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Report
Number 118

June 2011

The Effect of Food and Beverage Prices on Children's Weights

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Recommended citation format for this publication:

Wendt, Minh and Jessica E. Todd. *The Effect of Food and Beverage Prices on Children's Weights.* ERR-118, U.S. Department of Agriculture, Economic Research Service. June 2011.

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A Report from the Economic Research Service

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The Effect of Food and Beverage Prices on Children's Weights

Minh Wendt

Jessica E. Todd

Abstract

One factor that may be important in explaining rising childhood obesity is food prices. This report explores the effect of food prices on children's Body Mass Index (BMI) using data from the Early Childhood Longitudinal Study, Kindergarten Class of 1998-99 (ECLS-K) and the Quarterly Food-at-Home Price Database. On average, higher prices for soda, 100 percent juices, starchy vegetables, and sweet snacks are associated with lower BMIs among children. In addition, lower prices for dark green vegetables and lowfat milk are associated with reduced BMI. The effect of subsidizing healthy food may be just as large as raising prices of less healthy foods.

Keywords: Food prices, BMI, ECLS-K, Quarterly Food-at-Home Price Database (QFAHPD).

Acknowledgments

Many thanks to Corttney Penberthy, who outlined the methodology for calculating the Thrifty Food Plan weekly cost. Thanks to Lisa Powell, Institute for Health Research and Policy, University of Illinois-Chicago; Ashlesha Datar, RAND Corporation, Santa Monica, CA; Shin-Yi Chou, Department of Economics, Lehigh University, and Ilya Rahkovsky, Economic Research Service, USDA for their comments and suggestions. The authors also thank Dale B. Simms for editorial assistance and Cynthia A. Ray for layout and design.

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Summary

The rate of overweight among children has tripled over the past 30 years. First Lady Michelle Obama's *Let's Move* campaign highlights the growing public interest in finding ways to reverse this trend. One factor that may be important in shaping children's dietary intake and weight is food prices. Previous research has shown that there is substantial geographic variation the relative price of healthy foods (Todd et al., 2011). This report estimates the effect of food prices on children's Body Mass Index (BMI) using variation in food prices across time and geographic areas.

What Did the Study Find?

Food prices have small but statistically significant effects on children's BMI, but not all food prices have the same effect. While the magnitude of the price effects is similar for healthier and less healthy foods, the direction differs. Lower prices for some healthier foods, such as lowfat milk and dark green vegetables, are associated with decreases in children's BMI. In contrast, lower prices for soda, 100 percent juices, starchy vegetables, and sweet snacks are associated with increases in children's BMI. These results show that the effect of subsidizing healthy food may be just as large as raising prices of less healthy foods. Specifically:

- A 10-percent price decrease for lowfat milk in the previous quarter is associated with a decrease in BMI of approximately 0.35 percent, or about 0.07 BMI units average for an 8- to 9-year-old.
- A 10-percent drop in the price of dark green vegetables (e.g., spinach and broccoli) in the previous quarter is associated with a reduction in BMI of 0.28 percent.
- A decrease in the price of sweet snacks during the previous quarter is associated with an increase in BMI of 0.27 percent.

Not surprisingly, there is sometimes a delay between when prices change and when measurable changes occur in children's BMI.

- A 10-percent price increase for carbonated beverages 1 year prior is associated with a decrease of 0.42 percent in the average child's BMI. The same price increase for 100 percent juices or starchy vegetables (e.g., potatoes and corn) is associated with a decrease in BMI of 0.3 percent 1 year later.

In addition to the effects varying over time, the effects of prices vary by other characteristics.

- Soda prices have a greater effect on children in households with income below 200 percent of the Federal poverty line, as compared with children in households with higher income.
- Prices for healthy foods such as lowfat milk and green vegetables have larger effects on higher BMI children than on children of average weight.

- Prices for less healthy food groups such as carbonated beverages, fruit drinks, and starchy vegetables have larger effects on BMI for children of average weight.

How Was the Study Conducted?

Panel data on children's BMI, demographic, and household characteristics from the Early Childhood Longitudinal Study, Kindergarten Class of 1998-99 were linked to average retail food prices from the Quarterly Food-at-Home Price Database. BMI was regressed on lagged prices (one-quarter and 1-year lags) using fixed-effects regressions to control for unobserved factors that are likely correlated with BMI. Alternative specifications included price changes over the previous quarter and previous year. Regressions were conducted on the full sample and also separately for boys and girls. Quantile regressions were used to explore whether heavier children have different responses to food prices than thinner children.

Introduction

The prevalence of childhood overweight has risen dramatically in the last several decades in the United States, and is currently considered to be epidemic (U.S. Department of Health and Human Services, 2007; Institute of Medicine, 2008). According to the Centers of Disease Control and Prevention (CDC), overweight rates of U.S. children and adolescents age 6-11 have more than tripled in the last 3 decades, from 6.5 percent in the 1970s to 19.6 percent in 2007-08 (Ogden and Carroll, 2010).[1] Moreover, the extent to which children's body mass index (BMI) exceeds the overweight threshold is also increasing (Flegal and Troiano, 2000; Jolliffe, 2004).

Childhood overweight is linked to a number of medical problems such as type II diabetes, high blood pressure, sleep apnea, and breathing problems; obese children are also more likely to become obese adults than are children of normal weight (U.S. DHHS, 2007; Steinberger et al., 2001; Must and Strauss, 1999; Whitaker et al., 1997). For children and adolescents age 6 to 17, overweight-related hospital costs increased more than threefold from $35 million per year during 1979-81 to $127 million during 1997-99 (Wang and Dietz, 2002).[2] As overweight and obese children become adults, their weight-related morbidities will lead to even greater economic costs. Medical costs of obesity in the United States were estimated to be as high as $147 billion in 2008, up from $78.5 billion in 1998 (Finkelstein et al., 2009).

First Lady Michelle Obama's *Let's Move* campaign highlights the growing national interest in identifying ways to reverse this trend. Recognizing that obesity is the result of many interrelated factors, the campaign encourages families, schools, and communities to improve dietary intake and increase energy expenditure among children.

One factor that may be important in shaping children's dietary intake is food prices. Previous research has show that there is substantial geographic variation in both the absolute price of foods (Todd and Leibtag, 2010) as well as the relative price of healthy foods (Todd et al., 2011). Economic literature on consumer behavior has shown that consumers change their purchases in response to prices changes. Previous research has shown that own-price elasticities (the percentage change in purchases of a good from a 1-percent change in its price) of foods and beverages are relatively large, ranging from 0.27 to 0.81, with food away from home, soft drinks, juice, and meat being most responsive to price changes (Andreyeva et al., 2010).

Recent studies have investigated the relationship between prices of certain food groups—such as meat, fruits/vegetables, and fast food—and childhood obesity. The consensus thus far is that higher prices for fast food and lower prices for fruits and vegetables are associated with lower children's weights (Auld and Powell, 2009; Powell and Bao, 2009; Sturm and Datar, 2008, 2005). However, while these studies examined the effect of market-level food prices, they did not study the effect of beverage prices.

This study's main innovation is to estimate the impact of food prices on childhood obesity by directly linking a unique database of food prices, the Quarterly Food-at-Home-Price Database (QFAHPD), with clinically measured body mass of children. The average retail prices for five beverage

[1]According to the CDC definitions, overweight children age 2 to 19 have BMI-for-age between the 85th and 95th percentiles in the BMI-for-age and gender growth charts, obese children have BMI-for-age at or above the 95th percentile in the BMI-for-age and gender growth charts. BMI is defined as the ratio of weight (in kilograms) over height (in meters) squared. It can also be expressed as weight (in pounds) divided by height (in inches) squared and multiplied by 703.

[2]In constant (2001) dollar value.

types, two types of vegetables, and sweet snack foods are linked to a longitudinal database tracking children's height and weight from kindergarten through eighth grade. The QFAHPD allows the comparison of food and beverage prices over time within and across geographic areas, enabling us to identify the effect of food prices on children's weight status.

We estimate models that test whether prices of carbonated beverages, fruit drinks, 100 percent juices, lowfat milk, whole and 2% milk, starchy vegetables (e.g., corn and potatoes), dark green vegetables (e.g., spinach and broccoli), and sweet snacks affect BMI among a cohort of U.S. children as they age from 5 to 14 years old. We selected these food groups because, with the exception of dark green vegetables, they represent a substantial portion of daily calorie intake among children and adolescents. Nielsen and Popkin (2004) show that soft drinks, fruit drinks, milk, fruit juice, and other beverages comprised 22.4 percent of daily calorie intake for children 2-18 years old in 1999-2001. Almost half of these beverage calories (10.3 percent) were from soft drinks and fruit drinks. Reedy and Krebs-Smith (2010) show that grain-based desserts (e.g., cakes and cookies) comprised 7.2 percent of average daily caloric intake among children age 2-18 in 2005-06. We include prices for dark green vegetables because they are nutrient-dense and low-calorie alternatives to starchy vegetables.

Food and Beverage Prices and Consumption Among U.S. Children and Adolescents

The price index for carbonated drinks has been below both the consumer price index (CPI) and the indexes for all non-alcoholic beverages and whole milk over the last 25 years or so (fig. 1). That is, the real prices for carbonated drinks are actually declining over time. In contrast, the price index for all fruits and vegetables,[3] particularly fresh, is increasing faster than the CPI.[4]

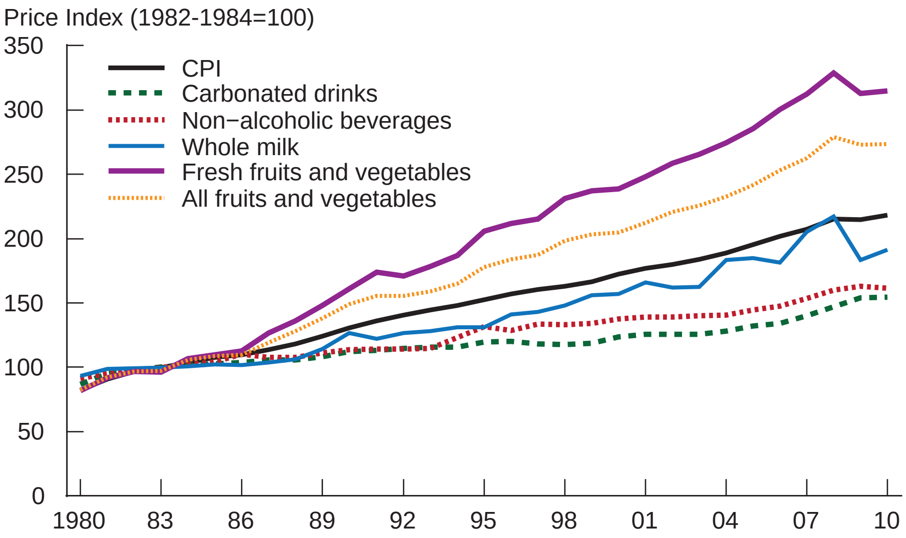
At the same time, consumption of carbonated sweetened beverages (CSBs) and fruit drinks has increased among U.S. children and adolescents, while consumption of milk has declined. Mean intake of CSBs more than doubled, from 5 fluid ounces per day in 1977-78 to 12 fluid ounces in 1994-98 (fig. 2). Per capita daily caloric contribution from CSBs and 100 percent fruit juices increased from 242 kcal per day in 1988-94 to 270 kcal per day in 1999-2004. The largest increase—of about 20 percent—occurred among children age 6 to 11 years (Wang et al., 2008).

The combination of lower real prices and increased consumption lead many to argue that prices have a strong influence on consumption. However, this is ultimately an empirical question, as the full price effect depends on how much intake responds to price and how much weight changes in response to changes in caloric intake (Chow and Hall, 2008). We estimate the (reduced form) relationship between price and weight outcomes based on a traditional household economic framework.

[3]Includes fresh, canned, and frozen categories.

[4]This price structure does not take into account either the quality or variety of fresh fruits and vegetables, which have improved over the last 30 years. See Kuchler and Stewart (2008) for more details.

Figure 1
Price indexes for selected foods and beverages, 1980-2010

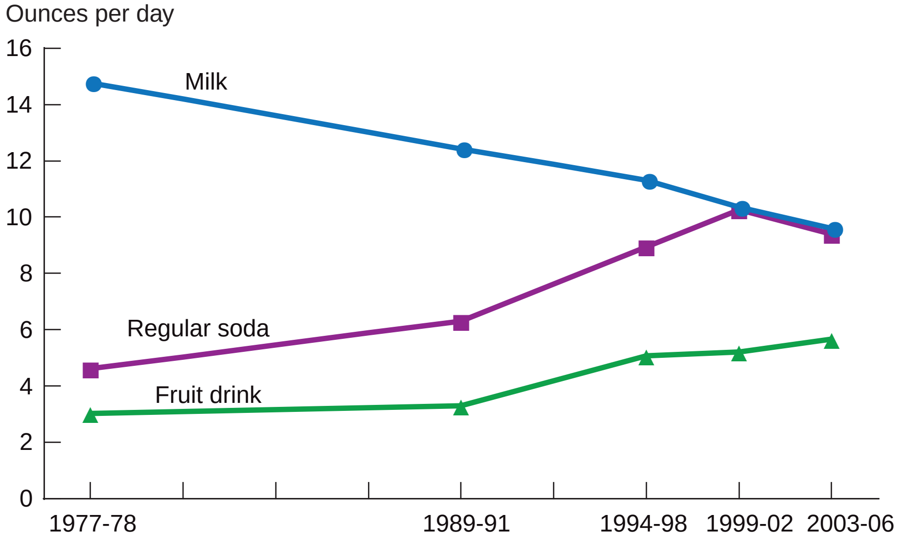


Notes: Prices for each group are annual average prices for all urban consumers. All fruits and vegetables include fresh, canned, and frozen. Base period 1982-84=100.

Source: Bureau of Labor Statistics, http://data.bls.gov/pdq/querytool.jsp?survey=cu

Figure 2

Soda, fruit drink, and milk consumption trend for children age 2-19, 1977-78 to 2003-06



Source: Smith et al., 2010. Data are from 1977-78, NFCS (Nationwide Food Consumption Survey), USDA; 1989-91 and 1994-98 CSFII (Continuing Survey of Food Intakes by Individuals), USDA; 1999-2006 NHANES (National Health and Nutrition Examination Survey).

Applying the Household Economic Framework

The household production function (Becker, 1965) has been widely used in economics to study determinants of children's health in the United States (Variyam et al., 1999; Senauer and Garcia, 1991). In this framework, households combine time, human capital (knowledge and skills), and purchased goods to produce outcomes—such as health of a child—to maximize the overall household's utility. The market goods purchased by households (e.g., foods) derive their values by supplying characteristics (e.g., nutrients) necessary for the production of the outcome (e.g., body weight), in addition to other benefits such as taste and socialization while eating. In this model, when the price of a particular type of food increases, households reduce their consumption of that food in order to equate price with the benefit enjoyed from the last unit purchased (marginal utility).[5] Since weight is determined by net energy intake, we assume that children's body weight is determined by food intake as well as other factors (X) that would affect activity, such as household income and parents' education.

$$\text{BMI} = f(\text{food}, X) \tag{1}$$

Food intake is, in turn, determined by food prices, income, and demographic factors that affect preferences (Z).

$$\text{Food} = g(\text{food prices, income}, Z) \tag{2}$$

Since we do not directly observe the amount of food consumed by individuals, we can substitute equation 2 into equation 1 and obtain a (reduced-form) equation for children's BMI.

$$\text{BMI} = k(\text{food prices, income}, Z, X) \tag{3}$$

Thus, we can think of a child's weight or BMI as determined by food prices, income, and other factors, such as personal characteristics. Equation 3 allows us to estimate the effect of food prices on BMI, recognizing that the effect is transmitted through the effect that prices have on food intake.

[5]Although substitution both within and across food groups could influence how these price effects translate into weight changes.

Data and Variables

Individual and Household Data

Individual and household data are from the Early Childhood Longitudinal Study, Kindergarten Class of 1998-99 (ECLS-K). The ECLS-K is a nationally representative sample of kindergarten students who were in kindergarten during the 1998-99 school year. Children are observed in kindergarten as well as during 1st, 3rd, 5th, and 8th grade. The five rounds of data used in this study correspond to the 1998-99, 1999-2000, 2001-02, 2003-04, and 2006-07 school years.[6]

[6]We merged two waves of data that were collected in the fall and spring of the kindergarten year to form the first round of data in our analysis.

The ECLS-K includes detailed household information, students' demographics, parents' background and characteristics, as well as classroom and school environment. An advantage of this survey is that, unlike other child-level data that rely on self-reported measurements, children's height and weight were measured by survey staff and collected during all survey rounds. Some children are lost from the sample mainly because they changed schools or their families moved outside of the survey's primary sampling units. Approximately 50 percent of "movers" were randomly selected to be followed by ECLS-K. Therefore, most of the children lost for followup were those randomly selected and would be unlikely to bias the results. For more details on sample attrition, including nonresponse and change in eligibility status over time, see Tourangeau et al. (2009).

Food Price Data

Food prices are from the ERS Quarterly Food–at–Home Price Database (QFAHPD).[7] The QFAHPD was constructed from Nielsen Homescan data, in which households report their food-at-home purchases from all store types, including grocery stores, convenience stores, mass merchandisers, club stores, and supercenters. Average quarterly prices are provided for 52 narrowly defined food groups, such as carbonated soda, fruit drinks, and vegetables grouped by type (dark green, starchy, orange) and processing method (fresh, frozen, or canned). These prices were estimated as the weighted average of household-level quarterly prices for each food group, where the household-level prices are the mean price paid by each household for foods within each food group weighted by purchase frequency, not expenditure share within the food group (see Todd et al., 2010, for more details on the construction of the QFAHPD).

[7]The QFAHPD can be downloaded at <http://www.ers.usda.gov/Data/qfahpd/index.htm>

The QFAHPD includes prices for market areas covering the contiguous United States. There are 26 metropolitan markets, which are either single metro areas—such as Philadelphia, Baltimore, and Los Angeles—or a group of metro areas, such as Metro Ohio, which includes Cincinnati, Cleveland, and Columbus. Between 1998 and 2001, areas in the lower 48 States not included in these 26 metro markets are grouped into 4 nonmetro regions; between 2002 and 2006, they are grouped into 9 census divisions (see fig. A1). Although these prices are constructed from household-level purchase data, and therefore are affected by market-level demand, they allow for identification of price effects because they are averages for large geographic areas. This means that they are not sensitive to any one household's demand and are thus not influenced by individual household preferences.

The QFAHPD provides a list of all of the county Federal information processing standards (FIPS) codes covered by each market. We first assign a QFAHPD market to each child based on the child's county of residence and then merge the QFAHPD prices to each child-year observation. Since Alaska and Hawaii are not included in the QFAHPD (or in the Homescan data), 190 children living in these States in the ECLS-K sample are excluded from the analysis.[8] An additional 60 children from the lower 48 States are excluded because their FIPS county code lacks a corresponding code in the QFAHPD data (perhaps due to coding errors in ECLS-K or unidentified changes in FIPS coding over time). QFAHPD prices are nominal, so we convert them to real prices (in 2000 dollars) using the average monthly CPI for each quarter, calculated from monthly data from the Bureau of Labor Statistics.

[8]Due to rules regarding access and use of restricted data, all numbers of observations in this report are rounded to the nearest 10.

Variables

Our main outcome variable is children's BMI as calculated from each child's survey-collected height and weight. Although each student's height and weight were measured by trained field workers, recording errors might occur. We check for consistency across survey waves to correct recording errors, and limit the range of extreme BMI measures using CDC growth charts. The 3rd percentile of BMI for children age 4 to 16 is 13.6, and the 97th percentile is 29.3 (CDC, 2000), so we limit the lowest BMI measure to 10 (affecting 50 children's measures) and the highest to 42 (affecting 90 children). We delete from the sample 10 children with obvious recording errors, such as having BMI greater than or equal to 98. We also determine whether each child is above the 85th (overweight) or 95th percentile (obese) of the growth charts in each wave using the assessment date information and children's birthdays (available in the restricted-use data) to calculate each child's age in months at the time height and weight were measured.[9]

[9]We also estimated our model using standardized continuous BMI (z-scores) and percentiles in the BMI-for-age distributions as the dependent variable. The continuous BMI scores are provided by ECLS-K. BMI z-scores are calculated based on the 2000 CDC Growth Reference. BMI percentiles are calculated by normalizing the z-scores. These are standard measures of children's BMI that are used in previous research. Each measure has its advantages and disadvantages. For detailed discussion, see Cole et al. (2005). The results are consistent and comparable to our main measure.

To control for students' demographics and characteristics, we include their age, race, gender, and birth weight. Students' family structure is captured by their living arrangements categorized as living with two biological parents, one biological and one other parent, single mother, single father, or with adoptive parents or a guardian. We also control for household income relative to the poverty threshold (four categories) and parent's education level (five categories).

To control for market demand conditions, we include the median household income in the county for the year (obtained from the U.S. Census Bureau). To control for the overall price level of food, we include the average weekly price of a market basket (the Thrifty Food Plan, TFP) that provides a healthy diet to a family of four, constructed from the QFAHPD data, in real 2000 dollars. The TFP outlines the quantities (in pounds) of various food groups for individuals by age and gender that will provide a diet that meets the 2005 *Dietary Guidelines* at a low cost (Carlson et al., 2007). We use average market prices, not lowest cost, to construct the TFP basket cost for a family of four, so the measure reflects the average cost of a healthy diet in the child's market area (see Appendix B for more details on the construction of the TFP basket price).

Sample

Our analysis sample is limited to those students with nonmissing explanatory variables, for a total of 15,090 children, with 51,160 child-by-year observations. All children that live in Hawaii are excluded due to lack of food price information.[10]

The average BMI in the sample is 18.46, and obesity (BMI>95th percentile) is estimated at 16.2 percent (table 1). The obesity rate in our sample is comparable to national estimates for children age 6-11 (16.3 percent) and adolescents age 12-19 (16.7 percent) in 2001-02 from the National Health and Nutrition Examination Survey (Ogden and Carroll, 2010). The average age over all child-by-year observations is 106 months (a few months shy of 9 years old); 51 percent are girls, 64 percent are White, 5 percent are Asian, 11 percent are Black, 16 percent are Hispanic, and 4 percent are some other race or ethnicity.

Thirty-eight percent of the child-by-years have at least one parent who completed a college degree or more education, 34 percent have a parent whose highest education is some college, 21 percent have parents whose highest education is a high school degree, and 7 percent have parents with less than a high school education. About 68 percent of the sample lives with two biological parents. The other children in the sample live with two adults where one is a biological parent (9 percent), their single mother (19 percent), their single father (2 percent), or adoptive or foster parents (3 percent).

Mean QFAHPD prices across the sample (table 1) indicate that sweet snacks are the most expensive items per 100 grams (at $0.74), while carbonated beverages are the least expensive ($0.07). Lowfat milk is less expensive than whole milk ($0.09 vs. $0.11 per 100 grams); 100% juice ($0.16 per 100 grams) is more expensive than fruit drinks ($0.11) and carbonated beverages. Dark green vegetables are more expensive per 100 grams ($0.26) than starchy vegetables ($0.17). The average weekly TFP cost for a family of four was $166 over 1998-2007.

[10]The ECLS-K did not sample in Alaska.

Table 1
Descriptive statistics (N=51,160 observations on 15,090 children

Variable	Mean	SD	Min	Max
Body Mass Index (BMI) - mean	18.46	4.18	10	42
Percent obese (BMI>95th percentile)	16.16			
Child characteristics				
Age (months)	105.64	32.85	52.50	190.50
Female	0.51	0.50	0	1
Birth weight (ounces)	118.57	21.10	16	219
White	0.64	0.48		
Asian	0.05	0.22		
Black	0.11	0.32		
Hispanic	0.16	0.36		
Other race/ethnicity	0.04	0.21		
Household/community characteristics				
Parents have less than high school education	0.07	0.26		
Parents completed high school	0.21	0.41		
Parents completed some college	0.34	0.47		
Parents completed college or more	0.38	0.48		
Household income >200% poverty threshold	0.64	0.48		
Household income between 130 and 200% poverty threshold	0.13	0.34		
Household income between 100 and 130% poverty threshold	0.07	0.26		
Household income below poverty threshold	0.16	0.36		
Child lives with 2 biological parents	0.68	0.47		
Child lives with 2 other parents	0.09	0.29		
Child lives with single mother	0.18	0.39		
Child lives with single father	0.02	0.13		
Child lives with other guardians	0.03	0.16		
County median annual household income ($)	44,870	11,758	17,344	104,984
(Prices, 1 quarter lag, $ per 100 grams)				
Carbonated beverages	0.07	0.01	0.06	0.09
Fruit drinks	0.11	0.02	0.07	0.19
100 percent juices	0.16	0.03	0.11	0.25
Lowfat milk (skim, and 1%)	0.09	0.01	0.05	0.12
Whole milk	0.11	0.01	0.08	0.14
Fresh and frozen dark green vegetables	0.26	0.03	0.19	0.41
Fresh and frozen starchy vegetables	0.17	0.02	0.11	0.24
Sweet snacks	0.74	0.07	0.60	1.07
Thrifty food plan basket weekly cost ($2000)	166.31	14.75	137.13	211.67

Note: Number of observation is rounded to the nearest 10.

Source: ERS calculations based on data from the Early Childhood Longitudinal Study, Kindergarten Class of 1998-99, rounds covering 1998-2007.

Empirical Analysis

One of the most common concerns when estimating the effect of various factors on BMI is omitted variable bias, or failing to control for factors that might affect both the explanatory variable of interest (i.e. food prices) and the outcome (i.e., children's body weight). Examples of possible omitted variables in this study include availability of food retailers in an area and other neighborhood or locality characteristics. Since these factors are either unobservable or unavailable, econometric techniques should be used to reduce possible bias in the results. We employ the fixed-effects regression method, which controls for unobserved characteristics of each child—gender, race, and preferences for health and nutrition in the household—that do not change over time. We compare results from the fixed-effects model to a model that does not control for individual-level unobserved characteristics (ordinary least squares, OLS) to explore the extent to which ignoring these characteristics would change our estimated effects.[11] We also employ another model (quantile regression) to investigate whether the effects of prices differ for heavier versus thinner children (at different levels of the conditional BMI distribution).

[11]A Hausman test rejected a random-effects model with a chi-square value of 146.55 and 24 degrees of freedom

More technically, since we are using a fixed-effects model (a within estimator), only the variation over time in BMI for each child is used to identify the effect of price. This gives us short-term estimates of the effects of price changes. In contrast, a cross-sectional model that uses only variation across geographic areas (across individuals) provides a longrun estimate of the effect of price. Thus, our contribution complements previous research by providing shortrun estimates of price effects. Given the frequency of food price spikes in recent years, the significance of shortrun price changes is heightened.

In our fixed-effects model, we compare results using different measures of price: the previous quarter's price and the price four quarters prior. Recent research indicates that changes in caloric intake take time to lead to changes in weight and vary according to the type of macronutrients consumed (Chow and Hall, 2008).[12] Comparing the results using the previous quarter's price to price from four quarters prior tests whether there are differences in when price changes result in weight changes. Given that the market definitions in QFAHPD change for "nonmetro" counties over the time period of the study, price changes in these areas may be due more to the changing definition of markets than actual price changes. Thus, we also estimate a model where children in these "nonmetro" areas are excluded to test the robustness of our full-sample results.

[12]In addition, Chow and Hall (2008) find that changes in weight are not necessarily constant over time (linear).

In our fixed-effects model, we include all child and household-level variables that vary over time, and in our OLS and quantile models, we include all child and household-level characteristics listed in table 1. In all models, we correct for clustering at the school level and for heteroscedasticity using the Huber-White covariance matrix.[13]

[13]We also test the sensitivity of our specification by clustering at the county level, and the results are not affected.

Results

Average Effects of Food Prices

Table 2 reports the results from the fixed-effects (FE) and OLS models, providing estimates of the average associations between prices of selected foods/beverages and children's BMI. Generally, higher prices for lowfat milk and dark green vegetables are associated with higher body weight while higher prices for sweet snacks are correlated with lower weight 3 months later. On the other hand, when 1-year lagged prices are used, higher prices for carbonated beverages, 100 percent fruit juice, and starchy vegetables are associated with lower weight. This means that the effects of prices on body

Table 2
Estimation results, fixed-effects (FE) and OLS models, lagged prices

	FE			OLS	
	1st quarter	1-year	1-year[1]	1st quarter	1-year
BMI (Body Mass Index)	(1)	(2)	(3)	(4)	(5)
Carbonated beverages	-0.003	-0.042***	-0.030**	-0.028	-0.030
	(0.014)	(0.013)	(0.015)	(0.019)	(0.019)
Fruit drinks	0.004	-0.007	-0.013	-0.007	0.002
	(0.007)	(0.006)	(0.008)	(0.011)	(0.009)
100 percent juices	-0.005	-0.030***	-0.039***	-0.012	-0.030***
	(0.007)	(0.009)	(0.013)	(0.009)	(0.011)
Lowfat milk (skim, and 1%)	0.035***	0.012	0.011	0.019	0.036**
	(0.010)	(0.010)	(0.012)	(0.014)	(0.016)
Whole milk	0.001	0.008	0.006	-0.008	-0.022
	(0.007)	(0.010)	(0.011)	(0.012)	(0.017)
Fresh and frozen dark green vegetables	0.028**	0.012	0.024**	0.037*	0.047***
	(0.012)	(0.010)	(0.012)	(0.020)	(0.015)
Fresh and frozen starchy vegetables	-0.006	-0.030***	-0.013	-0.029**	-0.025*
	(0.008)	(0.007)	(0.008)	(0.014)	(0.013)
Sweet snacks	-0.027***	0.003	0.000	-0.008	0.000
	(0.008)	(0.010)	(0.011)	(0.015)	(0.016)
Thrifty Food Plan basket	-0.055**	-0.010	-0.058*	0.032	-0.025
	(0.027)	(0.026)	(0.032)	(0.045)	(0.034)
Number of observations	51,160	51,160	36,770	51,160	51,160
Number of student clusters	15,090	15,090	11,150		
R-squared (within)	0.710	0.710	0.699		
R-squared (between)	0.131	0.131	0.130		
R-squared (overall)	0.290	0.291	0.284	0.327	0.327

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Notes: Number of observations is rounded to the nearest 10. Standard errors in parentheses are adjusted using Huber-White covariance matrix estimate. FE control variables include the child's age (in months), household income, parent types, and survey round of data. The OLS control variables also include birth weight, indicators for whether the child is female, Asian, Black, Hispanic, or other race/ethnicity, and parent's education. BMI and all prices are in log scale.

[1]Children in the "nonmetro" areas in QFAHPD are excluded.

Source: ERS estimates using data from the Early Childhood Longitudinal Study, Kindergarten Class of 1998-99 and the Quarterly Food-at-Home Price Database.

weight vary not only by type of food/drink, but that the same food or drink can have price effects that become more pronounced over time. The FE and OLS estimates differ, indicating that not accounting for unobserved characteristics would bias our estimates. Thus, our preferred model is FE, so we focus on interpreting the FE results going forward.

Since BMI and all prices are in log scale, the estimated coefficients tell us the percentage change in BMI associated with a 1-percent change in price. More technically, the estimated coefficients are the price elasticities of BMI. Unlike adults, children growing normally should see increases in BMI as they age. To provide context for the magnitude of the changes in BMI that are associated with price, we convert the percent changes to BMI unit changes using the average BMI in the sample. The BMI unit changes are actually quite small, but by comparing them to the expected change (growth) over 1 year at a certain point in the BMI distribution (such as the overweight threshold for a given age), we highlight the extent to which price influences short-term changes in BMI among children.

All else equal, a 10-percent price increase for lowfat milk in the previous quarter is associated with a 0.35-percent increase in children's BMI. For the average BMI measure in our sample, 18.5, at the average age of 8 years old (see table 1), such a price increase in lowfat milk equals an average increase of 0.07 unit of BMI. This is equivalent to about 13 percent of annual BMI growth for an 85th percentile boy, and 11 percent for an 85th percentile girl. This estimate assumes that a boy at the 85th percentile for BMI will gain about 0.5 BMI units between age 8 and 9 (2.8 percent, from 18.06 to 18.57), while a girl will gain 0.6 units (3.3 percent, from 18.44 to 19.06).

We also find that higher prices for dark green vegetables in the previous quarter are associated with greater BMI; a 10-percent price increase leads to an increase in BMI of 0.28 percent (or 0.05 unit, on average), equivalent to 10 percent and 8 percent of annual growth for a boy and girl, respectively, at the 85th percentile of BMI. The previous quarter's price of starchy vegetables is not significantly related to BMI. On the other hand, a price increase for sweet snacks has an effect in magnitude similar to dark green vegetables, but with the opposite effect: a 10-percent increase is associated with a 0.27-percent decrease in BMI. Higher overall food prices, as measured by weekly cost of the TFP, reduce BMI, but including this variable does not affect our estimates for specific foods.

Results are different when we model 1-year lagged prices instead of the previous quarter's prices (column 2). A 10-percent price increase for carbonated beverages is associated with a decrease in BMI of 0.42 percent (0.08 unit) 1 year later, while a 10-percent price increase for 100 percent juices reduces BMI 0.3 percent (0.06 unit). A 10-percent price increase for fresh and frozen starchy vegetables is associated with a 0.3-percent decrease in BMI 1 year later.

The 1-year lagged prices for carbonated beverages, 100 percent juices, and starchy vegetables are larger and statistically stronger than their one-quarter lagged prices, while the opposite is true for lowfat milk, dark green vegetables, and sweet snacks. This means that the prices of lowfat milk, dark green vegetables, and sweet snacks might have stronger immediate effects on children's BMI, while carbonated beverages, 100 percent juices, and starchy vegetables might either take some time to appear or have longlasting effects that get stronger over time.

Approximately 25 percent of our sample resides in "nonmetro" areas as defined in the QFAHPD, and the definition of these areas changes slightly over the study's time period. Thus, the QFAHPD prices may not be as reliable for children in these areas as in the metro market areas. As a robustness check, we estimate the model using 4th quarter lag prices when these children are excluded. The results are fairly similar to those from the full sample, except for vegetables, in which the effect of the price of dark green vegetables is now positive and significant, while that for starchy vegetables is no longer significant (table 2, column 3).

Robustness Checks

Our results do not change when we use other measures of BMI and weight status, lending confidence to our main findings. Specifically, we test the sensitivity of our regression results in several ways. First, we use standardized z-scores for BMI according to the U.S. 2000 reference growth charts as our dependent variable. Standardized z-scores compare the difference in an individual's BMI and the mean BMI in units of standard deviation. Although we do control for age and gender in all of our models, standardized z-scores might be more sensitive to subtle changes in BMI for children across time. Second, we also use percentiles that are normalized from the BMI z-scores as a dependent variable. While the percentiles are easier to match up with standard growth charts, they are bounded between 0 and 100, which poses some econometric challenges in selecting appropriate models for analyzing the data. Therefore, we use these results for confirming and validating purposes only. The results of these two alternative measures for BMI, although different in magnitude, are consistent in terms of signs and significance levels with our main model's results.[14]

[14]As a further robustness check, we also estimated a model where the 4th quarter lag price is replaced with the average price of the 4th-7th previous quarters, and found qualitatively and quantitatively similar results (results available upon request).

Differences in Effects by BMI

It is possible that individuals of different BMIs might respond differently to changes in food prices. More precisely, do food prices affect children with higher BMI differently than children with lower BMI? To test for this, we use quantile regression, an econometric method that allows us to compare the effects of prices across different levels of BMI.

Prices of healthier foods (e.g., lowfat milk, 100 percent juice, and dark green vegetables) have larger effects on children with higher BMI, while prices of less healthy foods (carbonated beverages, fruit drinks, whole milk, starchy vegetables) have greater impacts on children with lower BMI (table 3). One possible explanation for this is that while carbonated beverages are widely regarded as unhealthy drinks, less attention is devoted to other calorie-dense drinks such as fruit juice. Therefore, parents might restrict overweight children from consuming soda but not other calorie-dense beverages. Another possibility is that preferences for carbonated beverages are more entrenched among heavier children, such that their consumption responds less to price as compared to children with lower BMI.

Table 3
Estimation results, quantile regression, lagged prices

	Lagged prices			Lagged prices		
	1 quarter			1 year		
	25th quantile	50th quantile	85th quantile	25th quantile	50th quantile	85th quantile
BMI (Body Mass Index)	(1)	(2)	(3)	(4)	(5)	(6)
Carbonated beverages	-0.044***	-0.036**	-0.010	-0.032***	-0.026**	-0.000
	(0.013)	(0.014)	(0.024)	(0.011)	(0.012)	(0.026)
Fruit drinks	0.005	0.007	-0.019	0.017***	0.012*	-0.015
	(0.006)	(0.008)	(0.017)	(0.006)	(0.007)	(0.014)
100 percent juices	0.001	-0.012	-0.033**	-0.015**	-0.036***	-0.068***
	(0.007)	(0.007)	(0.015)	(0.006)	(0.007)	(0.018)
Lowfat milk (skim, and 1%)	0.003	0.014	0.048***	0.022**	0.026**	0.048**
	(0.008)	(0.009)	(0.018)	(0.009)	(0.011)	(0.023)
Whole milk	0.017**	-0.009	-0.034**	-0.012	-0.024**	-0.019
	(0.007)	(0.009)	(0.016)	(0.009)	(0.012)	(0.023)
Fresh and frozen dark green vegetables	0.006	0.041***	0.075***	0.019*	0.037***	0.082***
	(0.011)	(0.014)	(0.026)	(0.011)	(0.013)	(0.025)
Fresh and frozen starchy vegetables	-0.019*	-0.019	-0.025	-0.041***	-0.021**	0.007
	(0.010)	(0.013)	(0.018)	(0.009)	(0.010)	(0.023)
Sweet snacks	-0.012	-0.005	-0.021	-0.008	0.002	0.003
	(0.009)	(0.012)	(0.024)	(0.010)	(0.014)	(0.025)
Thrifty food plan basket	0.016	0.016	0.052	0.003	-0.004	-0.041
	(0.027)	(0.037)	(0.063)	(0.023)	(0.027)	(0.054)
Number of observations	51,380	51,380	51,380	51,380	51,380	51,380
Number of student clusters	15,090	15,090	15,090	15,090	15,090	15,090
Pseudo R-squared	0.151	0.192	0.228	0.151	0.193	0.228

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Notes: Number of observations is rounded to the nearest 10. Tests of equality of the coefficients across the two quantiles for drinks (carbonated beverages, fruit drink, 100 percent juice, both types of milk) and foods (dark green vegetables, starchy vegetables, and sweet snacks) are statistically significant at 95%. Standard errors in parentheses are adjusted using Huber-White covariance matrix estimate. Fixed-effects control variables include the child's age (in months), household income, parent types, and survey round of data. The ordinary least squares control variables also include birth weight; indicators for whether the child is female, Asian, Black, Hispanic, or other race/ethnicity; and parent's education. Body Mass Index and all prices are in log scale.

Source: ERS estimates using data from the Early Childhood Longitudinal Study, Kindergarten Class of 1998-99 and the Quarterly Food-at-Home Price Database.

More technically, we use quantile regressions to test for heterogeneity in price responses examining the 25th, 50th, and 85th quantiles, estimating the effect of one-quarter and 1-year lagged prices separately.[15] It is difficult to incorporate individual fixed-effects in a quantile regression, but we are more interested in the pattern of response across the distribution of BMI and so we focus on comparing the results and not on individual coefficients per se.

Some interesting patterns emerge across the conditional distribution of BMI. First, for carbonated beverages, the effects of price are largest at the low end of the distribution and insignificant at the 85th quantile for both 1 quarter and 1-year lagged prices; the result is similar for starchy vegetables. In contrast, the effect of the price of 100 percent juices is largest at the 85th quantile

[15]Because the quantile regression examines the relationship between the independent variables and conditional quantiles of the independent variable, not percentiles in the BMI growth charts, the 85th quantile translates to approximately the 95th percentile in the BMI growth charts. Note that about 16 percent of the sample can be classified as overweight (over the 85th percentile in BMI-for-age).

(BMI), with a similar result for lowfat milk and dark green vegetables. The effects of prices for fruit drinks, 100 percent fruit juice, both types of milk, and dark green vegetables on the BMIs of children at the 85th quantile are statistically different from those for children at the median.

Our quantile regression results are similar to those of Auld and Powell (2009), although different specifications make it difficult to compare. First, the price index used in Auld and Powell's study is for a group of seven fruits and vegetables, while ours has specific categories. Second, they analyze a sample of adolescents while our sample is younger. Third, they include a price index for fast food but not for drinks, while we have specific categories for different drinks but not for fast food. However, the overall conclusions are similar in that the price effects of certain foods are more significant for children at the 85th percentile compared to children at the median of the weight distribution.

Subgroup Analyses

In addition to comparing effects by BMI, we estimate models for various population subgroups: gender, three income groups, and race (table 4). Overall, the effects of prices on children's body weight vary somewhat between boys and girls, across income levels, and among ethnic groups.

Generally, girls' and boys' BMI responds similarly to food prices. The two exceptions are that a higher price for carbonated soda reduces boys' BMI but does not affect girls', while higher prices of dark green vegetables increases girls' BMI but not boys'.

We also estimate separate models for three income groups: household income over 185 percent of the poverty line, between 130 and 185 percent of the poverty line, and at or below 130 percent of the poverty line. Consistent with expectations that price elasticities are smaller among higher income households, we find that higher prices of carbonated soda reduce BMI of children in households with income below 200 percent of the Federal poverty line, but not of children in higher income households. There is also variation across income groups in the significance of the prices of other foods (juice, dark green vegetables, and starchy vegetables).

Across racial groups, higher prices of carbonated beverages reduce BMI for White and Hispanic children, but not Blacks. Higher prices for juice reduce BMI of White and Black children, but not Hispanics. The price of starchy vegetables is significant for White children only.

Table 4

Estimation results, fixed effects, 1-year lagged prices, by gender, income group and race

BMI (Body Mass Index)	Boys	Girls	Household income > 185% pov.	Household income 130 -185% pov.	Household income <130% pov.	White	Black	Hispanic
Carbonated beverages	-0.058***	-0.023	-0.021	-0.085**	-0.051*	-0.031**	-0.032	-0.071**
	(0.016)	(0.016)	(0.014)	(0.037)	(0.026)	(0.015)	(0.032)	(0.030)
Fruit drinks	-0.007	-0.005	-0.011	0.008	-0.003	-0.001	0.023	-0.009
	(0.008)	(0.008)	(0.007)	(0.019)	(0.011)	(0.007)	(0.019)	(0.011)
100 percent juices	-0.027**	-0.034***	-0.022**	-0.040	-0.033**	-0.030***	-0.071***	-0.024
	(0.012)	(0.012)	(0.011)	(0.026)	(0.016)	(0.011)	(0.027)	(0.018)
Lowfat milk (skim, and 1%)	0.003	0.022*	0.019	0.022	0.010	0.012	-0.004	0.016
	(0.013)	(0.012)	(0.011)	(0.028)	(0.019)	(0.012)	(0.023)	(0.023)
Whole milk	0.010	0.008	0.007	0.017	-0.004	0.014	0.040	-0.021
	(0.013)	(0.012)	(0.012)	(0.030)	(0.019)	(0.011)	(0.030)	(0.023)
Fresh and frozen dark green vegetables	-0.006	0.029**	0.009	-0.065**	0.021	-0.011	0.014	0.004
	(0.013)	(0.012)	(0.011)	(0.029)	(0.018)	(0.011)	(0.030)	(0.024)
Fresh and frozen starchy vegetables	-0.035***	-0.024**	-0.030***	-0.022	-0.014	-0.042***	-0.008	-0.025
	(0.009)	(0.010)	(0.008)	(0.023)	(0.015)	(0.008)	(0.021)	(0.018)
Sweet snacks	0.015	-0.009	-0.009	-0.012	0.015	-0.001	0.016	0.007
	(0.012)	(0.013)	(0.012)	(0.029)	(0.017)	(0.013)	(0.027)	(0.020)
Thrifty Food Plan basket	0.018	-0.040	-0.009	0.216***	-0.018	0.060**	0.016	0.013
	(0.033)	(0.033)	(0.028)	(0.071)	(0.050)	(0.028)	(0.079)	(0.061)
Number of observations	25,920	25,250	32,850	6,660	15,330	32,620	5,810	7,940
Number of children	7,700	7,390	10,520	4,120	6,900	9,040	2,040	2,510
R-squared (within)	0.694	0.727	0.701	0.709	0.723	0.708	0.734	0.731
R-squared (between)	0.136	0.125	0.177	0.251	0.209	0.126	0.151	0.142
R-squared (overall)	0.286	0.296	0.289	0.292	0.297	0.301	0.301	0.295

*** p < 0.01, ** p < 0.05, * p < 0.1

Notes: Number of observations is rounded to the nearest 10. Standard errors in parentheses are adjusted using Huber-White covariance matrix estimate. Fixed-effects control variables include the child's age (in months), household income (not for income subgroups), parent types, and survey round of data. Body Mass Index and all prices are in log scale.

Source: ERS estimates using data from the Early Childhood Longitudinal Study, Kindergarten Class of 1998-99 and the Quarterly Food-at-Home Price Database.

Implications

There are three main implications of our findings. First, they support the idea that food prices have small, but statistically significant effects on children's BMI. Lower prices for soda, starchy vegetables, and sweet snacks have likely led to increases in children's BMI. The reverse is true for some healthier foods such as lowfat milk and dark green vegetables. Others have found that lower real prices for fruits and vegetables predict lower weight (Powell and Bao, 2009; Auld and Powell, 2009) or a smaller gain in BMI for young school-age children (Sturm and Datar, 2005, 2008). By separating the price of dark green vegetables from higher calorie starchy vegetables, we find that the price effect is not the same for all vegetables.

A second implication of our analysis is that there may be a considerable delay between when prices change and measurable changes in children's BMI. That is, although changes in food prices might affect purchasing behavior immediately, effects on BMI are likely to take some time to appear, depending on the type of food. This finding highlights the need to have longitudinal data, allowing for individuals to be tracked over time and a rigorous examination of the longrun effects of changes in food prices on children's BMI and overweight status.

Third, these results highlight the fact that there are heterogeneous responses to changes in price, particularly across household income and the distribution of BMI. Larger effects among children in lower income households are consistent with economic theory that higher income households are less responsive to price. The finding of differences across the BMI distribution is consistent with Sturm et al. (2010), who found no average effect of State-level soda sales taxes on BMI, but a negative and statistically significant effect on BMI among children at or above the 85th percentile.

While lower food-at-home prices for some foods likely contribute to rising obesity rates, we cannot comment on the effects in comparison with other factors, such as prices of food-away-from-home, access to specific foods in schools, or availability of calorie content labels in restaurants and other eating places. Cross-sectional studies find that higher fast food prices are associated with lower adolescent BMI (Chou et al., 2008; Auld and Powell, 2009) and a lower probability of overweight (Powell et al., 2009).

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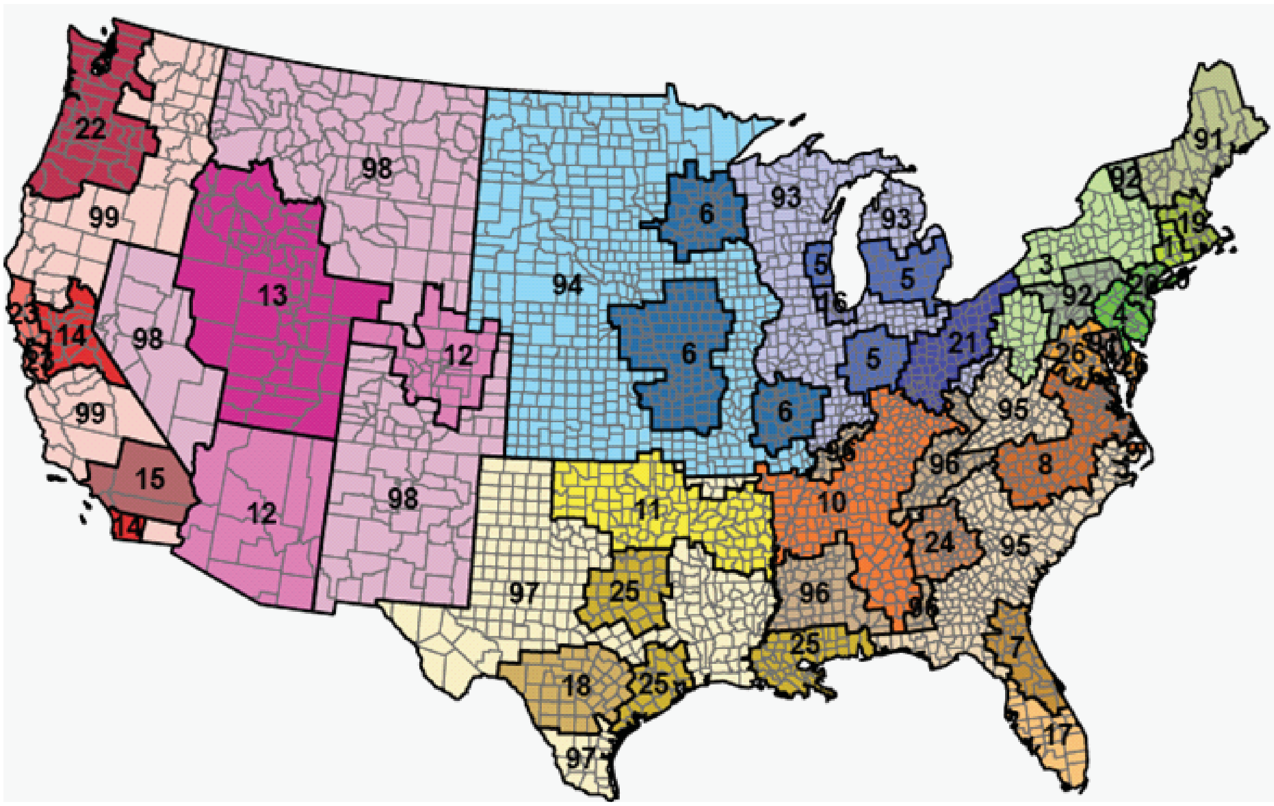
Appendix A—Quarterly Food-at-Home Price Database Market Groups, 2002-06



1 Hartford
2 Urban NY
3 Western NY/PA
4 Philadelphia
5 Metro Midwest1
6 Metro Midwest2
7 North Florida
8 Metro South 1
9 Baltimore
10 Metro South 2
11 Metro South 3
12 Metro Mountain
13 Salt Lake City
14 Metro California
15 Los Angeles
16 Chicago
17 South Florida
18 San Antonio
19 Boston
20 Other NY
21 Metro Ohio
22 North Pacific
23 San Francisco
24 Atlanta
25 Metro South 4
26 Washington, DC
91 Nonmetro New England
92 Nonmetro Middle Atlantic
93 Nonmetro East North Central
94 Nonmetro West North Central
95 Nonmetro South Atlantic
96 Nonmetro East South Central
97 Nonmetro West South Central
98 Nonmetro Mountain
99 Nonmetro Pacific

Notes: For 1999-2001, market 81 is composed of markets 91 and 92; market 82 is composed of markets 93 and 94; market 83 is composed of markets 95, 96, and 97; and market 84 is composed of markets 98 and 99.

Source: Todd et al. (2010).

Appendix B – Construction of the Thrifty Food Plan Weekly Cost

The Thrifty Food Plan (TFP) identifies quantities (in pounds) of foods as purchased that will allow an individual or family to consume a healthy diet (one that meets the dietary guidelines) at a low cost. The cost of the TFP is used to determine the maximum Supplemental Nutrition Assistance Program (SNAP) benefit, but is estimated at the national level only. Here, we document how we calculated the average cost of the TFP basket for a family of four (two adults, age 19-50, one child age 6-8 and one child age 9-11) for each quarter and an average for the year in each Quarterly Food-at-Home Price Database (QFAHPD) market group.

There is not a perfect correspondence between the TFP food categories and the QFAHPD categories. For example, the TFP includes fresh, frozen, and canned forms in its total pounds of dark green vegetables, while the QFAHPD includes market prices for fresh and frozen dark green vegetables and another set of prices for canned dark green vegetables. In such cases, we compute the national expenditure share on each form within a category. The price for the TFP category is then the weighted average of the QFAHPD prices, weighted by that national expenditure shares.

In other cases, the TFP identifies quantities for groups that are not identified in the QFAHPD (such as popcorn and other whole-grain snacks). In these cases, we use the QFAHPD price that is most similar (in this case, salty snacks) to serve as the price for the TFP category.

A few of the TFP categories that are not priced in the QFAHPD are excluded from our calculations of the TFP. These include coffee and tea, dry soups, and gravies, sauces, and condiments. A list of the comparisons is at the end of this appendix.

The TFP lists the pounds of each food category for various age/gender groups, from which we determine the total for our family of four. The total TFP weekly cost is simply the sum of the costs of each food category, calculated by multiplying the total pounds needed times the price per pound.

Since the QFAHPD provides average market group prices and not necessarily the lowest available prices, our estimates of the cost of the TFP may be higher than the minimum required to purchase a healthy diet. However, because the basket identifies a nutritionally adequate diet that meets the Dietary Guidelines, we feel that this metric is useful to compare costs of a fixed basket of foods over time.

Appendix table B1

Thrifty Food Plan (TFP) categories and corresponding Quarterly Food-at-Home-Price Database (QFAHPD) food groups

TFP category	QFAHPD food groups
Whole fruits	Fresh and frozen whole fruit; canned fruit
Fruit juices	Fruit juice
Dark green vegetables	Fresh and frozen dark green vegetables; canned dark green vegetables
Orange vegetables	Fresh and frozen orange vegetables; canned orange vegetables
All potato products	Fresh and frozen starchy vegetables; canned starchy vegetables
Other vegetables	Fresh and frozen other vegetables with select nutrients; canned vegetables with select nutrients; fresh and frozen other vegetables; canned other vegetables
Canned and dry beans/legumes	Fresh and frozen legumes; canned legumes
Whole grain breads, pasta, flours, cereals, and snacks	Whole grain packaged products; whole grain flours and mixes; frozen ready-to-cook whole grains
Refined grain breads, pasta, cereals, flours, pies, pastries, and snacks	Refined-grain packaged products; refined-grain flours and mixes; frozen ready-to-cook refined grains, commercially prepared baking mixes, ready-to-eat bakery items, commercially prepared packaged snacks
Lower fat and skim milk and yogurt	Lowfat and skim milk; low fat yogurt
Whole fat milk, yogurt, and cream	Whole and 2% milk, whole-milk yogurt; other whole-fat dairy products
Milk drinks and milk desserts	Frozen ice cream and other frozen desserts
All cheese	Lowfat cheese; regular fat cheese
Beef, pork, veal, lamb, bacon, sausages, and lunch meats	Fresh and frozen low-fat meat; fresh and frozen regular fat meat; canned meat
Chicken, turkey, and game birds	Fresh and frozen poultry; canned poultry
Fish and fish products	Fresh and frozen fish; canned fish
Nuts, nut butters, and seeds	Raw nuts and seeds; processed nuts and nut butters
Eggs	Eggs
Table fats and oils	Oils; solid fats
Soft drinks, sodas, fruit drinks, and ades	Carbonated soft drinks; noncarbonated fruit drinks and ades
Sugars, sweets, and candies	Raw sugars and sweeteners; packaged sweet snacks
Frozen or refrigerated entrees	Frozen entrees
Soups (ready-to-serve and condensed)	Canned soups and sauces

TFP categories not included in QFAHPD price estimate:
Gravies, sauces, and condiments
Coffee and tea
Soups (dry)