Food Prices and Obesity: Evidence and Policy Implications for Taxes and Subsidies

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Context: Pricing policies have been posited as potential policy instruments to address the increasing prevalence of obesity. This article examines whether altering the cost of unhealthy, energy-dense foods, compared with healthy, less-dense foods through the use of fiscal pricing (tax or subsidy) policy instruments would, in fact, change food consumption patterns and overall diet enough to significantly reduce individuals' weight outcomes.

Methods: This article examined empirical evidence regarding the food and restaurant price sensitivity of weight outcomes based on a literature search to identify peer-reviewed English-language articles published between 1990 and 2008. Studies were identified from the Medline, PubMed, Econlit, and PAIS databases. The fifteen search combinations used the terms *obesity*, *body mass index*, and *BMI* each in combination with the terms *price*, *prices*, *tax*, *taxation*, and *subsidy*.

Findings: The studies reviewed showed that when statistically significant associations were found between food and restaurant prices (taxes) and weight outcomes, the effects were generally small in magnitude, although in some cases they were larger for low–socioeconomic status (SES) populations and for those at risk for overweight or obesity.

Conclusions: The limited existing evidence suggests that small taxes or subsidies are not likely to produce significant changes in BMI or obesity prevalence but that nontrivial pricing interventions may have some measurable effects on Americans' weight outcomes, particularly for children and adolescents,

low-SES populations, and those most at risk for overweight. Additional research is needed to be able to draw strong policy conclusions regarding the effectiveness of fiscal-pricing interventions aimed at reducing obesity.

Keywords: Obesity, body mass index, food prices, taxes, subsidies.

I NCREASING POOR DIETARY BEHAVIORS, THE RELATED RISE IN obesity rates, and estimated obesity-related medical expenditures have raised the question of whether food taxes and/or subsidies could be used as policy instruments to curb the obesity public health crisis (Caraher and Cowburn 2005; Cawley 2004; Finkelstein et al. 2004; Jacobson and Brownell 2000; Kim and Kawachi 2006; Kuchler, Tegene, and Harris 2005; Leicester and Windmeijer 2004). The use of food pricing policies has received attention because the price of a calorie has been shown to be substantially cheaper when obtained from unhealthful, energy-dense foods, instead of from more healthful, less-dense foods (Drewnowski and Darmon 2005; Drewnowski and Specter 2004). The idea of using pricing policies to address obesity is to change the price of unhealthy, energy-dense foods relative to that of more healthy, less-dense foods, which, in turn, is expected to shift consumption patterns toward a more healthful diet and a healthier weight outcome. The question at hand is whether changes in food prices will alter dietary intake enough to have significant measurable effects on weight outcomes.

Americans consume too much dietary fat and sugar and not enough fruits and vegetables, and their intake of micronutrients does not satisfy dietary recommendations (Fox et al. 2001; Gidding et al. 2006; Krebs-Smith et al. 1996; Lin, Guthrie, and Frazão 2001; McDowell et al. 1994; Munoz et al. 1997; Pesa and Turner 2001). The intake of fats, snacks, sugar-rich foods, soft drinks, and fast foods is found to be associated with greater energy intake, higher body mass index (BMI), and obesity based on cross-sectional studies, prospective cohort studies, and feeding trials (Astrup 2001; Binkley, Eales, and Jekanowski 2000; Bowman and Vinyard 2004; Bowman et al. 2004; Bray and Popkin 1998; Lin and Morrison 2002; Ludwig, Peterson, and Gortmaker 2001; Malik, Schulze, and Hu 2006).

Recent statistics show that obesity (age- and gender-specific BMI $\geq$ 95th percentile) rates were 12.4, 17.0, and 17.6 percent among children

aged two to five, six to eleven, and twelve to nineteen, respectively, between 2003 and 2006 (Ogden, Carroll, and Flegal 2008) and 33.2 and 31.1 percent among adult females and males, respectively, in 2003 and 2004 (Ogden et al. 2006). Obesity-related medical expenditures were estimated to be $92.6 billion (in 2002 dollars), with taxpayers responsible for approximately one-half the costs through Medicaid and Medicare (Finkelstein, Fiebelkorn, and Wang 2003).

Food taxes in the United States are currently imposed mainly on such categories of food as soft drinks, candy, and snacks, the revenue from which in most jurisdictions goes into the general treasury (Chriqui et al. 2008). Similarly, a number of other countries, like Canada and Australia, impose general sales taxes, and the United Kingdom, Ireland, and other European Union countries impose value-added taxes on certain products such as soft drinks, snack foods, and sweets/confections (Caraher and Cowburn 2005; Leicester and Windmeijer 2004). The most recent comprehensive study of U.S. state-level food taxes, by Chriqui and colleagues (2008), shows that forty states impose sales taxes on at least one of soft drinks, candy, or snack items. For example, thirty-four states apply sales taxes to soft drinks; thirty states tax candy; twenty-nine states tax chewing gum; and fifteen states tax chips and pretzels. Sales taxes were found to be highest for soft drinks (mean = 3.43 percent in grocery stores and mean = 4.02 percent in vending machines), lowest for snack items (mean = 1.2 percent in grocery stores, and mean = 3.13 percent in vending machines) and were higher, on average, for items purchased from a vending machine versus a grocery store.

Food in the United States is subsidized for low-income individuals and families through a number of programs such as Food Stamps; the Women, Infant and Children (WIC) Nutrition Program; the Child and Adult Care Food Program; and the National School Lunch and Breakfast Programs. Subsidies for consumers generally are not for specific food items, although some food subsidies such as WIC can be used only for certain foods, and others are delivered through the provision of regulated foods such as school breakfasts and lunches. California recently passed legislation to conduct a "Healthy Purchase" pilot program targeting subsidies within the food stamp program, in which for each dollar of food stamps spent on fresh produce, participants would be subsidized a portion of the cost (Guthrie et al. 2007).

This article examines whether altering the cost of unhealthy, energy-dense foods relative to that of more healthy, less-dense foods through

the use of fiscal pricing (tax or subsidy) policy instruments would, in fact, change food consumption patterns and overall diet enough to significantly reduce individuals' weight outcomes. We look at the existing empirical evidence that assesses the extent to which we can expect food taxes or subsidies to result in changes in weight outcomes. We consider this question both theoretically and empirically. We begin by providing some background on the rationales for food-pricing interventions, evidence regarding the price sensitivity of demand to determine whether we may expect price changes to translate into weight changes, and economic models of the relationship between food prices and weight outcomes. We then synthesize and compare the results of a review of the empirical literature on the relationship between food and restaurant prices and weight outcomes. We conclude with a discussion of the potential barriers and challenges related to fiscal food policies and the policy implications of the existing research and suggestions for future research.

Background

The public health aims of improving individuals' diet and reducing obesity are key rationales for food-pricing interventions such as taxes and subsidies. Indeed, the risks to public health associated with obesity are numerous and have been well documented to include, for example, premature death, type 2 diabetes, heart disease, stroke, hypertension, gallbladder disease, osteoarthritis, sleep apnea, asthma, breathing problems, cancer, high blood cholesterol, complications of pregnancy, menstrual irregularities, hirsutism, stress incontinence, and depression (USDHHS 2001).

Pricing-policy interventions also are supported by economic rationales based on market failures (Cawley 2004; Finkelstein, Ruhm, and Kosa 2005; Kim and Kawachi 2006; Marshall 2000). Negative externalities resulting from significant health care costs of treating diseases and disabilities caused by obesity may be imposed in the form of higher private-group health insurance premiums and higher government expenditures by Medicaid and Medicare. Additional costs may result from productivity losses and reduced tax revenues. Some people also may have time-inconsistent preferences that would require interventions to capture internal costs. Also, some people may not appropriately discount the future costs of their behaviors; for example, it is difficult for children

to take into account the future consequences of their actions (Komlos, Smith, and Bogin 2004; Smith, Bogin, and Bishai 2005).

Similar efforts to improve public health and address market failures have led to government intervention using fiscal policies in other markets, most notably tobacco. Most tobacco use begins during childhood and adolescence, when young people have a poor understanding of the health consequences of its use and its addictive potential (USDHHS 1994). Even many adult smokers do not fully understand the health consequences of continued tobacco use and the health benefits of cessation (Slovic 2001). Consequently, a considerable amount of public and private resources must be spent to treat the diseases caused by tobacco use and the exposure to tobacco smoke that harms the health of non-smokers (USDHHS 2004, 2006). These market failures have been used effectively to support government interventions targeting tobacco use, including relatively blunt policies like higher taxes on tobacco products (Jha and Chaloupka 1999; Jha, Chaloupka, and Yurekli 2000; Warner et al. 1995).

The government's intervention in the food and beverage markets could be motivated by the public health crisis of obesity combined with market failures that have contributed to the health crisis. In this sense, individuals may not make optimal food consumption decisions which, in turn, results in higher weight outcomes. Evidence of the extent to which food consumption is in fact price sensitive motivates the possibility for using pricing policies, since in order for the pricing policies to affect weight outcomes successfully, food consumption must respond to prices. Price elasticities reflect the magnitude of such impacts and are defined as the percentage change in the outcome (such as food consumption or weight) resulting from a 1 percent change in price.

A number of studies have provided evidence for the extent to which we can expect changes in food prices to affect food consumption or purchases. Controlled laboratory experiments manipulating the prices of healthy, low energy–dense foods compared with unhealthy, energy-dense foods found that purchases of both types of foods by youths were price elastic (i.e., a 1 percent rise in price was associated with a greater than 1 percent reduction in purchases) (Epstein et al. 2006); purchases of low energy–dense food by mothers was inelastic (a 1 percent rise in price was associated with a less than 1 percent reduction in purchases); and the demand for high energy–dense food was roughly unit elastic (Epstein et al. 2007). Furthermore, a number of controlled field experiments suggest

that significantly lower prices would result in substantial increases in the consumption of healthful food. For example, a 50 percent reduction in high school cafeteria prices of fruit and salad led to a quadrupling of fruit sales and a doubling of carrot sales but no change in salad sales during the intervention period (French, Story, et al. 1997). A similar 50 percent price reduction in a university office building cafeteria led to a threefold increase in fruit and salad sales (Jeffery et al. 1994). An experiment that reduced restaurant prices of targeted low-fat items also showed a substantial increase in the sales of these items (Horgen and Brownell 2002). In vending machines, a 50 percent reduction in low-fat snack vending prices was found to increase the sales of low-fat snacks by 127 percent (French, Jeffery, et al. 1997) and, in a second study, price reductions of 10, 25, and 50 percent were associated with increases in low-fat snack sales of 9, 39, and 93 percent, respectively (French et al. 2001).

Cross-sectional analyses using scanner data on household purchases measured the price sensitivity of dairy products (Chouinard et al. 2007) and salty snacks (Kuchler, Tegene, and Harris 2005) and found that demand was generally price inelastic. In addition, several other cross-sectional studies used survey data (in particular, the 1987–1988 Nationwide Food Consumption Survey) and found that food expenditures were generally price inelastic, with the demand for some items approaching unit elastic (Huang and Lin 2000; Park and Capps 1997; Yen, Kamhon, and Shew-Jivan 2002). A recent cross-sectional study of adolescents found that the own-price effect for frequent fruit and vegetable consumption was only weakly statistically significant and inelastic but that higher prices for fast foods were significantly associated with greater fruit and vegetable consumption, though still price inelastic (Powell et al. 2007). When the impact of restaurant prices on a sample of adults was examined, caloric intake was not found to be statistically significantly related to restaurant prices generally, although fast-food versus full-service prices were not separately controlled (Rashad 2006).

Whereas price changes in controlled environments may produce relatively large consumption changes, their external validity is low; and overall diet may not change substantially if individuals compensate in uncontrolled environments. Even when based on nationally representative expenditure or survey data, statistically significant (inelastic or unit elastic) price elasticities of demand may not translate into significant

overall changes in diet or weight if individuals substitute lower-priced, energy-dense products. In this regard, evidence from reduced-form models that examine the direct effects of food prices on weight outcomes will help determine whether changes in food prices translate into changes in BMI or the prevalence of obesity.

Economists offer a framework in which obesity is consistent with rational, albeit less than fully informed, behavior. The demand for and production of health were established in an economic framework in which individuals seek to maximize utility (including health), subject to a number of constraints, including time and income (Grossman 1972). Applied to obesity (see details in Cawley 2004), individuals in such a framework engage in behaviors related to work, leisure, and home production; they produce and demand health and weight; and they also consume food that both directly and indirectly (through changes in weight and health) affects utility. Three constraints operate in this framework. First, the standard budget constraint is affected by income and prices. Second, time traded between leisure and a variety of production activities (including work) is constrained to the twenty-four hours in a day. And third, weight is constrained by biology, so that changes in caloric intake and energy expenditure affect weight. Outcomes like food consumption and activity decisions are derived from marginal costs and benefits.

The increase in obesity observed over the past few decades has been shown to be consistent within such a rational-choice model. The relative costs of food and physical activity have shifted over time, so that individuals' behaviors have correspondingly shifted toward less activity and more consumption of energy-dense food. For example, the declining real price of food and the relatively low cost and greater convenience of energy-dense foods, in particular, are hypothesized as key contributors to overweight, based on substantial reductions in the cost of consuming a calorie (Cutler, Glaeser, and Shapiro 2003; Drewnowski and Darmon 2005; Lakdawalla and Philipson 2002; Philipson and Posner 2003). At the same time, technological improvements are shown to have raised the costs of energy expenditure on the job, thereby contributing to increased obesity (Philipson and Posner 2003). Recent evidence based on cross-national data suggests that the rising rate of obesity is primarily the result of the overconsumption of calories associated with both technological innovations and changes in sociodemographic factors (Bleich et al. 2008).

In economic models, the demands for food products are functions of their own prices and the prices of other food products, the prices of other goods, income (purchasing power), and other factors that affect preferences, such as advertising. Changes in the relative price of different food products such as healthy versus nonhealthy items are expected to affect the relative demand for these products. Exogenous shocks such as taxes and/or subsidies that alter these relative prices can be expected to change consumption as well. However, the taxation of unhealthy, energy-dense foods will reduce weight only if individuals do not substitute nontaxed, high-calorie foods.

Furthermore, even in a simple two-good world with healthy, less energy–dense foods and unhealthy, energy-dense foods, it is not clear how changes in the relative price of such goods would affect weight. Auld and Powell (in press) presented a theory of the consumption of energy-dense and less-dense foods showing that aside from any changes in food expenditures caused by changes in food prices, changes in relative prices would change the intake of calories in a way that could be predicted solely by the relative cost of purchasing a calorie from high or low energy–dense 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 would decrease (increase) total caloric intake. This result would depend only on the convexity of indifference curves and not on any mechanism related to the physiological effects of energy-dense foods. As we noted earlier, it has been well established that a calorie can be purchased at a lower price if the food chosen is energy dense. The model predicts that increases in the price of energy-dense foods through taxation or decreases in the price of less energy-dense food through subsidies can be expected to lower body weight. This model is consistent with Cutler, Glaeser, and Shapiro's (2003) hypothesis that technological changes have lowered the relative full price of mass-produced, energy-dense foods and that the resulting changes in consumption patterns have contributed to higher levels of obesity.

Review of Empirical Evidence for Prices and Weight Outcomes

We conducted a literature search in September 2008 to identify English-language peer-reviewed articles published between 1990 and 2008,

using the Medline, PubMed, Econlit, and PAIS databases. Our fifteen search combinations used the terms *obesity*, *body mass index*, and *BMI* each in combination with the terms *price*, *prices*, *tax*, *taxation*, and *subsidy*. The search yielded a sample of 196 articles. The articles were reviewed by two people to determine their appropriateness for inclusion in our review, based on the criterion that the paper needed to provide peer-reviewed, original quantitative empirical evidence for the relationship between food prices (or taxes or subsidies) and body weight outcome measures using U.S. data. Of the 196 articles, forty-two used non-U.S. data, and just one, using Egyptian data, would have satisfied our criterion of providing empirical evidence for prices and weight outcomes. Next, we found that an additional twenty-seven articles focused on specific medical outcomes or topics tangential to our topic of interest. This left 103 articles, many of which examined either price-related or obesity topics but not both, and many did not provide empirical evidence. Hence, a total of six empirical articles met our search criterion. In addition, based on the authors' knowledge of the existing literature, particularly studies in press and available online, we included another three papers. Thus, the nine articles described in table 1 met our inclusion criterion and are analyzed as part of our literature review.

Table 1 summarizes the nine peer-reviewed studies that examine the relationship between food and restaurant prices or taxes and weight outcomes. Seven of the nine studies are cross-sectional, and two employ a longitudinal design. One study examines aggregate state-level obesity prevalence rates rather than individual-level weight outcomes. This literature is not vast, in part because of the limited availability of geographic price measures and geocode identifiers within individual-level data sets. In fact, six of the nine studies used food and restaurant price data drawn from the American Chamber of Commerce Researchers Association (ACCRA) Cost of Living Index reports, which provide quarterly information on prices in approximately 300 U.S. cities. One study used state-level soda and snack sales tax data, and two studies used county-level food prices drawn from the National Agricultural Statistics Service, USDA.

Several of the studies that examined children and adolescents found statistically significant effects of prices on weight outcomes. Using longitudinal data on children followed from kindergarten through third grade from the Early Childhood Longitudinal Study, Sturm and Datar (2005) found that changes in the children's weight were positively related to the

TABLE 1
Review of Evidence on Price Effects on Body Weight Outcomes

Author	Outcome Measure	Price/Tax Measure (Source)	Data Set	Population	Model	Results
Auld and Powell in press	BMI	Prices of fruits and vegetables and fast food (ACCRA)	Monitoring the Future Survey, 1997–2003	Adolescents in 8th and 10th grade (n = 73,041)	Cross-sectional	Statistically significant association between fast-food prices (−0.03) and fruit and vegetable prices (0.02) and BMI. Larger effects found at higher BMI quantiles, e.g., for males and females, the fast-food price elasticities were −0.10 and −0.11, respectively, at the 90th quantile and the fruit and vegetable price elasticities were 0.05 and 0.06, respectively, at the 95th quantile.
Beydoun, Powell, and Wang 2008	BMI and obesity	Prices of fruits and vegetables and fast food (ACCRA)	Continuing Survey of Food Intakes by Individuals, 1994–1996	Adults aged 20 to 65 (n = 7,331)	Cross-sectional	No statistically significant association between fast-food prices and BMI or obesity. No statistically significant association between fruit and vegetable prices and obesity. Statistically significant fruit and vegetable price elasticity for BMI of −0.11.

Study	Outcome	Prices/Measure	Data source	Sample	Design	Results
Chou, Grossman, and Saffer 2004	BMI and obesity	Full-service restaurant prices, fast-food restaurant prices, and prices of food at home (ACCRA)	Behavior Risk Factor Surveillance System, 1984–1999	Adults 18 years and older ($n = 1,111,074$)	Cross-sectional	Statistically significant full-service restaurant price elasticity for BMI (-0.021) and obesity (-0.667); statistically significant price of food at home for BMI (-0.039) and obesity (-0.622). Fast-food price elasticity for BMI (-0.048) and not statistically significant for obesity (-0.650).
Kim and Kawachi 2006	State-level obesity prevalence	State-level taxes on soft drinks and snacks	Behavior Risk Factor Surveillance System, 1991–1998	State-level averages of adults	Cross-sectional	Compared with states with taxes, weak statistical evidence that states that had repealed a soft-drink or snack-food tax were 13 times more likely to have a high ($> = 75$ percentile in the relative increase) relative increase in obesity prevalence. No statistically significant differences in obesity between states with no taxes and those with a tax or with at least a 5% tax.

(Continued)

TABLE 1—*Continued*

Author	Outcome Measure	Price/Tax Measure (Source)	Data Set	Population	Model	Results
Miljkovic and Nganje 2008	Overweight and obesity	Prices of sugar, potatoes, and whole milk (National Agricultural Statistics Service, USDA)	Behavior Risk Factor Surveillance System, 1991, 1997, and 2002	Adults 18 years and older ($n = 45,440$)	Cross-sectional	Higher current price of sugar statistically significantly associated with lower probability of obesity, and higher prices of potatoes and milk statistically significantly associated with higher obesity prevalence (based on a myopic addiction model controlling historical prices).
Miljkovic, Nganje, and de Chastenet 2008	Overweight and obesity	Prices of sugar, potatoes, and whole milk (National Agricultural Statistics Service, USDA)	Behavior Risk Factor Surveillance System, 1991, 1997, and 2002	Adults 18 years and older ($n = 55,550$)	Cross-sectional	Higher current price of sugar and whole milk statistically significantly associated with lower probability of obesity, and higher price of potatoes statistically significantly associated with higher obesity prevalence (based on a rational addiction model of controlling historical and future prices).

Powell et al. 2007	BMI and overweight	Prices of fruits and vegetables and fast food (ACCRA)	Monitoring the Future Survey, 1997–2003	Adolescents in 8th and 10th grade ($n = 72,854$)	Cross-sectional	Statistically significant price of fast-food elasticity of BMI (-0.04) and overweight (-0.59). Price of fruits and vegetables is positively but not statistically significantly related to BMI and overweight.
Sturm and Datar 2005	BMI changes	Price indices for meat, fruits and vegetables, dairy, and fast food (ACCRA)	Early Childhood Longitudinal Study, 1998–2002	Children K through 3rd grade ($n = 6,918$)	Longitudinal	Increasing the price of fruits and vegetables by one standard deviation raised BMI by 0.11 BMI units by third grade (implied fruit and vegetable price elasticity for BMI of roughly 0.05).
Sturm and Datar 2008	BMI changes	Price indices for meat, fruits and vegetables, dairy, and fast food (ACCRA)	Early Childhood Longitudinal Study, 1998–2004	Children K through 5th grade ($n = 4,557$)	Longitudinal	Increasing the price of fruits and vegetables by one standard deviation raised BMI by 0.09 BMI units by third grade and 0.18 units by fifth grade.

price of fruits and vegetables but not statistically significantly related to changes in meat, dairy, or fast-food prices. An increase in the price of fruits and vegetables by one standard deviation raised their BMI by 0.11 units by third grade (equivalent to a BMI price elasticity of approximately 0.05). Examining a number of subpopulations, Sturm and Datar found that children in poverty and those at risk for overweight were roughly 50 and 39 percent, respectively, more price sensitive compared with their nonpoor and not-at-risk counterparts.

In a second study, Sturm and Datar (2008) followed the children from kindergarten through third grade and on to fifth grade. The extended panel results confirmed their previous finding, that the children's BMI was sensitive to changes in fruit and vegetable prices. The more recent study estimated that one standard deviation increase in the price of fruits and vegetables increased the children's BMI by 0.09 units by third grade and by 0.18 units by fifth grade. These results suggest a consistent long-term effect of fruit and vegetable prices on children's weight outcomes.

Examining cross-sectional data on eighth- and tenth-grade adolescents, Powell and colleagues (2007) found that the price of fast food was weakly statistically significantly related to lower BMI levels among youths (elasticity of −0.04) and statistically significantly related to a lower probability of overweight (elasticity of −0.59). The price of fruits and vegetables was positively but not statistically significantly related to the youths' BMI or obesity. The substantially higher fast-food price elasticity for overweight compared with BMI suggested that individuals at the higher end of the BMI distribution were more price elastic, which motivated an additional study. Auld and Powell (in press) used quantile regression analyses to assess the differential relationship between fast-food and fruit and vegetable prices across the BMI distribution of adolescents. The BMI regression results showed that food prices were statistically significantly associated with higher BMI but that the effects were not large. The fast-food price elasticity for BMI was −0.03, and the price elasticity for fruits and vegetables was 0.02. The results from the quantile regressions, however, suggested that changes in food prices would have little effect on adolescents of normal weight but substantially larger effects on overweight teens (those above the 80th or so quantile of the conditional distribution of BMI). For males and females, the effects of the prices of fruits and vegetables and fast-food meals at the 90th or 95th quantile were found to be three to five times greater

than across the distribution as a whole. For example, for male and female adolescents, the BMI fast-food price elasticities were −0.10 and −0.11, respectively, at the 90th BMI quantile, and the BMI fruit and vegetable price elasticities were 0.05 and 0.06, respectively, at the 95th BMI quantile. These results suggest that taxes on fast food or subsidies for fruits and vegetables would have the greatest effect on reducing the weight of teens most at risk for overweight.

Focusing on adults, Chou, Grossman, and Saffer (2004) undertook cross-sectional analyses using data from the Behavior Risk Factor Surveillance System (BRFSS) and found adults' BMI to be statistically significantly negatively related to the price of full-service restaurants (elasticity of −0.02), fast-food restaurants (elasticity of −0.05), and food at home (elasticity of −0.04). Obesity prevalence was found to be statistically significantly related to the price of full-service restaurants (elasticity of −0.67) and the price of food at home (elasticity of −0.62) and negatively but not statistically significantly related to fast-food prices (elasticity of −0.65). Similar to Powell and colleagues' (2007) findings, these BMI and obesity elasticity results also suggest that heavier adults are more price elastic. This study did not distinguish fruit and vegetable prices within the food at home category, which may differentially (positively) affect weight outcomes.

Recently, two additional studies drew on the individual-level BRFSS data that were merged with county-level price data obtained from the USDA on sugar, potatoes, and whole milk to examine associations between current prices and overweight and obesity prevalence within a rational addiction model that controlled for historical and future prices (Miljkovic, Nganje, and de Chastenet 2008) and using a myopic addiction model that controlled historical prices (Miljkovic and Nganje 2008). In the first study, which included future prices, the authors found that individuals' weight was significantly negatively associated with the current price of sweet foods but that a future increase in the price of sweet foods was not associated with a current reduction in weight. In their second study, the authors argued that the myopic model was more appropriate and that such addicts were unable to exhibit self-control or rationalize their behavior and were unlikely to be able to predict changes in future prices and adjust their consumption (Miljkovic and Nganje 2008). The results from this study showed that a one-dollar increase in the current price of sugar (the addictive food product) was associated with a 0.20 and 0.33 percentage point reduction in the probability

of overweight and obesity, respectively. Based on the summary statistics provided in the paper, the marginal effects correspond to a current price of sugar elasticity of −0.20 for overweight and −0.81 for obesity. In addition, statistically significant large associations were found between the historical price of sugar and overweight, suggesting that the myopic model of addictive behavior explains food consumption habits and related weight outcomes. Overall, these results suggest that taxing high-sugar food items may have long-run significant effects on weight outcomes.

Beydoun, Powell, and Wang (2008) drew on the 1994–1996 Continuing Survey of Food Intakes by Individuals (CSFII) to examine the importance of fast-food and fruit and vegetable prices and found no evidence that taxes on fast food or subsidies for fruits and vegetables would improve adults' weight outcomes. Similar to the study by Chou, Grossman, and Saffer (2004), they did not find a statistically significant negative relationship between fast-food prices and obesity prevalence. However, they also did not find a statistically significant association with BMI. In addition, although lower fruit and vegetable prices were not statistically significantly associated with obesity, they were associated with higher BMI.

Finally, in their state-level study of food and beverage sales taxes and obesity prevalence, Kim and Kawachi (2006) found no statistically significant differences in obesity prevalence between states without taxes and those with taxes or those with at least a 5 percent tax. They did find weak statistical evidence (p-value $= 0.09$) that, compared with states with taxes, states that had repealed a soft-drink or snack-food tax were thirteen times more likely to have had a high (≥ 75 percentile in the relative increase) relative increase in obesity prevalence.

Overall, the studies we reviewed suggest that when statistically significant associations were found between food and restaurant prices (taxes) and weight outcomes, the effects were generally small in magnitude, although in some cases they were larger for low-SES populations and those at risk for overweight or obesity. Nonetheless, even though this emerging body of literature suggests some possible relationships between food prices and body weight outcomes, the studies are subject to a number of limitations. Most important, all but Sturm and Datar's two studies (2005, 2008) examining children used cross-sectional data, which limits our ability to draw conclusions about the potential causal relationship between prices and weight outcomes.

Another key issue in examining the effect of food and restaurant prices on weight outcomes is the importance of not confounding the potential price effects with those of other food-related contextual factors, such as the availability of food stores and restaurants, given that prices may be lower in areas with greater availability. Three studies (Auld and Powell in press; Sturm and Datar 2005, 2008) controlled for both local area restaurant and food store availability, and two other studies controlled for restaurant availability only (Chou, Grossman, and Saffer 2004; Powell et al. 2007). However, three of the studies that examined adults did not include any local area food-related outlet control measures (Beydoun, Powell, and Wang 2008; Miljkovic and Nganje 2008; Miljkovic, Nganje, and de Chastenet 2008), nor did the state-level aggregated study by Kim and Kawachi (2006). Furthermore, the aggregated state-level data that Kim and Kawachi (2006) used provide only broad associations based on outcomes and controls averaged over very large populations.

The individual-level MTF, BRFSS, and CSFII anthropometric data used in a number of the studies were based on self-reported data, which may have introduced measurement error and biased the results toward the null. Generally, most studies were able to control for a rich set of individual-level covariates, with some exceptions: the two studies using the adolescent MTF data were able to control for parental education but not income, which may have led to omitted variable bias. Finally, several of the cross sections of the individual-level data, particularly the CSFII data, are almost or more than a decade old, and these important relationships may be changing over time. Moreover, we saw evidence that heavier individuals may be more price sensitive, and indeed, the U.S. population's weight has been rising. In this regard, estimates based on older data may underestimate the overall price sensitivity.

As we noted earlier, the evidence for the effect of food prices on weight outcomes is limited partly because of the lack of available data on food prices. Owing to the national coverage of the ACCRA price data, the majority of studies we reviewed in this article used these prices, but these price data also have limitations. First, the ACCRA data are collected in larger cities and metropolitan statistical areas, and they do not provide price data at lower geographic units. Second, the collection of price data is based on establishment samples that reflect a midmanagement (a higher) standard of living. Taken together, these first two limitations can lead to considerable measurement error in cases in which the data are

matched to low-income or rural populations. Third, ACCRA does not always continuously sample the same cities, and hence the data are not fully comparable over time. Fourth, only a small number of food items are surveyed, and so the data are limited in their representativeness across food groups; for example, the prices of only seven fruits and vegetables were surveyed.

Discussion of Challenges for Fiscal Food Policy Interventions

In recent years, state governments have been introducing bills and enacting statutes that targeted childhood obesity but were limited mainly to school nutrition and physical education (Cawley and Liu 2008). A few states, however, have adopted broader-based policies, including pricing policies, aimed at curbing obesity in all segments of the population. The current body of empirical literature that we reviewed offers limited evidence that weight outcomes could be improved by using fiscal policies and that substantial price changes are needed to improve these outcomes significantly. Given this evidence, policymakers will face a number of challenges with regard to implementing food-pricing policies, especially taxes. These challenges are related to both the design and the potentially adverse effects of these policies, not to mention the politics of taxing food.

Even though food taxes could be based on nutrient content (i.e., fat taxes), it would be easier legislatively to tax specific categories of food, particularly those with low nutritional value (Caraher and Cowburn 2005; Jacobson and Brownell 2000). As we noted earlier, several "categories" of food items with little or low nutritional content, such as soft drinks, candy, snack foods, and fast foods, have been related to a greater prevalence of obesity. Nonetheless, some caution may be warranted when several items within a broad category like fast food are taxed; for example, higher beef prices have been shown to be associated with anemia (Lakdawalla, Philipson, and Bhattacharya 2005). Huang (1997) similarly found that higher beef prices were related to lower levels of iron but, conversely, would also reduce levels of saturated fatty acids and cholesterol. Beydoun, Powell, and Wang (2008) found that higher fast-food prices were associated with higher fiber intake, lower saturated fat, and better overall diet quality.

A common objection to food and beverage taxation on equity grounds is its regressive nature, since low-income individuals spend a higher proportion of their income on food (Frazão et al. 2007). A recent study showed the adverse distributional effects of a "fat tax" on low-income households (Leicester and Windmeijer 2004). However, if low-income individuals were more price elastic and/or consumed proportionately more of the taxed good, then they would derive greater benefits from the related reductions in consumption. To offset the regressive nature of food taxes, if the goal is to alter the prices of healthy compared with unhealthy foods, instruments in the form of subsidies may be called for on normative grounds, particularly if they could be targeted to low-income households, such as in the pilot project described earlier to subsidize fruits and vegetables for food stamp recipients. The revenue from these taxes could be used for subsidies to offset the potential regressive financial burden. The estimated cost of subsidizing fruits and vegetables by 10 percent for food stamp recipients (based on a caseload of 35.7 million) is $500 million (Lin and Guthrie 2007).

Note that when considering low-income populations, food purchases by low-income individuals under the federal food stamp program are exempt from state sales taxes. Therefore, low-income food stamp recipients do not pay these taxes on their food purchases made with food stamps, although they are estimated to pay about 29 percent of their grocery expenses with their own money (Guthrie et al. 2007). Accordingly, if the objective of the tax policy is to alter food consumption behavior, then the imposition of or increase in such taxes would be expected to have a relatively small impact on low-income food stamp recipients. Subsidies for healthful foods, however, are likely to be more successful for this population (Lin and Guthrie 2007). Alternatively, if extending food sales taxes (even specific taxes) to food stamp recipients is not feasible, then restricting products (i.e., no soda or candy) eligible for purchase with food stamps would effectively subject food stamp recipients to the targeted taxes.

Further challenges to the implementation of food taxes are likely to come from the general public, industry, and special-interest groups. Several polls indicate only moderate acceptance by the population for small taxes on soft drinks and snack foods when the revenues from these taxes would be used to fund health education and obesity prevention programs, whereas there is a large likelihood of opposition to these taxes by the food and beverage industries, convenience store associations, and

restaurants, among others (Caraher and Cowburn 2005; Finkelstein et al. 2004; Jacobson and Brownell 2000; Kim and Kawachi 2006). For example, only 33 percent of surveyed individuals supported a proposal to tax snack foods in order to subsidize policies aimed at promoting healthy eating (Oliver and Lee 2005). In another study that examined support for childhood obesity interventions, only 39 percent favored increasing the tax on fast foods and less healthy foods marketed to children, but 64 percent of respondents were willing to pay $50 a year more in taxes for more nutritious school lunches (Evans et al. 2005). A recent study, however, found the respondents willing to pay only $46.41, on average, for a substantial (50 percent) reduction in childhood obesity (Cawley 2008).

Some comparisons can be drawn from the states' successful experiences with tobacco taxation over the past two decades. Although tobacco products are well defined, clearly harmful, and relatively easy to tax, and it is much more difficult to pinpoint the problematic categories of food and tax them (or identify the good foods and subsidize them), the debates over tobacco tax increases encountered similar challenges (and several others). The tobacco industry and related interest groups invested considerable resources to defeat initiatives to raise tobacco taxes and strengthen other tobacco control policies. Arguments about the regressivity of tobacco taxes were addressed by demonstrating the potential progressivity of tobacco tax increases, owing to the greater price sensitivity of poor smokers and the use of revenues generated by the tax increases to support public insurance and other programs targeting low-income populations (Chaloupka et al. 2000). Some of these tax revenues have been earmarked for state tobacco control programs and have been found to reduce overall tobacco consumption and to reduce the prevalence of both youth and adult smoking (Farrelly, Pechacek, and Chaloupka 2003; Farrelly et al. 2008; Tauras et al. 2005). Moreover, public support for tobacco taxes, even by smokers, is considerably higher when some of the revenue from these tax increases would be used to support state tobacco control programs (Campaign for Tobacco Free Kids 2007). These programs typically include a mix of educational, regulatory, clinical, and other strategies that change social norms regarding tobacco, support cessation efforts by current smokers, and prevent potential smokers from starting (CDC 2007).

A number of studies have made the case for very small taxes on unhealthy food items in order to fund health programs aimed at reducing obesity (Jacobson and Brownell 2000; Kuchler, Tegene, and Harris

2005). The argument is that small taxes are more politically feasible and that on a broad base they could raise significant revenue. For example, a one-cent tax per 12-ounce soft drink would generate $1.5 billion per year, and a one-cent tax per pound on candy, chips, and other snack foods would raise an additional $70 million, $54 million, and $190 million, respectively (Jacobson and Brownell 2000). At first glance, the objectives of using tax policy to reduce the consumption of unhealthy foods and to raise substantial funds from a broad base to fund obesity reduction programs may seem at odds with each other, since any tax that successfully reduces the consumption of a given product would shrink the tax base. But because the existing taxes account for only a small share of the price and because estimates from nonexperimental studies generally show that the demand for these products is inelastic, increases in these taxes (or their adoption where they currently do not exist) are likely to generate substantial new revenues at the same time as they change consumption patterns.

Conclusions

Would fiscal pricing policies help reverse the obesity epidemic? If so, how high would the taxes or subsidies need to be to have a measurable impact on the weight of Americans? Based on the findings of the studies we reviewed, we estimated that small taxes or subsidies were not likely to produce significant changes in BMI or obesity prevalence but that nontrivial pricing interventions might have a measurable effect on Americans' weight outcomes, particularly those of children and adolescents, low-SES populations, and those most at risk for overweight. Even though they would have only a small impact on individual behavior, such interventions could have a large impact at the population level when applied broadly. The empirical evidence supports a multipronged approach, especially for children and adolescents, of changing relative prices by both taxing less healthy, energy-dense foods and subsidizing healthier, less-dense foods. As proxied by the prices of energy-dense fast foods and sugar, adolescents' and adults' weight was found to be price sensitive. Subsidies of fruits and vegetables also were estimated to improve children's and adolescents' weight outcomes. In addition to greater price elasticity estimates for heavier children, such subsidies were also shown to have greater effects on children from low-SES families. Hence,

subsidies directed toward low-SES households not only may change behavior and reduce weight but also may offset equity concerns related to food taxes.

Currently, state taxes on sodas and various junk foods are relatively low, and no state or local government has used these taxes to promote healthier eating and reduce obesity (Chriqui et al. 2008). The same was generally true for state cigarette taxes before the public became aware of the health consequences of smoking, when cigarette excise taxes were only a few cents per pack and revenue generation was their primary purpose. But as evidence accumulated about the health and economic consequences of tobacco use and as research demonstrated the effectiveness of higher taxes and prices in reducing tobacco use, governments have increasingly used these taxes to promote public health. Inflation-adjusted state cigarette taxes more than tripled, on average, from 1982 to 2007, contributing to a more than 160 percent rise in average cigarette prices during this period (Chaloupka, in press). In turn, these price increases have been credited with driving most of the recent declines in adult smoking prevalence (Levy, Mikolayev, and Mumford 2005).

No studies to date have linked tax data to individual-level data to derive BMI or obesity tax elasticity estimates. Future research should estimate the direct effects of these taxes on weight outcomes, especially analyses of soda taxes, since soda has no nutritional value and is found to be a key contributor to sugar intake (Guthrie and Morton 2000). Because youths and young adults consume the greatest number of soft drinks (Nielsen and Popkin 2004), if such elasticities are higher for them than among the general population, then we can expect to see more beneficial changes in these younger groups' behavior and related weight outcomes. This is particularly important because our food consumption patterns are less apt to change as we age and obesity has been shown to continue into adulthood. Again, this has been demonstrated for tobacco, in which young people have been found to be as much as three times more sensitive to cigarette price increases than are adults (Chaloupka, in press).

In sum, we need more research to build the evidence base; indeed, the existing evidence is both sparse and limited. In particular, studies that use longitudinal data or randomized experimental designs; those that draw on alternative sources for price data, such as food and beverage taxes; and those that include appropriate local area controls for confounding contextual influences, such as food store and restaurant availability, would provide stronger evidence for policymakers on the

potential effectiveness of using taxes and subsidies to improve weight outcomes. In addition, evaluations of pilot projects and experiments that subsidize healthful foods, especially for low-income populations, would contribute to the evidence base regarding fiscal interventions. As governments consider policy options, some are likely to use those interventions that reduced tobacco use, such as taxing unhealthy products and dedicating revenues from these taxes for obesity prevention programs. The experiences of those jurisdictions that adopted these interventions will provide natural experiments for new research on the effectiveness of these efforts in promoting healthy eating and curbing the obesity epidemic.

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