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# Fast food costs and adolescent body mass index: Evidence from panel data☆

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ABSTRACT

This study draws on four waves of the 1997 National Longitudinal Survey of Youth and external data to examine the relationship between adolescent body mass index (BMI) and fast food prices and fast food restaurant availability using panel data estimation methods to account for individual-level unobserved heterogeneity. Analyses also control for contextual factors including general food prices and the availability of full-service restaurants, supermarkets, grocery stores, convenience stores and commercial physical activity-related facilities. The longitudinal individual-level fixed effects results confirm cross-sectional findings that the price of fast food but not the availability of fast food restaurants has a statistically significant effect on teen BMI with an estimated price elasticity of −0.08. The results suggest that the cross-sectional model over-estimates the price of fast food BMI effect by about 25%. There is evidence that the weight of teens in low- to middle-socioeconomic status families is most sensitive to fast food prices.


## 1. Introduction

Obesity rates among American youths have tripled over the last few decades. Current estimates show that 17.6% of U.S. adolescents age 12 through 19 are overweight (age- and sex-specific body mass index (BMI) greater than or equal to the 95th percentile) (Ogden et al., 2008). Parallel to the rising obesity epidemic, survey data on food consumption patterns and household expenditures show a marked upward trend in total energy intake derived from away-from-home sources, in particular fast food outlets (Stewart et al., 2004; Guthrie et al., 2002; Nielsen et al., 2002). Adolescents consume the largest proportion of calories away from home at quick service restaurants (Guthrie et al., 2002) and, in addition, to influencing family food purchases, they represent an important consumer market as they are much more likely than younger children to be direct consumers. US adolescents are estimated to have spent $159 billion in 2005 (Teenage Research Unlimited, 2005). Further, the most frequently seen food product advertisements by teens age 12 through 17 are for fast food (Powell et al., 2007b).

Several studies have examined associations between fast food consumption and energy and nutrient intake and weight outcomes. Fast food consumption has been associated with higher total energy intake and higher intake of fat, saturated fat, carbohydrates, sugar, and carbonated soft drinks and lower intake of micronutrients and fruit and vegetables (Lin et al., 1999; Binkley et al., 2000; French et al., 2000, 2001; Paeratakul et al., 2003; Bowman et al., 2004; Bowman and Vinyard, 2004; Befort et al., 2006). Also, studies have found significant associations between fast food consumption and increased BMI (Binkley et al., 2000), increased body weight (French et al., 2000) and a higher probability of being overweight (Bowman and Vinyard, 2004).

The declining real price of food and the relative low cost and convenience of energy dense foods, in particular, are hypothesized as key contributors to overweight (Lakdawalla and Philipson, 2002; Cutler et al., 2003; Drewnowski and Darmon, 2005). Only a limited number of studies, however, have examined the extent to which economic mechanisms related to energy dense fast food consumption such as price and availability are related to weight outcomes and most of these studies have used cross-sectional data. Higher fast food prices and food at home prices have been related

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to lower weight outcomes among adults using cross-sections of the 1984–1999 Behavioral Risk Factor Surveillance System (Chou et al., 2004). Higher fast food prices have been related to lower BMI and obesity among adolescents using cross-sections from 1997 to 2003 of the Monitoring the Future data (Powell et al., 2007a; Auld and Powell, in press), 1997–1999 cross-sections of the National Longitudinal Survey of Youth 97 (Chou et al., 2005, 2008) and 2001–2003 cross-sections of the Medical Expenditure Panel Survey (Monheit et al., 2007). Study results based on random effects models using longitudinal data from the Early Childhood Longitudinal Study on children followed from kindergarten through third grade (Sturm and Datar, 2005) and through fifth grade (Sturm and Datar, 2008) and using data from the children of the National Longitudinal Survey of Youth 1979 (Powell and Bao, 2009) have found that changes in child weight are statistically significantly positively related to the price of fruit and vegetables but not statistically significantly related to changes in fast food prices. Although the latter study (Powell and Bao, 2009) found that fast food prices were statistically significantly related to lower BMI when the sample was restricted to older children 13–17 years of age. The relationship between fast food restaurant availability and child or adolescent weight outcomes has not been found to be statistically significant (Chou et al., 2005; Sturm and Datar, 2005, 2008; Auld and Powell, in press; Monheit et al., 2007; Powell et al., 2007a; Powell and Bao, 2009) although Chou et al. (2004) found greater numbers of available total restaurants (full service and fast food) to be significantly associated with higher adult obesity.

This study examines the relationship between adolescent BMI and fast food prices and fast food restaurant availability using panel data estimation methods. In particular, unobserved individual-level heterogeneity is accounted for by estimating individual-level fixed effects models. The analyses also control for additional neighborhood contextual factors including general food prices and the availability of full-service restaurants, supermarkets, grocery stores, convenience stores and commercial physical activity-related facilities. In sensitivity analyses, local area median household income also is controlled for. This study draws on four waves of the 1997 National Longitudinal Survey of Youth (NLSY97) to examine the determinants of adolescents' BMI. Food price and outlet density data are linked to the NLSY97 by year and county-level geocode identifiers. Using cross-sectional estimation methods the findings confirm results from previous cross-sectional studies that the price of fast food has a statistically significant weak negative association with adolescent BMI. Controlling for individual-level fixed effects, a statistically significant negative relationship between fast food prices and weight is found but the effect size is lower than the cross-sectional estimate. Examining price responsiveness by parental income and education, there is evidence that the weight of teens in low- to middle-socioeconomic status (SES) families is most sensitive to fast food prices.

## 2. Data

This study combines individual-level panel data from the NLSY97 on adolescents with external data on fast food prices and general food prices obtained from the American Chamber of Commerce Researchers Association (ACCRA) and outlet density data obtained from business lists developed by Dun and Bradstreet (D&B). The external food price and outlet density measures are matched to the individual-level data using county-level geocode identifiers for each NLSY97 panel wave from 1997 through 2003. Population data used to generate per capita outlet density measures and data on median household income used in sensitivity analyses are drawn from the Census 2000 (U.S. Census Bureau, 2002).

### *2.1. NLSY97 panel data*

This paper uses four waves (1997 through 2000) of the NLSY97 where respondents were between the ages of 12 and 17 in 1997. This study is limited to adolescents who live at home. With regard to parental information, data on parental income was reported by parents in all four waves and was obtained from the 1997 parental questionnaire and the 1998–2000 household income update questionnaire. Data on mother's education and work status was obtained from the 1997 parental questionnaire and in subsequent years was reported by youths in the annual household roster data. Based on non-missing data, the estimation sample includes 11,900 person-year observations on an unbalanced panel of 5215 individuals living in 392 different counties across the U.S.

The main outcome measure in this study is BMI. BMI was calculated based on the self-reported anthropometric information (height and weight) available in the NLSY97 survey. BMI is calculated as equal to weight (kilogram)/height (meter)-squared. Adolescents were classified as overweight when BMI ≥ age-sex-specific 95th percentile based on the CDC growth chart (Kuczmarski et al., 2001). Individual- and household-level control characteristics include age, race (White, Black, Hispanic, Asian and Other race), gender, youth's income (which includes earned income and allowance from parents), family structure (young adult lives with one parent versus both parents), youth's annual hours of work, parental income, mothers' education (less than high school, high school, some college and more), mother's work status (not working, working part-time, working full-time) and rural, suburban and urban indictors.

### *2.2. Fast food price and fast food restaurant availability measures*

Fast food price data were obtained from the ACCRA Cost of Living Index reports. These reports contain quarterly information on prices across more than 300 US cities. These price data were matched to the NLSY97 sample based on the closest city match available in the ACCRA data using the county-level geocode identifier. Observations for which price matches were not available from the same or contiguous county were not included in the analyses. Further, a price match indicator was included in the estimation to control for price matches based on a contiguous versus exact county match. A fast food price index was generated based on the following three items included in the ACCRA data: a McDonald's Quarter-Pounder with cheese, a thin crust regular cheese pizza at Pizza Hut and/or Pizza Inn, and fried chicken (thigh and drumstick) at Kentucky Fried Chicken and/or Church's Fried Chicken. The price index was weighted based on expenditure shares provided by ACCRA derived from the Bureau of Labor Statistics (BLS) Consumer Expenditure Survey. All prices were deflated by the BLS Consumer Price Index (CPI) (1982–1984 = 1).

The fast food restaurant outlet density measure was developed using data obtained from business lists developed by D&B through MarketPlace software. MarketPlace allows sorting by multiple criteria such as location and Standard Industry Classification (SIC) codes. Restaurant outlet data are available from D&B under the 4-digit classification of "Eating Places". Fast food restaurants are defined by the full set of primary 8-digit SIC codes that fall under "Fast food restaurants and stands" excluding coffee shops and including the two primary 8-digit SIC codes for chain and independent pizzerias.

### 2.3. Additional contextual price, outlet density measures and neighborhood SES controls

In addition to fast food contextual variables, this study also controls for general food prices drawn from the ACCRA data and a number of outlet density measures drawn from D&B including full-service restaurants, food stores and physical activity-related facilities. The food at home food price measure is derived from thirteen general grocery food prices available in the ACCRA data constructed similarly to the food at home price measure used by Chou et al. (2004, 2005, 2008). This food at home price index was weighted using BLS expenditure share weights and deflated by the CPI.

A number of outlet density measures drawn from the D&B data are used to control for additional aspects of the built environment that may affect weight through food consumption patterns or physical activity. First, a measure of full-service restaurants are defined as the total number of “Eating Places” minus fast food restaurants and excluding coffee shops, ice cream, soft drink and soda fountain stands, caterers, and contract food services. Second, information on food store outlets available in the D&B data set was pulled at the 6-digit SIC code level and food stores were defined separately by type according to their primary SIC code as supermarkets, convenience stores, and grocery stores. Third, a measure of commercial physical activity-related facilities is also included which was defined based on a list of facilities drawn from100 different physical activity-related 8-digit SIC codes. These business SIC codes included facilities such as physical fitness facilities, membership sports and recreation clubs, public golf courses, ice rinks, swimming pools, dance studios, sports and athletic instruction (i.e. gymnastics), tennis courts, YMCA, etc. All outlet density measures are computed as the number of available outlets per 10,000 capita using Census 2000 county-level population estimates.

Finally, in sensitivity analyses, in addition to the food price and neighborhood outlet density control measures, county-level local area median household income also is controlled for. These data are drawn from the Census 2000 and are merged to the NLSY97 by the county-level geocode identifiers.

## 3. Empirical model

The empirical model is based on an economic framework where individuals engage in behaviors related to work, leisure, and home production; they produce and demand health and weight; and finally, they also consume food which directly and indirectly (through changes in weight and health) impacts utility (Cawley, 2004). Within this framework the standard budget constraint is affected by income and prices; time traded off between leisure and a variety of production activities constrained to 24 h in a day; and, finally, weight is constrained by biology such that changes in caloric intake and energy expenditure affect weight. Outcomes such as food consumption and activity decisions are derived based on marginal costs and benefits. Changes in the relative price of different food products such as healthy versus non-healthy items are expected to affect the relative demand for these products and in turn affect weight outcomes.

However, even in a simple two good world where there are healthy less energy dense foods and unhealthy energy dense foods it is not clear how changes in the relative price of such goods will affect weight. Auld and Powell (in press) present a theory of the consumption of energy dense and less dense foods. The authors show that, putting aside any changes in food expenditures caused by changes in food prices, changes in relative prices change caloric intake in a manner that can be predicted solely by the relative cost of purchasing a calorie from high or low energy density food: if the price of a calorie of dense food is lower (higher) than the price of a calorie of less dense food, increases in the price of dense food decrease (increase) total caloric intake. This result depends only on the convexity of indifference curves and not any mechanism related to the physiological effects of energy dense foods. Indeed, it has been well established that a calorie can be purchased at a lower price if the food chosen is energy dense (Drewnowski and Darmon, 2005). The model predicts that increases in the price of energy dense foods through taxation or decreases in the cost of less dense food through subsidies can be expected to decrease body weight. This model is consistent with Cutler et al.'s (2003) hypothesis that technological changes have decreased the relative full price of mass produced energy dense food and the resulting changes in consumption patterns have contributed to higher levels of obesity.

The goal of the empirical work in this study is to examine the effect of the underlying cost mechanisms of energy dense fast food consumption versus other food consumption on adolescent BMI. The primary objective is to use longitudinal panel data to assess whether controlling for unobserved individual-level heterogeneity there exists any evidence of an economic and statistically significant relationship between the cost of fast food and adolescent BMI. The direct money cost of fast food is measured by a fast food price index and the opportunity cost of the time spent acquiring fast food is measured by the per capita availability of fast food restaurants. In addition to controlling for a rich set of individual and household-level characteristics, the estimation also controls for additional neighborhood contextual factors that may be expected to affect eating patterns and physical activity and related weight outcomes. Controlling for additional county-level contextual variables helps to remove county-level heterogeneity that may be correlated with general neighborhood socioeconomic patterns and to control for potential unobserved county-level time-varying heterogeneity.

A reduced form empirical model of adolescent BMI of the following form is estimated:

$$BMI_{ist} = \beta_0 + \beta_1 FFprice_{st} + \beta_2 FFrest_{st} + \beta_3 OC_{st} + \beta_4 X_{it} + \beta_5 D_t + \varepsilon_{ist} \quad (1)$$

where $FFprice_{st}$ measures fast food prices in geographic area $s$ at time $t$, $FFrest_{st}$ measures the per capita availability of fast food restaurants in geographic area $s$ at time $t$, $OC_{st}$ is a vector which measures other local area contextual factors including general food prices and the availability of full-service restaurants, supermarkets, convenience stores, grocery stores and physical activity-related facilities in area $s$ at the time $t$, $X_{it}$ is a vector of individual and household characteristics and $D_t$ is a vector of year dummy variables. $\beta$ are conformable vectors of parameters to be estimated and $\varepsilon_{ist}$ is a standard residual term. The characteristics in the vector $X_{it}$ include race/ethnicity, youth's income and hours of work, parental income, highest level of schooling completed by mother, whether the mother works part-time or full-time and urbanicity indicators. In the cross-sectional models, $X_{it}$ also includes complete sets of gender-specific age dummy variables to remove gender-specific differences in BMI growth. The coefficients on other covariates may then be interpreted as reflecting variation around arbitrary gender-specific growth curves.

For comparison purposes to the previous literature which has used cross-sectional estimation methods, naïve ordinary least squares (OLS) BMI models of Eq. (1) are estimated first. Cross-sectional estimates based on Eq. (1) may be biased and standard errors may be underestimated if there exists unobserved individual-level effects. $\varepsilon_{ist} = v_i + w_{ist}$ is rewritten and Eq. (1) then

**Table 1**
Summary statistics outcome, price, and outlet variables.

| Variables | Mean | S.D. | % Change from 1997 to 2000 |
|---|---|---|---|
| BMI | 22.68 | 4.54 | +9.08% |
| Price of fast food ($1982–1984) | 2.77 | 0.17 | −2.73% |
| Number of fast food restaurants (per 10,000 capita) | 2.42 | 0.78 | +17.31% |
| Price of food at home ($1982–1984) | 1.10 | 0.11 | −0.45% |
| Number of full-service restaurants (per 10,000 capita) | 10.83 | 3.18 | −1.35% |
| Number of grocery stores (per 10,000 capita) | 3.12 | 1.63 | −6.62% |
| Number of convenience stores (per 10,000 capita) | 1.96 | 1.21 | +8.08% |
| Number of supermarkets (per 10,000 capita) | 0.55 | 0.27 | −2.37% |
| Number of total physical activity facility (per 10,000 capita) | 3.58 | 1.23 | +5.07% |

*Notes*: Summary statistics are weighted using the NLSY sampling weights.

can be rewritten into:

$$BMI_{ist} = \delta_0 + \delta_1 FFprice_{st} + \delta_2 FFrest_{st} + \delta_3 OC_{st} + \delta_4 X_{it} + \delta_5 D_t + v_i + w_{ist} \quad (2)$$

where $v_i$ is the constant individual-specific residual and $w_{ist}$ is a standard residual.

To account for unobserved individual-level heterogeneity, the longitudinal panel data are used to present results from two estimation methods. First, Eq. (2) is estimated using a random effects (RE) model which provides a weighted average of the between and within estimates and assumes that $v_i$ and the independent variables are uncorrelated (Wooldridge, 2002). Next, to account for individual-level heterogeneity an individual-level fixed effects (FE) model is estimated. The fixed effects panel estimation allows $v_i$ to be arbitrarily correlated with the independent variables and the time-invariant covariates in the vector $X_i$ and the constant individual-specific residual $v_i$ are differenced out and within person equation estimates are provided (Wooldridge, 2002). The fixed effects estimates will be consistent but are less efficient than the estimates from the random effects model. Therefore, a Hausman test is run to examine whether the random effects model yields consistent results and the test results ($P$-value $\leq 0.01$) suggests that fixed effects is the preferred model. Nonetheless, results are presented from both models for comparison with previous studies that have estimated random effects models.

## 4. Results

The summary statistics and changes over time for the outcome and contextual variables are shown in Table 1. Mean BMI of adolescents aged 12 through 17 is 22.68 and it increased by 9.1% over the 1997–2000 period. The mean real fast food price is $2.77 and it remained relatively constant trending downwards just slightly (−2.7%). The per 10,000 capita number of available fast food restaurants is 2.42 and it increased by 17.3% over the 1997–2000 period. The per 10,000 capita number of supermarkets (mean of 0.55) and full-service restaurants (mean of 10.83) availability remained relatively constant from 1997 to 2000 while the available numbers of convenience stores (mean of 1.96) and physical activity-related facilities (3.58) trended upwards and the availability of grocery stores (mean of 3.12) declined slightly. The mean real price of food at home index is $1.10 and remained constant over the 1997–2000 period.

Table 2 presents the summary statistics for the control variables. Just over half (51.7%) of the sample is male and 69.5% are white, 14.4% are African American, 11.8% are Hispanic, 1.7% are Asian and 2.6% are of another race. On average, one quarter of the teens live in single-parent households and approximately one half of teens have a mother who has some or have completed college while another 35.7% have mothers who had completed high school. Teens have an average annual income of $820.00 ($1982–84) and live in households with average parental income of $33,274.00 ($1982–84). Adolescents work, on average over the year, 13 h per week and 62.7% of teens have mothers who work full-time and another 17% have part-time working mothers.

Table 3 presents the cross-sectional OLS and longitudinal individual-level random effects and fixed effects estimation results. The cross-sectional OLS results show that higher fast food prices are marginally statistically significantly associated with lower BMI. A one dollar increase in the price of fast food is estimated to reduce BMI by 0.778 units and the corresponding fast food price elasticity of BMI is estimated to be −0.095. The availability of fast food restaurants is found to be positively associated with BMI but the relationship is not statistically significant (although the effect is statistically significant and larger when year fixed effects are excluded, estimates not shown in tables). The price of food at home and the availability of different types of food stores are not found to be statistically significantly related to teen weight. Finally, the presence of one additional commercial physical activity-related facility per 10,000 capita is associated with a 0.16 unit reduction in BMI.

Turning to the longitudinal estimation results, the second column of Table 3 shows that the results for the fast food and other

**Table 2**
Summary statistics.

| Variables | Mean/frequency | S.D. |
|---|---|---|
| Age | 15.48 | 1.74 |
| Male | 51.7% | – |
| White | 69.5% | – |
| African American | 14.4% | – |
| Asian | 1.7% | – |
| Other | 2.6% | – |
| Hispanic | 11.8% | – |
| Youth lives with one parent | 26.0% | – |
| Youth income (in ten thousands of $1982–1984) | 0.08 | 0.17 |
| Hours of work per week | 13.02 | 15.39 |
| Parental income (in ten thousands of $1982–1984) | 3.33 | 3.07 |
| Mother not completed high school | 14.7% | – |
| Mother completed high school | 35.7% | – |
| Mother completed some college or more | 49.6% | – |
| Mother does not work | 20.3% | – |
| Mother works part time | 17.0% | – |
| Mother works full time | 62.7% | – |
| Lives in urban area | 75.1% | – |
| Lives in suburban area | 9.0% | – |
| Lives in rural area | 15.9% | – |
| County level median household income (in ten thousands of $2000) | 4.33 | 1.01 |
| 1997 | 27.9% | – |
| 1998 | 29.1% | – |
| 1999 | 22.9% | – |
| 2000 | 20.1% | – |

*Notes*: $N$ = 11,900. Summary statistics are weighted using the NLSY sampling weights.

**Table 3**
Cross-sectional and longitudinal regression estimates of the determinants of adolescent BMI.

| | Cross-sectional OLS model | Longitudinal individual-level random effects model | Longitudinal individual-level fixed effects model |
|---|---|---|---|
| Price of fast food | −0.7782* (0.4281) | −0.6908** (0.2682) | −0.6455** (0.2979) |
| Number† of fast food restaurants | 0.1215 (0.1164) | 0.0730 (0.0750) | 0.0098 (0.0983) |
| Price of food at home | −0.2187 (0.7655) | −0.5601 (0.5128) | −0.0807 (0.7641) |
| Number† of full-service restaurants | 0.0318 (0.0314) | −0.0144 (0.0188) | −0.0323 (0.0276) |
| Number† of grocery stores | −0.0074 (0.0466) | −0.0403 (0.0315) | −0.0325 (0.0409) |
| Number† of convenience stores | 0.0459 (0.0730) | 0.0698 (0.0647) | 0.1480 (0.0963) |
| Number† of supermarkets | 0.1703 (0.2736) | 0.1918 (0.2231) | 0.2447 (0.2621) |
| Number† of physical activity facilities | −0.1596** (0.0722) | −0.1177** (0.0510) | −0.1216 (0.0865) |
| African American | 1.2331*** (0.2322) | 1.3992*** (0.2007) | |
| Asian | −0.6625 (0.4206) | −0.8590** (0.3966) | |
| Other | 1.0349** (0.5043) | 1.1250** (0.4722) | |
| Hispanic | 0.5152** (0.2546) | 0.9333*** (0.1917) | |
| Youth lives with one parent | 0.4672*** (0.1646) | 0.2527*** (0.0971) | −0.0164 (0.1317) |
| Youth income | 0.0631 (0.3038) | 0.2670* (0.1623) | −0.0774 (0.1700) |
| Hours of work per week | 0.0066* (0.0035) | 0.0030* (0.0018) | 0.0003 (0.0020) |
| Parental Income | −0.0717*** (0.0190) | −0.0112 (0.0093) | 0.0089 (0.0102) |
| Mother completed high school | −0.0276 (0.2146) | −0.2430 (0.1737) | −0.5071 (0.3143) |
| Mother completed some college or more | −0.1276 (0.2130) | −0.1956 (0.1646) | 0.1454 (0.3192) |
| Mother works part time | −0.4424** (0.1792) | −0.2136** (0.0896) | −0.2028** (0.0937) |
| Mother works full time | −0.1843 (0.1690) | −0.1577* (0.0929) | −0.1678* (0.1002) |
| Lives in suburban area | −0.4587** (0.1987) | −0.3319* (0.1797) | −0.2171 (0.3474) |
| Lives in rural area | 0.5748** (0.2619) | 0.2918 (0.2033) | −0.2421 (0.2552) |

*Notes*: Regressions include a dummy variable indicator of the quality of the price match and year fixed effects. The OLS and RE models include the full set of age*gender interaction dummy variables. Standard errors are reported in parentheses and are robust and clustered at the county level. $N = 11{,}900$.

* Significance at 10%.
** Significance at 5%.
*** Significance at 1%.
† Per 10,000 capita.

contextual factors from the random effects estimator are similar to the cross-sectional estimates though slightly smaller in magnitude. Higher fast food prices but not the availability of fast food restaurants significantly reduces teen BMI. The fast food price elasticity of BMI is estimated to be −0.084. Also, greater availability of commercial physical activity facilities is statistically significantly related to lower BMI.

Controlling for unobserved individual-level heterogeneity using the fixed effects estimator, the results reveal a statistically significant relationship between changes in adolescents' BMI and changes in fast food prices but no statistically significant relationship is found with fast food outlet availability or any other contextual economic factor. A one dollar increase in the price of fast food is estimated to reduce adolescent BMI by 0.646 units corresponding to a fast food price elasticity of −0.078. Estimates from the longitudinal model controlling for individual-fixed effects suggest that the cross-sectional model over-estimates the price of fast food BMI effect by about 25%. In addition, unlike the results based on the cross-sectional and random effects models, the negative relationship between the availability of physical activity-related facilities and BMI is not statistically significant once individual-level heterogeneity is accounted for using fixed effects.

In terms of the individual- and household-level control variables, the results for the time-constant race indicators from the cross-sectional OLS model are consistent with the previous literature finding BMI to be significantly higher among minority races (with the exception of Asian). Examining the results of the time-varying control covariates, whereas adolescents living in families with higher parental income are found to have significantly lower BMI in the cross-sectional estimates, the results from the FE panel estimates show no within person effect of parental income on teen BMI. In addition, whereas the OLS results show a significant positive relationship between teen BMI and living in a single-parent versus two-parent household this effect is not found to be present in the FE model. There is evidence in both the cross-sectional and panel estimates that increases in maternal work hours are related to lower teen BMI. This finding differs from previous longitudinal research on younger children which found a positive relationship between mothers' hours of work and child overweight status (Anderson et al., 2003).

Table 4 examines the robustness of the fast food price effects from both the cross-sectional and longitudinal panel models to the inclusion of local area median household income and to the exclusion of the various local area outlet density controls and other food prices. Model 1 shows the results from the cross-sectional and longitudinal models as specified in Table 3. The sensitivity analyses begin by showing that the fast food price estimate is robust to adding a control for county-level local area median household income, in addition to the price of food and outlet density control measures. These results show that the price estimate is robust to controlling for the local area economic conditions. Models 3 through 7 show the price estimates based on models that consecutively omit the remaining contextual controls. In the final set of sensitivity analyses, to help assess the potential influence of local area demand for fast food, the price estimates are compared with and without controlling for fast food outlet availability (comparing Models 6 and 7). The results show that the fast food price estimates are robust to the exclusion of fast food restaurant availability. Overall, the sensitivity analyses reveal that the price of fast food point estimates would be over-estimated by about 20% in both the cross-sectional and longitudinal models if these contextual covariates were not controlled for in the regressions.

Finally, potential differences in the relationship between fast food prices and BMI across populations of different socioeconomic status are explored. Table 5 presents fast food price elasticities of BMI for the full sample and by parental income tertiles and parental education based on estimates from individual-level fixed effects models. Teens with low-educated mothers (high school or less) are found to be more price elastic (fast food price elasticity of −0.133) than those with mothers with college education. Estimates

**Table 4**
BMI fast food price estimates for cross-sectional and longitudinal models by alternative specifications.

| | Cross-sectional OLS model | Longitudinal individual-level random effects model | Longitudinal individual-level fixed effects model |
|---|---|---|---|
| Model 1: Full specification as shown in Table 3 | −0.7782* (0.4281) | −0.6908** (0.2682) | −0.6455** (0.2979) |
| Model 2: Model 1 plus neighborhood income | −0.7565* (0.4441) | −0.6720** (0.2697) | −0.6369** (0.2971) |
| Model 3: Model 1 with Fast food restaurants: YES; Food at home price: YES; Full-service restaurants: YES; Food stores: YES; Physical activity facilities: NO | −0.7827* (0.4330) | −0.7166*** (0.2687) | −0.6875** (0.3012) |
| Model 4: Model 1 with Fast food restaurants: YES; Food at home price: YES; Full-service restaurants: YES; Food stores: NO; Physical activity facilities: NO | −0.9146** (0.4302) | −0.7787*** (0.2753) | −0.7820** (0.3049) |
| Model 5: Model 1 with Fast food restaurants: YES; Food at home price: YES; Full-service restaurants: NO; Food stores: NO; Physical activity facilities: NO | −0.9168** (0.4272) | −0.8032*** (0.2766) | −0.7549** (0.3060) |
| Model 6: Model 1 with Fast food restaurants: YES; Food at home price: NO; Full-service restaurants: NO; Food stores: NO; Physical activity facilities: NO | −0.9477*** (0.3489) | −0.9931*** (0.2515) | −0.7734*** (0.2984) |
| Model 7: Model 1 with Fast food restaurants: NO; Food at home price: NO; Full-service restaurants: NO; Food stores: NO; Physical activity facilities: NO | −1.0049*** (0.3550) | −0.9980*** (0.2511) | −0.7748*** (0.2993) |

*Notes*: The regression models include all variables shown in Table 3 and those described in the notes of Table 3. Standard errors are reported in parentheses and are robust and clustered at the county level. $N = 11,900$.
* Significance at 10%.
** Significance at 5%.
*** Significance at 1%.

by income tertiles reveal significant price sensitivity for teens living in middle-income households: teens in middle-income families are found to have a relatively large and statistically significant negative relationship between the price of fast food and BMI with a BMI fast food price elasticity of −0.313. The regression estimates do not find a statistically significant relationship between fast food prices and weight among the adolescents from families with higher educated mothers or from high-income families. It should be noted that the youths in the higher SES families are significantly less likely to be overweight compared to their low-SES counterparts. For example, 7.5% of youths from high-income families are overweight compared to 11.8% and 14.8% from middle- and low-income families, respectively. Similarly, the teens with higher educated mothers (college education or more) are less likely to be overweight (9.6% overweight) compared to teens with mothers who have at most a high school education (12.1% overweight). In this regard, these findings are consistent with recent evidence based on quantile regression methods that showed that the weight of adolescents in the upper tail of the BMI distribution was four to five times more sensitive to fast food prices compared to teens of normal weight (Auld and Powell, in press).

**Table 5**
Fast food price elasticities of BMI based on individual-level fixed effects model estimates: full-sample and by income and education.

| | Fast food price elasticity of BMI |
|---|---|
| Full sample | −0.0782** |
| By mother's education | |
| High school or less | −0.1338*** |
| Some college or more | −0.0310 |
| By parental income | |
| Low income | 0.0658 |
| Middle income | −0.3130*** |
| High income | 0.0547 |

*Notes*: Elasticities are calculated based on regression estimates from the full sample and sub-samples from the FE model as specified in Table 3 and average fast food prices and mean BMI within each subsample. The income subgroups are defined by parental income tertiles.
** Significance at 5%.
*** Significance at 1%.

If higher-SES teens consume less fast food then they also would be expected to be less price sensitive. Further, teens of higher educated parents may limit fast food consumption even as prices fall as they may be more likely to be informed on the health risks of excessive fast food consumption. Evidence on teens' fast food consumption by SES is sparse, however a recent study by Hastert et al. (2008) shows just this, albeit for a sample based on California youths. The study found that the percent of adolescents ages 12–17 who reported consuming fast food differed significantly by SES: 37% of teens with household incomes of 300% or greater of the federal poverty level (FPL) reported consuming fast food on the previous day compared with 46% of teens in families with incomes of 200–299% of the FPL and 49% of teens in families with incomes below 100 of the FPL.

## 5. Conclusions

With increasing rates of adolescent overweight, policymakers continue to assess a number of potential policy interventions to reverse this course and fast food taxes are one such instrument. Adolescents make significant food purchases of their own and fast food consumption is well within the financial reach of many teenagers if it is not purchased for them directly by their parents. Further, adolescents on their own are not likely to understand the nutritional and health implications of their food choices and they may have high rates of time preference. Adolescence is an important transition period as food consumption patterns begin to become more permanent and teen overweight itself tracks into adulthood. A number of cross-sectional studies (Chou et al., 2005, 2008; Powell et al., 2007a; Auld and Powell, in press; Monheit et al., 2007) and one longitudinal random effects study (Powell and Bao, 2009) have found statistically significant negative associations between fast food prices and adolescents' BMI and/or overweight prevalence suggesting that fast food taxes may be an effective tool for curbing excessive fast food consumption and related overweight. Using cross-sectional estimation methods, this study similarly finds teen BMI to be sensitive to the price of fast food.

The goal of this study was to assess whether findings based on cross-sectional estimates are similarly observed when using panel data to control for unobserved individual-level heterogeneity. Using an individual-level fixed effects estimator the results reveal that higher fast food prices are statistically significantly related to decreases in adolescent BMI. The fast food price elasticity for BMI was −0.08 based on the FE model compared to −0.10 based on the OLS model suggesting that the cross-sectional estimates over-estimate the price sensitivity by about 25%.

In addition, there are a number of noteworthy findings in this study with respect to family-level characteristics. The negative relationship between parental income and adolescent weight found in the cross-sectional analysis was not found to be present in the panel data estimates. Accounting for unobserved individual-level heterogeneity, the estimates revealed that changes in parental income have effectively zero impact on changes in teen weight. Similarly the fixed effects estimates did not reveal any significant effects of living in a single versus two-parent family. This study did not find a positive relationship between mothers' hours of work and children's BMI. In fact, part-time maternal work status versus not working was statistically significantly related to lower teen BMI and full-time work versus not working had a weakly statistically significant negative effect. These findings are different to previous panel estimates for younger children that found that greater hours of maternal work are related to increased child overweight (Anderson et al., 2003). This study suggests that these effects do not persist into adolescence.

In summary, accounting for individual-level unobserved heterogeneity, the results from the individual-level fixed effects model confirm the cross-sectional finding that higher fast food prices are expected to reduce teen BMI. Overall, however, the modest price elasticities albeit larger for the low- to middle-SES populations suggest that fast food taxes would have to be substantial in order to have any notable effect on weight. Additional longitudinal studies are needed in order to better understand the extent to which we may expect the introduction of new fast food taxes to significantly reduce adolescent weight. In particular, longitudinal studies that are able to control for the local food environment at more proximate geographic levels such as the zip code or census tract level would contribute immensely to the evidence base.

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