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Effects of Contextual Economic Factors on Childhood Obesity

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Abstract

Objectives To examine the association between changes in contextual economic factors on childhood obesity in the US.
Methods We combined data from 2003, 2007, and 2011/2012 National Surveys of Children's Health for 129,781 children aged 10–17 with 27 state-level variables capturing general economic conditions, labor supply, and the monetary or time costs of calorie intake, physical activity, and cigarette smoking. We employed regression models controlling for demographic factors and state and year fixed effects. We also examined heterogeneity in economic effects by household income.
Results Obesity risk increased with workforce proportion in blue-collar occupations, urban sprawl, female labor force participation, and number of convenience stores but declined with median household income, smoking ban in restaurants, and full service restaurants per capita. Most effects were specific to low income households, except for density of supercenters/warehouse clubs which was significantly associated with higher overweight/obesity risk only in higher income households.
Conclusions for Practice Changes in state-level economic factors related to labor supply and monetary or time cost of calorie intake may affect childhood obesity especially for children in low-income households. Policymakers should consider these effects when designing programs aimed at reducing childhood obesity.

Keywords Obesity · Children · Adolescents · Body Mass Index · Economic factors

Significance

Children's obesity has increased during the past three decades and understanding its causes remains a policy and research priority. Previous studies have examined the potential role of a few economic factors, one at a time, such as fast food prices, access to supermarkets, and maternal employment. This study simultaneously examines the effects of 27 theoretically relevant contextual economic factors on childhood obesity using nationally representative data. Several economic factors related to employment and monetary and time cost of calorie intake had significant associations with childhood obesity. Most of these associations were specific to or more pronounced in low-income households.

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Introduction

The rise of childhood overweight and obesity during the last three decades has raised great concern among public health professionals and policymakers. Worldwide, the prevalence of childhood overweight and obesity combined increased by 47.1% between 1980 and 2013 (Ng et al. 2014). In the US, children's obesity rate increased by 72% between 1988 and 2014 (Ogden et al. 2016), and nearly 17% (or 12.7 million) are obese (Ogden et al. 2015). The consequences of this high prevalence of youth obesity are many and multifaceted. Since obesity increases risks of chronic disorders such as diabetes and cardiovascular disease (Freedman et al. 2007; Hannon et al. 2005), children are increasingly facing premature morbidity (Wang et al. 2011). Moreover, obese children are more likely than others to suffer psychosocial problems including stigmatization and poor self-esteem (Han et al. 2010). In the long term, childhood overweight and obesity increase the risks of adult obesity (Simmonds et al. 2016) and related health problems such as diabetes, stroke, heart disease, and several types of cancer (Ogden et al. 2015). Therefore, understanding the core causes of childhood obesity that are amenable to policy interventions remains a public health priority.

The growing prevalence of youth obesity has been linked to complex dynamics of increasing access to and consumption of energy-dense nutrient-poor processed foods and sugary beverages, as well as a rise in sedentary lifestyle (Jacques-Tiura and Greenwald 2016; Karnik and Kanekar 2012). These channels have in turn been associated with not only individual/family characteristics but also contextual economic factors (Cawley and Liu 2012; Larson et al. 2013; Powell 2009). Prior studies have shown associations between youth obesity and restaurant prices (Powell et al. 2007a, 2010; Auld and Powell 2009; Powell and Chaloupka 2009; Beydoun et al. 2011), prices of fruits and vegetables (Auld and Powell 2009; Beydoun et al. 2011; Powell and Bao 2009; Powell and Chaloupka 2009; Powell et al. 2010; Sturm and Datar 2005), access to supermarkets and other food stores (Powell et al. 2007b, 2010; Powell and Bao 2009), access to restaurants (Powell et al. 2007a; Powell and Bao 2009), and maternal employment (Anderson et al. 2003; Courtemanche 2009; Courtemanche et al. 2017; Fertig et al. 2009; Larson et al. 2013; Morrissey 2013; Morrissey et al. 2011; Ruhm 2008; Ziol-Guest et al. 2013). Other studies examine soda taxes but found that, as currently practiced, they are too small to have much effect on children's weight (Fletcher et al. 2010; Powell et al. 2009; Sturm et al. 2010). Macro-level economic changes have also been considered, with recent work showing greater risk of child overweight/obesity with the county-level unemployment rise in California during the Great recession (Oddo et al. 2016).

Dramatic economic changes over the past several decades could have contributed to the rise in childhood obesity (Jacques-Tiura and Greenwald 2016). Cost of caloric intake has fallen due to lower prices for foods and drinks of questionable nutritional value, along with easier access to these products through the proliferation of supercenters and restaurants (Chou et al. 2004; Courtemanche and Carden 2011). Factors increasing the opportunity cost of physical activity include urban sprawl, which it makes less likely for children to walk or bike to school and reduces their time in physical activities (Zhao and Kaestner 2010), and falling inflation-adjusted gasoline prices, which incentivize driving as opposed to more active modes of transportation (Courtemanche 2011; Sen 2012). Other economic variables, such as general economic conditions or parental labor supply, could affect either eating or exercise through household budgets or available leisure time. Other factors such as job distributions or cigarette prices and smoking bans might more directly affect the weight of adults but could have indirect spillover effects on children (Mellor 2011).

We extend the research on economic factors and children's obesity by examining the importance of changes in numerous contextual economic changes over the past decade for the rise in child obesity in the US. We employ nationally representative data on child obesity and consider a wide range of economic factors suggested by microeconomic theory as potentially relevant including general economic indicators, labor supply variables, and variables related to monetary or time costs of calorie intake, physical activity and smoking. A key contribution is simultaneously examining multiple theoretically relevant economic factors. Because economic factors are correlated with each other, understanding their effects on child obesity requires examining them simultaneously as opposed to separately to reduce confounding and therefore the probability of over- or underestimating the importance of one or more factors (Courtemanche et al. 2016). Another contribution is to be, to our knowledge, the first to estimate the associations between several of these factors—specifically, proportion of the workforce in physically active and blue collar jobs, smoking bans, gasoline prices, urban sprawl, big box grocers, and alcohol prices—and childhood (as opposed to adult) obesity. In addition, we contribute by assessing heterogeneity in the effects of these factors by household income, as price and time cost effects may vary by household's purchasing power and labor supply and poorer households may be more constrained in their choices.

Methods

Data Sources, Variables and Study Sample

Individual-Level Data

We analyzed data from the 2003, 2007, and 2011–2012 waves of the National Surveys of Children's Health (NSCH). The NSCH were collected data on children's health and family and social contexts. The surveys provide national and state-level representative data on children and adolescents (≤ 17 years) in the US. The three waves are cross-sectional samples and not longitudinal interviews of the same children. We limited the analysis to children aged 10–17 years because this is the age for which the surveys included questions about Body Mass Index (BMI). From the sample of 134,672 children with BMI data, we excluded those with incomplete information on the key socio-demographic variables we consider in the analysis. Hence, the analytical sample included 129,781 children (n = 44,238 in 2003; n = 43,402 in 2007; n = 42,141 in 2011–2012).

We examined two measures of child weight based on the BMI-for-age variables already coded in the NSCH datasets. Each child was pre-coded based on his/her rank on the age and gender specific BMI distribution into: < 5th percentile, 5th to < 85th percentile, 85th to < 95th percentile, and ≥ 95th percentile. Following the standard definitions for children's obesity and overweight, obesity was defined as a binary variable for ranking at or above the age and gender specific 95th percentile of the BMI distribution. We also evaluated another binary indicator for overweight or obesity, based on ranking above the 85th percentile.

State-Level Economic Factors

Following Courtemanche et al. which evaluated the effects of multiple state-level economic factors on adult obesity in the US (Courtemanche et al. 2016), we grouped the state-level economic measures into five categories: general economic indicators; labor supply variables; monetary or time costs of calorie intake; monetary or time costs of physical activity; and monetary or time costs of smoking. We provide in the Appendix in Electronic Supplementary Material a discussion of the conceptual connections between these variables and children's obesity. The general state economic indicators were: median income, unemployment rate, and the ratios of the 90th to the 50th and the 50th to 10th percentiles of the earnings distribution. The labor supply variables encompassed: female and male labor force participation rates, the average number of work hours among employees, proportion of the workforce with a job that requires at least moderate physical activity (defined as a metabolic equivalent score of 3 or higher), and proportion of the workforce in blue collar occupations (construction, manufacturing, or extraction). Measures of the monetary or time costs of calorie intake included: numbers of supermarkets, restaurants, convenience stores, supercenters/warehouse clubs, and general merchandisers per 100,000 residents; prices of grocery food, restaurant fast-food, and alcohol; the price of fruits/vegetables relative to other grocery foods; and per capita food stamp spending. Variables capturing monetary or time costs of physical activity were: number of fitness centers per capita, gasoline price, and the proportion of the state population living in the central cities of the metropolitan statistical areas (a proxy for urban sprawl). Finally, we included cigarette price and dummies for smoking bans in private workplaces, restaurants, government workplaces, and other locations to capture monetary or time costs of smoking.

Data on state-level economic factors came from various sources. Price data were obtained from the Council for Community and Economic Research's (C2ER) Cost of Living Index, which estimates prices of various items including transportation, grocery, housing, and health care in about 300 local markets per quarter. Following previous analyses (Chou et al. 2004; Courtemanche et al. 2016), prices of items were averaged within the specified category (e.g. grocery foods) for each market according to the item's importance in the basket of goods. State prices were then defined as the population-weighted average of the prices in the state's C2ER markets and converted to 2011 dollars. Data on number of supermarkets, restaurants, convenience stores, and general merchandisers in each state came from the Quarterly Census of Employment and Wages (QCEW) collected by the Bureau of Labor Statistics (BLS) and from data used in Courtemanche et al. (2016) capturing Walmart Supercenters, Sam's Clubs, Costcos, and BJ's Wholesale Clubs.

The Current Population Study (CPS), conducted by the U.S. Census Bureau for the BLS was the source of data on median income, unemployment rate, female and male labor force participation, proportion of the workforce in a physically active and blue collar job, average work hours, and 90/50 and 50/10 ratios. Data on the Supplemental Nutrition Assistance Program (food stamp) benefits were obtained from the US Department of Agriculture, while data on share of the population living in MSA central cities were taken from the U.S. Census Bureau. Information from Impacteen and the classification scheme of the 1989 Surgeon General's Report was used to derive variables on smoking bans at state level (Centers for Disease Control 1989). Finally, cigarette prices were obtained from *The Tax Burden on Tobacco* (Orzechowski and Walker 2010).

The study used publicly available de-identified survey data; subjects consented to provide data for research purposes as part of participating in the survey.

Statistical Analysis

We merged the individual-level data from the NSCH by state and year to the 27 state-level economic variables derived for 2003, 2007 and 2011. We then assessed how these economic factors were associated with child obesity, using regressions that controlled for state and year fixed effects, which account for all state-level time-invariant confounders and national trends shared between states (akin to a difference-in-differences model), respectively. In order to ensure that only within-state variation in the economic variables over time was used to estimate their effects on child obesity, we estimated the regression using a linear probability model (OLS). Unlike OLS, logit or probit models that control for state and year fixed effects do not restrict the estimation to within-state variation and are therefore not necessarily optimal for this estimation (Greene 2002). Nonetheless, our results are robust to employing non-linear probability models as mentioned below.

The regression models also controlled for child's age, sex and ethnicity. Separate regressions were estimated for obesity and overweight/obesity. For each outcome, we estimated the model simultaneously including all economic variables together in a single regression to eliminate omitted variable bias from the different economic factors being correlated with each other. First, we estimated the models for the total sample and then stratified by household income which can affect how households respond to changes in economic conditions. Because poorer families are more constrained in their consumption, they may be more sensitive to economic changes, especially those related to food price and availability. Therefore, we estimated separate models for children below the sample median of household income measured in categories relative to federal poverty line (FPL) compared to those above median (≤ 300% FPL vs > 300% FPL). All economic variables were standardized to have a mean of zero and standard deviation of one, so their coefficients can be compared and interpreted as an effect of a one standard deviation increase. Models were weighted using sampling probability weights to generate nationally representative estimates, and standard errors were clustered at the state level. Supplementary Table 1 online shows descriptive statistics for the study variables.

We estimated alternative regression specifications with additional control variables as sensitivity checks. The first augmented regression added child's birth order, household education, and language spoken in the household. The second regression added to these individual-level controls child's general health and insurance status. We did not include these individual-level variables in the main specification as they are potentially endogenous to the economic factors we examine or to children's weight. In another model, we included smaller area fixed effects for the 35 states that had data on MSA versus non-MSA residence by replacing the state fixed effects with state-by-MSA status fixed effects in these states. We did this to assess whether area-level unobserved heterogeneity at a smaller level than state may be driving any of the results we are observing.

Results

We begin by showing the associations between the economic variables and childhood obesity in the total sample in Table 1. Childhood obesity increased with the proportion of the workforce in blue-collar occupations, female labor force participation, and convenience stores per capita, and declined with median household income, banning smoking in restaurants, proportion in central cities, and full service restaurants per capita. In terms of magnitudes, urban sprawl showed the strongest association, as a one standard deviation increase in proportion in central cities was associated with a 13.7 percentage-point decline in the probability of a child being obese. The magnitudes of the associations between one standard deviation changes and the other statistically significant variables were much smaller, ranging from 0.8 to 4.3 percentage-points.

When evaluating overweight/obesity, supercenters/warehouse clubs per capita had a significant positive effect, while proportion in central cities, restaurants per capita, and fast-food restaurant price (marginally significant) had negative effects (Table 1). The proportion in blue-collar jobs also had a marginally significant positive effect. Urban sprawl again had the largest effect, with a one standard deviation increase in proportion in central cities associated with lower overweight/obesity probability by 12.6 percentage-points. Results for both obesity and overweight/obesity were similar when estimating the models using logistic regression (Supplementary Table 2 Online). The observed differences in estimates between obesity and overweight/obesity are likely driven by differential associations between the economic factors and weight levels, rather than just the higher proportion of children who are obese or overweight when grouping the two together. This is so because the coefficients also changed after including the overweight threshold, not just the standard errors (or confidence intervals), which would change because of differences in outcome variation.

When stratifying by sample median of household income (≤ 300% vs > 300% FPL), economic factors had stronger associations with obesity among lower-income children (Table 2), as expected. These differences by income level were, however, not always statistically significant. Among poorer children, six economic factors had significant associations with obesity. Of these factors, median household income and proportion in central cities had negative effects on obesity, while labor force participation rate for both males and females, proportion in blue-collar jobs, and number of convenience stores per capita had positive effects. Also, fitness centers per capita had a marginally significant negative effect on obesity. Proportion in central cities again showed the strongest association, with a one standard deviation increase associated with 13.5 percentage-point decline in the probability of being obese. Another notably large magnitude is that a one standard deviation increase in convenience stores per capita was associated with increased probability of obesity by 8.4 percentage points. Among children in higher income households (> 300% FPL), only two variables related to smoking were marginally associated with obesity. Cigarette prices had a negative effect, while smoking bans in government workplaces had a positive effect. Both effects were small in magnitude.

Results for overweight/obesity also showed that economic changes were more relevant for children in lower income households, with various associations showing significant differences by income level (Table 3). Among children

Table 1 Associations between economic factors and children's obesity or overweight/obesity (children aged 10–17 years, n = 129,781)

	Obesity	Overweight/obesity
General economic indicators		
Unemployment rate	0.006 (0.006)	− 0.012 (0.009)
Median household income	− 0.018 (0.007)**	0.003 (0.010)
90/50 ratio	− 0.001 (0.004)	0.002 (0.005)
50/10 ratio	0.003 (0.004)	0.006 (0.005)
Labor supply variables		
Female labor force participation rate	0.016 (0.005)***	0.009 (0.008)
Male labor force participation rate	0.009 (0.006)	0.011 (0.007)
Average work hours	− 0.007 (0.004)	− 0.005 (0.006)
Proportion active job	0.001 (0.008)	− 0.007 (0.010)
Proportion blue collar	0.015 (0.005)***	0.018 (0.009)*
Variables related to monetary or time costs of smoking		
Cigarette price	0.0004 (0.0060)	0.002 (0.007)
Smoking ban: private	− 0.001 (0.004)	− 0.004 (0.007)
Smoking ban: government	0.002 (0.004)	− 0.0002 (0.0066)
Smoking ban: restaurant	− 0.008 (0.004)**	− 0.006 (0.004)
Smoking ban: other	0.003 (0.003)	− 0.003 (0.005)
Variables related to monetary or time costs of physical activity		
Fitness centers	0.001 (0.009)	− 0.018 (0.013)
Gasoline price	− 0.009 (0.012)	0.026 (0.019)
Proportion central city	− 0.137 (0.035)***	− 0.126 (0.047)**
Variables related to monetary or time costs of calorie intake		
Full service restaurants pc	− 0.032 (0.011)***	− 0.029 (0.014)**
Supercenters/warehouse clubs pc	0.005 (0.007)	0.022 (0.010)**
Supermarkets/grocery stores pc	0.002 (0.009)	0.009 (0.013)
All convenience stores pc	0.043 (0.016)***	0.034 (0.021)
General merchandisers pc	0.003 (0.012)	− 0.013 (0.012)
Relative price of fruits/vegetables	− 0.003 (0.004)	0.003 (0.005)
Fast-food restaurant price	− 0.004 (0.005)	− 0.012 (0.007)*
Alcohol price	0.004 (0.004)	0.006 (0.005)
Grocery food price	0.007 (0.005)	0.001 (0.006)
Food stamp benefits	0.001 (0.010)	0.013 (0.013)

Estimates are changes in the likelihood of the child being obese or overweight/obese with a one standard-deviation increase in the economic variables. Standard errors (heteroscedasticity-robust and clustered by state) are in parentheses. The model variables explained 4% of the variation in obesity and 5% of the variation in obesity/overweight

*p < 0.10; **p < 0.05; ***p < 0.01

from low-income households, significant negative associations with overweight/obesity were observed for unemployment rate, average work hours, and proportion in central cities. Positive significant associations were observed for proportion in blue collar jobs, male labor force participation rate, number of convenience stores per capita, and grocery food price. Also, female labor force participation rate had a marginally significant positive effect on overweight/obesity. Urban sprawl and convenience stores per capita again had the largest sized effects, with one standard deviation increases in these two variables associated with changes in the probability of being overweight/obesity of 22.9 and 5.7 percentage-points, respectively. Among children at higher income levels, four factors had significant positive associations with overweight/obesity: urban sprawl, median household income, supercenters/warehouse clubs, number of supermarkets/grocery stores, and proportion in central city, which interestingly, urban sprawl had opposite-signed effects for the two income groups.

We should also mention that the full sample decreased to 119,955 when we stratified by household income due to missing data. However, results for the full sample with income data (Supplementary Table 3 Online) were very similar to those from the total sample of 129,781 children, indicating no meaningful sample composition changes when stratifying by household income.

Table 2 Associations between economic factors and children's obesity by sample median of household income relative to federal poverty line (FPL), children aged 10–17 years, n = 119,955

	Household income ≤ 300% FPL	Household income > 300% FPL	p value for difference[a]
General economic indicators			
Unemployment rate	− 0.005 (0.008)	0.008 (0.007)	0.192
Median household income	− 0.035 (0.012)***	− 0.009 (0.013)	0.219
90/50 ratio	− 0.004 (0.004)	0.004 (0.005)	0.104
50/10 ratio	0.007 (0.004)*	− 0.003 (0.006)	0.163
Labor supply variables			
Female labor force participation rate	0.026 (0.007)***	0.008 (0.010)	0.254
Male labor force participation rate	0.019 (0.007)***	0.004 (0.009)	0.108
Average work hours	− 0.009 (0.006)	− 0.005 (0.007)	0.693
Proportion active job	− 0.008 (0.008)	0.010 (0.013)	0.225
Proportion blue collar	0.028 (0.006)***	− 0.001 (0.008)	0.002
Variables related to monetary or time costs of smoking			
Cigarette price	0.011 (0.007)	− 0.016 (0.009)*	0.005
Smoking ban: private	− 0.004 (0.007)	− 0.006 (0.006)	0.783
Smoking ban: government	− 0.004 (0.007)	0.010 (0.005)*	0.130
Smoking ban: restaurant	− 0.003 (0.006)	− 0.006 (0.008)	0.796
Smoking ban: other	0.007 (0.005)	0.003 (0.005)	0.582
Variables related to monetary or time costs of physical activity			
Fitness centers	− 0.021 (0.012)*	0.021 (0.014)	0.019
Gasoline price	− 0.030 (0.020)	− 0.011 (0.019)	0.540
Proportion central city	− 0.135 (0.054)**	− 0.082 (0.067)	0.588
Variables related to monetary or time costs of calorie intake			
Full service restaurants pc	− 0.020 (0.014)	− 0.030 (0.018)	0.658
Supercenters/warehouse clubs pc	0.020 (0.012)	− 0.006 (0.012)	0.157
Supermarkets/grocery stores pc	0.002 (0.017)	0.002 (0.014)	0.974
All convenience stores pc	0.084 (0.024)***	− 0.001 (0.026)	0.025
General merchandisers pc	0.004 (0.017)	0.003 (0.015)	0.983
Relative price of fruits/vegetables	0.0003 (0.0071)	− 0.005 (0.005)	0.539
Fast-food restaurant price	− 0.005 (0.009)	0.006 (0.007)	0.394
Alcohol price	0.001 (0.006)	0.006 (0.005)	0.541
Grocery food price	0.009 (0.008)	0.007 (0.009)	0.880
Food stamp benefits	− 0.015 (0.012)	0.028 (0.017)	0.036

Estimates are changes in the likelihood of the child being obese with a one SD increase in the economic variables. Standard errors (heteroscedasticity-robust and clustered by state) are in parentheses

*$p < 0.10$, **$p < 0.05$, ***$p < 0.01$

[a]p value for differences in associations by household income

Results from the sensitivity checks that control for additional individual-level child/household characteristics or smaller area-level fixed effects were similar to the main estimates (results shown in Appendix in Electronic Supplementary Material).

Discussion

We examined the relationship between child obesity over the last decade and various changing economic factors in

Table 3 Associations between economic factors and children's overweight/obesity by sample median of household income relative to federal poverty line (FPL), children aged 10–17 years, n = 119,955

	Household income ≤ 300% FPL	Household income > 300% FPL	*p* value for difference[a]
General economic indicators			
Unemployment rate	− 0.032 (0.011)***	0.002 (0.006)	0.001
Median household income	− 0.025 (0.018)	0.026 (0.009)***	0.005
90/50 ratio	0.001 (0.005)	0.001 (0.005)	0.973
50/10 ratio	0.010 (0.006)	0.0001 (0.0051)	0.165
Labor supply variables			
Female labor force participation rate	0.021 (0.012)*	− 0.014 (0.009)	0.012
Male labor force participation rate	0.020 (0.009)**	0.007 (0.008)	0.213
Average work hours	− 0.019 (0.008)**	0.005 (0.006)	0.016
Proportion active job	− 0.014 (0.013)	− 0.007 (0.011)	0.608
Proportion blue collar	0.040 (0.011)***	0.0002 (0.0108)	0.003
Variables related to monetary or time costs of smoking			
Cigarette price	0.005 (0.009)	− 0.006 (0.008)	0.228
Smoking ban: private	− 0.0004 (0.0096)	− 0.011 (0.008)	0.308
Smoking ban: government	− 0.012 (0.009)	0.009 (0.009)	0.030
Smoking ban: restaurant	− 0.002 (0.008)	− 0.001 (0.006)	0.968
Smoking ban: other	− 0.002 (0.007)	− 0.004 (0.006)	0.816
Variables related to monetary or time costs of physical activity			
Fitness centers	− 0.026 (0.019)	− 0.009 (0.012)	0.327
Gasoline price	0.024 (0.035)	0.002 (0.018)	0.596
Proportion central city	− 0.229 (0.065)***	0.114 (0.051)**	< 0.001
Variables related to monetary or time costs of calorie intake			
Full service restaurants pc	− 0.011 (0.018)	− 0.025 (0.019)	0.567
Supercenters/warehouse clubs pc	0.010 (0.014)	0.041 (0.010)***	0.060
Supermarkets/grocery stores pc	− 0.013 (0.021)	0.028 (0.011)**	0.094
All convenience stores pc	0.057 (0.027)**	0.009 (0.026)	0.147
General merchandisers pc	− 0.019 (0.020)	− 0.011 (0.012)	0.730
Relative price of fruits/vegetables	0.007 (0.008)	− 0.002 (0.005)	0.329
Fast-food restaurant price	− 0.019 (0.011)	0.0003 (0.0062)	0.095
Alcohol price	0.009 (0.009)	0.004 (0.004)	0.655
Grocery food price	0.018 (0.008)**	− 0.009 (0.007)	0.003
Food stamp benefits	0.023 (0.016)	0.012 (0.014)	0.512

Estimates are changes in the likelihood of the child being overweight/obese with a one standard-deviation increase in the economic variables. Standard errors (heteroscedasticity-robust and clustered by state) are in parentheses

*p < 0.10, **p < 0.05, ***p < 0.01

[a]p value for differences in associations by household income

the US. Using nationally representative data, we found significant associations with several economic conditions. In the full sample, obesity or overweight significantly increased with the proportion of the workforce in blue-collar occupations, female labor force participation rate, density of convenience stores, and density of supercenters/warehouse clubs, and significantly declined with the proportion of population living in central cities, number of full service restaurants, median household income, and banning smoking in restaurants. These effects are overall consistent with economic theory. Increasing time cost to cook at home (female labor force participation, proportion of workforce in blue-collar occupations typically involving less flexible working hours), and increased access to calorie-dense foods and cost of bulk shopping (density of convenience stores and supercenters/warehouse clubs) were associated with higher obesity or overweight. In contrast, increased access to healthier meals outside of home (density of full service restaurants) and lower monetary/time cost for physical activity (proportion in central cities) were associated with lower obesity or overweight.

Underlying these overall effects is important heterogeneity by household income. Labor supply, time cost measures, and convenience store density are associated with child obesity or overweight only among low income households (≤ 300% FPL). Furthermore, higher grocery food price is associated with higher obesity/overweight only for these households. These effects are consistent with these households being more economically constrained in their consumption and more dependent on convenience stores. In contrast, the density of supercenters/warehouse clubs and supermarkets is positively associated with children's obesity/overweight only among higher income households (> 300% FPL based on sample median). Perhaps lower income households are more constrained in how much they can purchase (and therefore extent of bulk shopping) at these places.

Another noteworthy difference is the direction of urban sprawl effect, which is associated with an increase (decrease) in overweight/obesity risk among lower (higher) income households. While an exact explanation for this discrepancy is beyond the scope of this paper, one possible explanation is that children in lower income households may experience greater commute time and reduction in physical activity because of urban sprawl than those in higher income households. Because children's physical activity and energy expenditure are highly dependent on ordinary time activities (such as playing at home or at school), a disproportionate increase in commute time would have a greater effect on children's BMI. Furthermore, higher income parents may be more proactive about offsetting the reduction in physical activity from a driving-oriented lifestyle with leisure-time exercise both for themselves and for their children than low-income parents. It is also worth mentioning that the proportion in central city had the largest association with children's obesity (or overweight/obesity), consistent with the urban sprawl of the past half-century contributing to the growing incidence of weight problems among lower-income children. Our findings are consistent with prior work showing that several economic contextual factors have a stronger effect on households with lower socioeconomic status (Oddo et al. 2016; Powell 2009). Families with higher incomes may be less sensitive in terms of their calorie consumption and expenditure to changing economic factors not only because they are less financially constrained in their decisions, but also because they tend to have higher educational level and higher levels of health literacy (Kutner et al. 2006). These informational differences have been significantly linked to differences in parental attitudes towards child weight loss strategies, feeding and physical activity-related child care behaviors, and health information-seeking preferences (Liechty et al. 2015; Yin et al. 2014). Our analyses also showed that an increasing proportion of the workforce in blue collar occupations was positively associated with children's obesity in low-income households. This finding would suggest that certain aspects of such jobs e.g., their relatively less flexible schedules, may decrease the likelihood of workers being involved in physical activities with their family or having time to cook at home. Higher share of blue collar jobs could also indicate lower economic resources within households which in turn can result in higher consumption of cheap, calorie-dense foods.

Our results add to a growing body of literature showing that different contextual economic factors are involved in the complex pathways leading to child obesity that should be considered when designing public policies and population-based interventions to tackle childhood obesity. In terms of public policy, the health benefits of any interventions to undo trends in economic factors should be weighed against the corresponding reductions in consumer surplus. For instance, policies to encourage denser urban design may reduce childhood obesity for lower income households, but at the expense of some of the conveniences of suburban living. Additionally, it does not seem reasonable to suggest a restriction on convenience stores or a reversal of the growing number of supercenters/warehouse clubs, especially given the gain in social welfare from the increase in purchasing power and access to goods. However, alternative approaches to make unhealthy, energy-dense food less easily available to children and adolescents should be considered. Policy alternatives that could be studied include taxes and subsidies that change the relative price of selected foods, financial incentives to increase the number of outlets providing healthy foods in certain communities which is particularly relevant to substitute for purchasing food at convenience stores, interventions on marketing practices that affect food choices and preferences (Lobstein et al. 2015), and measures to make calorie-dense foods and drinks less available in schools and other settings. Creating enabling environments for children and adolescents to learn healthy food preferences is particularly important as these preferences are more difficult to change later in life (Hawkes et al. 2015).

Limitations of this study should also be noted. First, it would have been preferable to use a smaller geographic unit for the economic factors, but that was not possible because the state was the smallest identifiable geographic unit in the NSCH. As noted above, we estimated a model with less aggregated area-level controls that replaced state with state-by-MSA status fixed effects in the states that had this data and observed similar results, suggesting that area-level time-invariant heterogeneity is unlikely a confounder for our estimates. However, examining these relationships at smaller areas would enable a more powered assessment (with more precise estimates) and should be considered in future research. Another limitation is potential measurement error in some economic factors that could have led to underestimate their effects. For example, the C2ER state-level food and alcohol price data were based on a restricted number of products and urban markets, which would result in some measurement error (Courtemanche et al. 2016). Additionally, we were not able to control for certain potential time varying-confounders such as increasing number of video games, television channels, tablets, cell phones, etc., for which it is difficult to measure cross-state over-time variation. Finally, with three waves of the NSCH, we could not check for the possibility of additional time-varying state confounders by including state-specific trends as this would leave too little variation in the state economic variables to obtain precise estimates.

In conclusion, we found significant associations between several state-level economic factors and children's obesity over the last decade in the US. We also found large and significant associations for urban sprawl, labor supply, time costs, grocery food price, and convenience store density only among children in low-income households. Future studies should explore additional economic variables and continue to evaluate the pathways linking different economic contextual variables and child obesity while considering likely heterogeneity by household income, in order to better guide policy development to reduce obesity and improve children's health.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

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