fast-food exposure measure	Mean	Minimum	Maximum
Total exposure (number of restaurants)	3.34 ± 4.45	0	58
Number of restaurants within 0.5 mile of residence	0.81 ± 1.76	0	20
Number of restaurants within 0.5 mile of school	1.33 ± 2.27	0	16
Number of restaurants within 50 m of route between school and home	1.20 ± 2.64	0	46
Proportion with no exposure (per cent)			
Within 0.5 mile of residence	69.6		
Within 0.5 mile of school	54.8		
Within 50 m of route between school and home	64.6		

Notes: $N = 155{,}510$. Mean reported with standard deviation. Route between school and home calculated as shortest network distance. Data are for the 2009–10SY, the latest year for which data are available on all three exposure types.

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 georeferenced 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, the third source is 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 socioeconomic status.

Table 1 summarizes the fast-food exposure measures for students during the 2009–10SY, the latest year for which we have data on all three exposure types. Using a radius of one-half mile to define exposure near home and school, the mean total exposure level is 3.34 restaurants. Route exposure contributes a substantial share of total exposure, 35.9 per cent, but what may be more striking is that the number of restaurants within 0.5 mile of the school attended is 65 per cent larger than the number of restaurants within 0.5 mile 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 per cent ($P < 0.01$). The majority of children in the sample have zero exposure within 0.5 mile of home (69.6 per cent). In contrast, 45.2 per cent of children have at least one fast-food restaurant located within 0.5 mile 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 second–fourth quintiles, while exposure near home and exposure along the shortest commuting route are roughly equal contributors. In the highest exposure quintile, however, exposure along the route is the largest contributor.

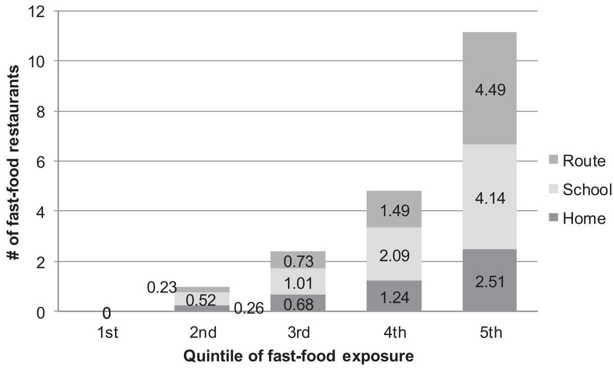

Figure 1. Fast-food restaurants around the home, school, and along the route between home and school. *Notes*: $N = 155{,}510$. *Home* exposure is the number of fast-food restaurants within 0.5 mile radius of residence. *School* exposure is the number of fast-food restaurants within 0.5 mile radius of residence. *Route* exposure is the number of fast-food restaurants within 100 m buffer along shortest network distance between school and residence.

Table 2. Spearman correlation coefficients between exposure count measures.

	Number of restaurants within 0.5 mile of residence	Number of restaurants within 0.5 mile of school
Number of restaurants within 0.5 mile of school	0.181*	
Number of restaurants within 50 m of route between school and home	0.152*	0.252*

Notes: $N = 155{,}510$. Route between school and home calculated as shortest network distance. * denotes statistical significance at $P < 0.01$.

Table 2 reports Spearman correlation coefficients for the four exposure methods. Although each of the correlations is positive and statistically significant at $P < 0.01$, the magnitude of the correlations is relatively small. Only the correlation between exposure near the 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, which is consistent with previous analyses for adults in England (Burgoine and Monsivais 2013).

5 Identification method

To identify the causal role of fast-food exposure in 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. Student A lives in a neighborhood without nearby fast-food restaurants and the elementary school she attends also does not have fast-food restaurants located nearby.

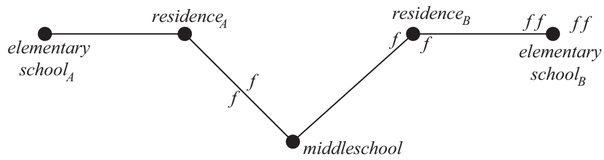

Figure 2. Heuristic of identification strategy.
Note: *f* denotes the location of a fast-food restaurant; solid lines indicate commuting routes.

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 lobby for policies restricting commercial zoning around elementary schools. In contrast, multiple fast-food restaurants are located near the residence and elementary school of student B. This may arise because his parents are less concerned about the food environment or are unable to afford a home in a better 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 attend the same school. 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 school to intermediate school transition, we consider two general grade structures. First, there are students who attended an elementary school for fourth grade, and then made one and only one transition to an intermediate school within the same school district for sixth grade. That is, we would include students who attended a K–fifth grade elementary school and a sixth–eighth grade middle school, but would not include students who attended a K–sixth grade elementary school (no transition) or attended a K–fourth grade elementary school, a fifth grade intermediate school, and a sixth–eighth grade junior high school (multiple transitions).

Second, there are students who attended an elementary school for fourth grade and made one and only one transition to an intermediate school within the same district for eighth grade. This sample would include students who attended a K–fifth grade elementary school and a sixth–eighth grade middle school as in the case above. It would not include students who attended a K–eighth grade primary school (no transition) or attended a K–fourth grade elementary school, a fifth–seventh grade middle school, and an eighth–ninth grade junior high school (multiple transitions).

We also consider the change between the sixth and eighth grades. Examples include a single transition from a K–sixth grade elementary school to an intermediate school housing the seventh and eighth grades or the transition between intermediate schools of two different levels as would be the case of a student who attends a fifth–sixth grade middle school and then a seventh–eighth grade junior high school. Again, inclusion in this sample requires one and only one school transition between the sixth and eighth 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 eighth grade, and afterward made one transition to a high school in the same school district for tenth grade. That is, we would include students who attended a sixth–eighth grade intermediate school and then attended a ninth–twelfth grade high school, but would not include students who attended a K–twelfth grade comprehensive school (no transition) or attended a sixth–eighth grade middle school, a ninth grade junior high school, and a tenth–twelfth grade high school (multiple transitions).

There is considerable diversity in how Arkansas public schools allocate grades to school buildings, especially among intermediate grades. This is potentially important in light of recent findings that sixth graders in middle schools are placed at an academic disadvantage relative to sixth graders 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.

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 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:

$$\Delta \mathrm{BMIZ}_{i,t} = \beta_0 + \beta_1 \Delta \mathrm{FF}_{i,t} + \beta_2 \Delta \mathrm{DIST}_{i,t} + X_i\gamma + Z_i\theta + \delta_i + \varepsilon_{i,t},$$

where $\Delta \mathrm{BMIZ}_{i,t}$ is the change in BMI *z*-score for student i making grade transition $t \in \{4 \to 6; 4 \to 8; 6 \to 8; 8 \to 10\}$; $\Delta \mathrm{FF}_{i,t}$ is the change in fast-food exposure for student i making grade transition t; $\Delta \mathrm{DIST}_{i,t}$ 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, and urban–rural indicator; Z_i is a vector of attributes for the Census block group in which student i resides, including median household income, per cent living under the poverty line, median gross rent, and educational attainment; δ_i is a school-district fixed effect (using school fixed effects produced similar results); 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 to which they transition. For example, a student who transitions from a K–sixth grade elementary school to a seventh–ninth grade middle school experiences 2 years of the food environment associated with the second school between fourth and eighth grades. In contrast, a student who transitions from a K–fourth grade elementary school to a fifth–eighth grade middle school experiences 3 years of the food environment associated with the second school between fourth and eighth grades. One might therefore expect a dose–response relationship between changes in fast-food exposure and weight outcomes. Therefore, the following specification is also estimated:

$$\Delta \mathrm{BMIZ}_{i,t} = \beta_0 + \beta_1 \Delta \mathrm{FF}_{i,t} + \beta_2 \Delta \mathrm{DIST}_{i,t} + \beta_3 \Delta \mathrm{FF}_{i,t} {*} \mathrm{EX}_{i,t} + X_i\gamma + Z_i\theta + \delta_i + \varepsilon_{i,t},$$

where $\mathrm{EX}_{i,t}$ 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 differences in preferences that drive 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 obesogenic 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 and 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 3 reports descriptive statistics for two groups of students during the 2007–8SY: those in fourth grade and those in twelfth grade (we use this particular SY because it is the last in which twelfth graders were routinely screened for height and weight). For the former, we calculate the change in BMI between K and fourth grade using data collected during the 2003–4SY. For the latter, we calculation the change in BMI between ninth grade and twelfth grade using data collected during the 2004–5SY. Fast-food exposure is calculated as the mean exposure over the period and then discretized to allow for nonlinear response functions.

Table 4 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, socioeconomic 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 five or more fast-food restaurants near their school (8 per cent of the sample) compared to students with no fast-food restaurants. Students in high school with two to four fast-food restaurants (15.1 per cent of the sample) along the commuting route also tend to have a change in BMI z-score that is 0.1 point 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 deviation would be considered a fairly sizable 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 policymakers 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 5 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 per cent (fourth to sixth grade transition) to 73 per cent (fourth to eighth grade transition) 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 school and middle school. As a result, they tend to pass slightly more fast-food restaurants. More importantly, the change in route exposure varies significantly at the individual level and at magnitudes similar to the observed variation in school exposure (Table 1). Specifically, the standard deviation

Table 3. Descriptive statistics for 2007–8SY.

	K to fourth grade	Ninth to twelfth grade
Restaurants along route		
1	0.123	0.160
	(0.329)	(0.366)
2–4	0.087	0.134
	(0.281)	(0.341)
5 or more	0.040	0.056
	(0.197)	(0.229)
Restaurants within 0.5 mile of school		
1	0.204	0.212
	(0.403)	(0.409)
2–4	0.181	0.167
	(0.385)	(0.373)
5 or more	0.071	0.064
	(0.257)	(0.246)
Restaurants within 0.5 mile of residence		
1	0.124	0.106
	(0.329)	(0.308)
2–4	0.106	0.080
	(0.308)	(0.271)
5 or more	0.041	0.023
	(0.198)	(0.150)
ΔBMI *z*-score	0.096	−0.140
	(0.710)	(0.528)
Lagged BMI	0.618	0.763
	(1.033)	(1.004)
Route distance	2.674	3.741
	(3.086)	(4.250)
Black	0.178	0.205
	(0.382)	(0.404)
Hispanic	0.075	0.017
	(0.263)	(0.128)
Female	1.492	1.480
	(0.500)	(0.500)
Free lunch	0.340	0.256
	(0.474)	(0.436)
Reduced lunch	0.103	0.077
	(0.305)	(0.266)
Urban	0.574	0.397
	(0.495)	(0.489)
Median household income	43.439	38.188
	(17.803)	(13.528)

Notes: The 2007–8SY was the last time that twelfth 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 2003–4SY for children in fourth grade. The change in BMI *z*-score is calculated based on the BMI *z*-score during the 2004–5SY for children in twelfth grade. Summary statistics for K–fourth grade are calculated over 2,580–2,622 observations. Summary statistics for ninth–twelfth grade are calculated over 4,237–4,133 observations. Race/ethnicity are most likely variables to be missing.

of the change in route exposure (2.4–3.1 restaurants, depending on the grade transition) is nearly twice the mean (1.3 restaurants within 0.5 mile) and slightly larger than the standard deviation (2.3 restaurants) of school exposure. Along with the large sample sizes used in the analysis, the sizable variation in treatment will allow us to provide point estimates with narrow confidence intervals.

Table 6 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

Table 4. Multivariate regression results for 2007–8SY.

	K to fourth grade ($N = 4{,}129$)				Ninth to twelfth 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 0.5 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 0.5 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)

(*Continued*)

Table 4. (*Continued*)

	K to fourth grade ($N = 4{,}129$)				Ninth to twelfth grade ($N = 2{,}576$)			
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)

Notes: The 2007–8SY was the last time that twelfth 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 2003–4SY for children in fourth grade. The change in BMI *z*-score is calculated based on the BMI *z*-score during the 2004–5SY for children in twelfth grade. Standard errors are clustered at the school-grade level. ** and * denote statistical significance at 1 and 5 per cent levels, respectively.

Table 5. Descriptive statistics by grade transition.

	Fourth to sixth grade	Fourth to eighth grade	Sixth to eighth grade	Eighth to tenth 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	33,308	10,597	33,130	34,758

example, increasing fast-food exposure by three restaurants moving from eighth to tenth grade (roughly one standard deviation) would increase mean change in BMI *z*-score by 0.003, less than 1 per cent (0.7 per cent) 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. We would again emphasize that the incredibly small magnitudes reported in Table 8 cannot reasonably be explained by attenuation bias from measurement error in route exposure: the signal-to-noise ratio would need to be an order of magnitude smaller than reported in previous studies that compared exposure along routes calculated by GIS software and routes mapped by GPS tracking software (Burgoine *et al.* 2015) to achieve anything approaching economically meaningful results.

Examining the coefficients on other explanatory variables, 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 eighth to tenth 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.

Table 6. Effect of changes in fast-food exposure by grade transition.

	Fourth to sixth grade		Fourth to eighth grade		Sixth to eighth grade		Eighth to tenth 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)
× 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, per cent 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. ** and * denote statistical significance at 1 and 5 per cent levels, respectively.

6.3 Results by gender, race/ethnicity, and location

Table 7 reports coefficient estimates from equation (1) by student gender for each grade transition. Again, the coefficients comprise 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 fourth to eighth grade) is negative and statistically significant at the 5 per cent level, but that should not be an unexpected outcome of hypothesis testing given the size of the test and number of coefficients reported.

Table 8 reports the coefficient on the change in fast-food exposure from estimation of equation (1) across race/ethnicity, residential location, and lunch status. 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 thirty-two coefficient estimates, only one is statistically significant at the 5 per cent level.

Because the mode of transportation utilized by students is unobserved, the estimates reported in Table 8 can only be interpreted as 'intention to treat'. Nevertheless, our conclusions continue to be supported when we define subsamples based on the distance traveled

Table 7. Effect of changes in fast-food exposure by grade transition and gender.

	Fourth to sixth grade		Fourth to eighth grade		Sixth to eighth grade		Eighth to tenth 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, per cent 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. ** and * denote statistical significance at 1 and 5 per cent levels, respectively.

Table 8. Effect of changes in fast-food exposure by grade transition, race/ethnicity, urbanicity, and lunch status.

	Fourth to sixth grade	Fourth to eighth grade	Sixth to eighth grade	Eighth to tenth 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. ** and * denote statistical significance at 1 and 5 per cent levels, respectively.

between home and school. For example, we do not find that students who live within one mile of school, and are thus least likely to use a bus, respond more strongly to changes in exposure than children who live more than two miles from school, and are thus least likely to walk. Coefficient estimates for both groups continue to be very close to zero with narrow confidence intervals.

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.

Findings presented above are of greatest policy relevance to local governments because of their ability to directly influence the food environment through the business zoning process. As noted in Section 1, concerns about high rates of childhood obesity have resulted in proposals aimed at restricting businesses, like fast-food restaurants, that sell foods deemed to be obesogenic in close proximity to schools. Our results focus on routes between the home and school and so do not speak to school vicinity bans directly. However, a reasonable objection to these kinds of restrictions is that they will be ineffective because students have ample access to fast foods elsewhere in their communities. On this point, our results suggest that attempts to improve student obesity outcomes by reducing exposure to fast food near schools will not be undercut by exposure to fast-food restaurants along commuting routes, even for the most mobile student subpopulations.

Researchers must provide policymakers the most accurate information available so that they can evaluate the potential benefits of costly public health interventions such as those aimed at improving the food environment. The current dearth of studies that offer plausibly exogenous variation in the attributes of the food environment remains a significant challenge for this policy evaluation process as demonstrated in the findings of this study. The naïve OLS regressions of route and school exposure show positive association between fast-food availability and BMI *z*-score. However, we find no evidence that plausibly exogenous changes in exposure along commuting routes are associated with changes in BMI. Moreover, we find no effect across any of the age ranges or across subsamples by gender, race, ethnicity, income, or urbanity. These findings suggest that simple exposure to fast-food establishments in the commercial food environment was not a primary driver of excess childhood weight gain among children in our sample. 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 fourth to eighth grade transition differ meaningfully from the fourth to sixth or sixth to eighth 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 age, rural versus urban, and distance between home and school, we do not find that older students, urban students, or students who live within one mile of school respond more strongly to changes in exposure than younger students, rural students, or students who live more than two miles from school.

Supplementary Data

Supplementary data are available at *QOPEN* online.

Funding

This research was funded by the Agriculture and Food Research Initiative of the United States Department of Agriculture National Institute of Food and Agriculture, grant number 2011-68001-30014; the United States Department of Agriculture National Institute of Food and Agriculture under a Hatch Grant, project TX09332; and the National Institutes of Health under Ruth L. Kirschstein National Research Service Award No. T32 MH18029-21 from the National Institute of Mental Health.

Acknowledgments

The authors would like to thank seminar participants at the University of Connecticut, the University of Milwaukee—Wisconsin, Bryn Mawr College, the 2014 ECHE/IHEA Joint Meetings, and the 2016 Western Economic Association International Annual Meetings. This work was covered by University of Arkansas at Fayetteville IRB Protocol Number 10-11-235.

Data availability

The data for this study cannot be shared publicly due to concerns about disclosure of individual health information. The data analysis for this manuscript took place within a secure facility on the premises of the Arkansas Center for Health Improvement (ACHI) in Little Rock, AR. Should other researchers wish to access these data for replication purposes, they should contact the corresponding author. He can facilitate the introductions necessary to initiate the process of developing a separate data use agreement for purposes of replication. These are the same conditions under which the authors had access to these data.

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