Experimental research on the relation between food price changes and food purchasing patterns: a targeted review

Experimental research on the relation between food price changes and food-purchasing patterns: a targeted review[1–4]

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ABSTRACT

One way in which to modify food purchases is to change prices through tax policy, subsidy policy, or both. We reviewed the growing body of experimental research conducted in the laboratory and in the field that investigates the following: the extent to which price changes influence purchases of targeted and nontargeted foods, total energy, or macronutrients purchased; the interaction of price changes with adjunctive interventions; and moderators of sensitivity to price changes. After a brief overview of economic principles and observational research that addresses these issues, we present a targeted review of experimental research. Experimental research suggests that price changes modify purchases of targeted foods, but research on the overall nutritional quality of purchases is mixed because of substitution effects. There is mixed support for combining price changes with adjunctive interventions, and there are no replicated findings on moderators to price sensitivity in experiments. Additional focused research is needed to better inform food policy development with the aim of improving eating behavior and preventing obesity. *Am J Clin Nutr* 2012;95:789–809.

INTRODUCTION

The obesity epidemic and growing evidence on the causal relation between poor diet and increased disease risk have led to renewed emphasis on public health strategies aimed at improving diet quality among children and adults. One strategy that has gained considerable attention is the use of targeted taxes, subsidies, or both to influence food purchases (1–6). Fiscal policy, including taxes and subsidies, has long been used to influence consumer behavior, largely operating through the economic principle known as the law of demand. This law states that, all other factors held constant, as the price of a good increases (or decreases), the quantity demanded of that good will decrease (or increase). This law was the driving force behind large increases in tobacco taxes and commensurate decreases in smoking rates (7–9).

A substantial literature has evolved that examines the extent to which price changes influence food purchasing. Price responsiveness is often measured by "own price elasticity," which is defined as the percentage change in quantity demanded that results from a given percentage change in price. In a review of 160 observational studies on the price-purchase relation for various food categories, Andreyeva et al (10) showed that the own-price elasticity for many less healthy food products is high. Food away from home, soft drinks, juice, and meats had elasticity estimates between 0.68 and 0.81. This suggests that taxes on these foods would significantly reduce their purchases. For example, soft drinks had an own-price elasticity of 0.79, suggesting that a 10% increase in soft drink prices would reduce their consumption by 7.9%. Elasticity estimates for healthier foods were only slightly lower: fruit had an estimated elasticity of 0.7, whereas for vegetables it was 0.58. This suggests that subsidies would also be effective in changing consumption of these foods.

Own-price elasticities do not account for potential changes in purchases of other food products that may result from a price change, changes that could offset some of the benefits of a reduction in purchases of the targeted/taxed product through a process of substitution (3, 11, 12). For example, Finkelstein et al (13) showed that the health benefits, in terms of reduced caloric intake, of a sugar-sweetened beverage tax are partly offset by an increase in purchases of other beverages. This substitution as a result of a price increase of a particular product, termed *cross-price elasticity*, is critical to consider if the goal is to improve overall diet quality. The ideal situation for an increase in price for a less healthy product A would be for the demand for product A to decrease, whereas the demand for the healthier alternative product B would increase. In this way, one would not have to discount prices for product B to increase purchases of this

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product. Substitution can also occur when discounts are offered for healthier foods (14). In the ideal situation, people would buy more of the healthier targeted foods and less of the less healthy foods that they had been eating. However, it is possible that people would use the savings from the discounted products to purchase other less healthy foods (11). Laboratory research has shown that more-impulsive people increase their purchase of less healthy, high-energy-dense foods when healthier foods are discounted in price (15).

Price changes represent one way to influence food-purchasing behavior, and there are other interventions that are being tested to improve shopping and nutritional characteristics of the diet. These include nutritional counseling (16) or point-of-purchase calorie and nutritional information (17). Although the evidence on these interventions is mixed as independent approaches to influence food purchasing, it is possible that these interventions add to or interact with price changes to improve purchasing and to influence health. This may be particularly important because some of the price changes that have been advocated are quite small (4, 18) and would likely have little impact on purchases but could generate funds for informational and educational programs (3, 18, 19). Showing additive or interactive effects with nonprice manipulations could have an important impact on public health, even if the price changes alone were too small to have a significant benefit.

The proximal dependent variable for price manipulation is purchases; most studies focus on this variable, and modifying purchases needs to be the first priority of a price change. Thus, decreases in the purchase of foods that are or could be taxed, such as soda, as well as increases in purchase of foods that could be subsidized or sold at a discount, such as fruit and vegetables, should occur after price manipulations. However, the goal of price changes should extend beyond modifying purchases of targeted products to improving overall dietary intake (12, 20), reducing weight gain (21) and obesity (22–24), and improving health (5, 11, 24). For example, Lakdawalla and Zheng (22) reviewed 13 observational studies examining the impact of food prices on body weight in children and adults. They generally reported that broad-based price increases lead to lower weight but that the relation is less clear when prices for specific foods are increased. Powell and Chaloupka (23) also reviewed observational research on price changes and obesity and concluded that small taxes or subsidies may not be associated with significant or meaningful changes in obesity and that large taxes would be needed to impact health.

One implication for using price changes to improve the quality of food purchasing, overall dietary intake, or health is that the price change interventions will affect all types of people equally. However, observational studies suggest that this is not the case. For example, taxes on specific foods may have a greater impact on low-income or less-well-educated persons who are more price sensitive (12, 20, 23), because these persons may reduce purchases of taxed foods more than would persons with higher income. Likewise, it has been argued that when foods are subsidized, people who are of normal weight and who are already interested in nutrition are most likely to benefit from these programs (25), and not necessarily the people who need the program the most. Moderators of sensitivity to price provide an idea of who will benefit the most from the price change intervention.

Observational studies can provide correlational evidence on the relation between food pricing policies, and there are many examples of studies that test potential effects of price changes on purchases or biological outcomes (3, 11–13, 20, 26). In the tradition of other biomedical research in obesity and weight-related disorders, observational studies are often used to generate hypotheses to be tested in experimental research, preferably by multiple randomized clinical trials (27). However, observational studies have limitations (22). First, price changes in one food may be the result of (or result in) price changes in other substitute or complementary foods. Second, it is difficult to disentangle whether food price changes are the cause or the effect of changes in consumer behavior. Estimating consumer responses to price changes requires that the changes be the result of changes in supply; however, that is often difficult to assess empirically. Although statistical techniques are available to adjust for potential biases in observational study designs, experimental study designs offer the strongest method of controlling such biases because the experimenter has full control over prices (22).

Experimental research provides a complementary approach to observational studies by allowing the researcher to manipulate prices directly. This technique ensures that the price changes are not a result of changes in demand, thus avoiding the primary shortcoming of the observational studies. Over the past decade, a series of experimental studies have been conducted that focus on the effects of price changes on food-purchasing patterns. The goal of this article is to review and synthesize the experimental literature and to set the stage for the next generation of experimental research. First, methodologic issues in experimental economics research are reviewed to provide a template for the evaluation of the empirical results from the reviewed studies. This review focuses on the following research issues: *1*) effects of price changes on food purchases and purchases of similar or complementary foods, *2*) the effect of price changes on nutritional quality, *3*) the interaction of price changes and complementary interventions on purchases, and *4*) moderators of response to price changes. The review concludes with recommendations for the next generation of experimental research on food pricing.

OVERVIEW OF EXPERIMENTAL ECONOMICS

The goal of this article is to review experimental research that can provide an evidence base for policy decisions that influence food purchasing, dietary intake, and health. In biomedical experimental research on obesity, randomized trials are considered the gold standard for creating an evidence base for evaluating interventions (27). The most stringent guidelines require replication of the experimental results to ensure reliability of the results before a particular intervention can be recommended (27). Our emphasis on experimental research is based on our belief that application of these standards to research on economic interventions will maximize the contribution of economic research to improving public health.

Two types of experimental designs have been used in experimental economic studies: between-subject and within-subject. In between-subject experiments, subjects (or experimental sites) are randomly assigned, and different interventions or control conditions are provided to subjects. For example, one study (16) randomly assigned shoppers to conditions in which

they either shopped as usual or were provided with discounts for purchases of fruit and vegetables. Consumer purchases and nutritional qualities of the purchases were measured over a year. A different type of experimental design would be to randomize different food-purchasing establishments to "sales as usual" and compare this with one of the experimental conditions (28). A major strength of randomized trials in which large numbers of subjects are randomly assigned is the ability to be confident that the groups are equal in most dimensions, whereas it is a challenge in experiments that randomize sites to interventions to ensure that randomized sites are in fact equal, so that any changes can be attributed to the experimental manipulations. A major strength of between-subject designs is that subjects in all conditions are participating in the interventions simultaneously, so that any natural trends that are occurring would affect subjects in all groups equally. In addition, the manipulations are completely independent of each other; the purpose of the study is therefore not clear to the participants, thereby diminishing demand characteristics.

A second type of experimental design is a within-subject design, in which the same subjects or populations of subjects participate in multiple experimental conditions. This can be done in laboratory experiments or in field experiments. For example, in laboratory experiments, subjects may participate in multiple sessions, with each session representing a different condition. This is the design used in experiments in which price changes were manipulated across sessions (14, 25, 29). Field studies also often use a within-subject design, in which multiple conditions are studied within a field or in a number of field settings. For example, an investigator may collect baseline data on shopping behavior, implement an intervention, and then return to baseline. Any differences in purchasing would be attributed to the intervention. Because the experiment manipulates conditions over time, it is possible that naturalistic changes may in part influence purchasing in that phase, which would compromise the attribution of effects to the intervention. The observation of a return to baseline purchasing when baseline experimental conditions are restored provides confidence that the observed changes during the experimental phase were in fact due to the experimental manipulation, and not to an uncontrolled variable associated with the experimental phase (30).

One of the strengths of experimental research is the opportunity to characterize individual differences and relate those individual differences to changes in purchasing treatment effects. This advantage includes both between-subject and within-subject designs. However, some experimental research may not track individual shopping and thus cannot examine individual differences in response to pricing manipulations. Consider a cafeteria that manipulates calorie information and prices across phases, with a baseline phase with usual prices and no calorie information, an intervention phase with reduced prices and calorie information, and then a return to the baseline phase. Many of the subjects regularly buy their meals in the cafeteria, and these same subjects may be sampled during all 3 phases of the experiment. However, it is also possible that the subjects are different in each phase, due to the timing of when the phases are introduced or due to additional variables that influence shopping in the cafeteria. It is possible that the discount intervention brings in a totally different set of subjects who participate only during the discount phase. If this did happen, the sample for the intervention would be substantially different from the sample in the 2 baseline conditions, which might compromise the attribution of changes to the experimental intervention. A stronger design would follow a cohort of individuals to examine within-person changes in food purchasing across experimental conditions rather than measure aggregate food purchases across conditions.

An important part of the research design is the choice of the dependent variable, and a variety of dependent variables have been studied. The majority of studies have appropriately focused on the effect of price changes on purchases of the items taxed or subsidized. Another set of studies used energy purchased or changes in specific nutrients as the dependent measure (14, 16, 31, 32). These studies provide a broader assessment of price changes, because they take into account nutrient changes that may occur for the foods that are taxed or subsidized. Measures of health can also be assessed, such as body weight or cardiovascular risk factors, for a health oriented assessment of a particular pricing intervention. This type of study, of which only one has been reported in the experimental literature (33), provides the most direct assessment of whether a pricing intervention can influence health. However, measures such as energy intake or foods purchased are more proximal to the manipulated variable and would be expected to change in response to the price change. Despite the enthusiasm often ascribed to price changes that influence health indexes such as body weight or cardiovascular risk factors (*see* references 6 and 24), there are many variables that may be influencing these factors so that it may be hard to expect one variable such as food price changes to have an observable effect.

Finally, there is often tension in experimental research between the internal and external validity of the experiment. Internal validity refers to the confidence that can be placed on attributing changes in the primary dependent variable to changes in the manipulated independent variable, whereas external validity refers to the confidence that the effects of the independent variable can be generalized to a large sample of participants. Controlled experimental settings, such as analog shopping environments, offer the strongest internal validity, may focus on a particular subject population, and prioritize high internal validity over external validity, whereas field studies may emphasize external validity or generalizing the results to broad populations. Although individual studies may have an emphasis on internal or external validity, there is no reason why a study cannot be strong in both aspects of validity by using a design that ensures confidence that the observed effect was in fact due to manipulation of the independent variable and with maximal generalizability to the population of interest. These introductory comments will be touched on as the experiments are reviewed, with the quality of the experimental designs being used to determine the quality of the evidence in the discussion.

STUDY SELECTION CRITERIA

We searched PsycInfo (http://www.apa.org/pubs/databases/psycinfo/index.aspx), PubMed (http://www.ncbi.nlm.nih.gov/pubmed), JSTOR (http://www.jstor.org/), and Google Scholar (http://scholar.google.com/) for original research articles that examined food and/or nonalcoholic beverage purchases as a function of price manipulation in at least one phase of their design. Searches that included various combinations of "health,"

"food," "beverage," "tax," "subsidy," "discount," "price elasticity," "food intake," "price change," and "demand elasticity" were used to identify relevant journal articles. Any peer-reviewed articles published in English between January 1980 and March 2011 that fit the criteria on the basis of title and abstract were reviewed for relevance. Studies that did not manipulate the price of food or nonalcoholic beverages, studies based on survey data, commentaries, essays, and editorials were excluded.

A total of 24 articles met the inclusion criteria. These articles are presented in **Table 1**. The articles are organized according to *1*) laboratory studies, *2*) cafeteria/restaurant studies, *3*) vending machine studies, and *4*) supermarket/farmers' market studies.

Laboratory experiments

Laboratory experiments provide the most experimental control, and thus the best internal validity of the research reported, but may have less external validity because participants are studied in analog contexts in which they purchase food. In all but one of the laboratory experiments (17) reviewed, the participants engaged in hypothetical purchases of products, often with a fixed hypothetical budget constraint. Hypothetical decision making means that consumers do not actually purchase the products but rather provide responses on what they would have purchased had these choices been available to them. This approach has a long tradition in behavioral economics research and, in many instances, has been shown to have strong external validity (48, 49).

Epstein et al (35) conducted experiments with the use of children and with children and their mothers (34) in an analog of a convenience store. In both studies, participants were provided with the opportunity to purchase healthier or less healthy foods across conditions in a within-subject design in which the prices of one type of food were increased or decreased while prices for the other type of food were held constant. In the first of 2 experiments, children aged 10–12 y could purchase a preferred high-energy-dense snack food or a preferred fruit or vegetable (35). Prices ranged from \$0.50 to \$2.50 in \$0.50 increments. For example, in one condition, the price of fruit and vegetables was constant at \$1.00, whereas the price of preferred snack foods ranged from \$0.50 to \$2.50. In the other condition, the price of preferred snack foods was constant at \$1.00, whereas the price of fruit and vegetables ranged from \$0.50 to \$2.50. Results showed that price changes influenced purchases of healthier and less healthy foods, and the changes were very similar. Thus, reducing the price of healthier foods increased purchases, whereas increasing the price of less healthy foods decreased purchases. The own-price elasticities of −1.01 and −0.921 for healthy and less healthy foods showed that the percentage increase in price was nearly exactly offset by a percentage decrease in quantity demanded.

In the second within-subject experiment (35), children were provided with either \$1, \$3, or \$5 to shop. Conditions were as follows: conditions in which there was an increase in prices for less healthy foods of 25% and 50% from the market prices, whereas the prices of healthy foods remained unchanged; a condition in which both types of foods were at market prices; and conditions in which the prices of healthier foods were reduced by 25% and 50%, whereas prices of less healthy foods remained at market prices. In this study, price changes again influenced purchases of healthier (apples, pretzels, yogurt, skim milk; own-price arc elasticity = −1.65) and less healthy (cookies, potato chips, pudding, cola; own-price arc elasticity = −2.11) foods, and children substituted healthier foods when the price of less healthy foods was increased (cross-price arc elasticity = 0.97). When the price of healthier foods was reduced, there was some reduction in purchases of less healthy food because children allocated more money for the healthy foods (cross-price arc elasticity = 0.49). In an experimental manipulation of money available to spend for food, the amount available interacted with food price to influence the purchase of substitute foods. When children had \$1 to spend, they substituted purchase of the alternative food when the price of the other type of food increased, but this did not occur when the children had \$3 or \$5 to spend, suggesting that the amount of money the child has to spend on food when shopping at a convenience store can influence whether they decide to substitute for other foods when the prices of favorite foods are increased.

The study of mother and child purchasing by Epstein et al (34) is unique in examining purchasing as a function of price changes in mothers and children. Because obesity runs in families (50, 51), food-purchasing behaviors may run in families. The same foods used in the first experiment of Epstein et al (35) were used in this study, and again it used a within-subject design across 5 purchasing conditions. Results showed both mothers and their children were sensitive to price changes in healthy and less healthy foods for the child: own-price elasticities for healthy and less healthy foods were −0.58, and −0.50, respectively, for children and −0.74 and −0.58, respectively, for parents. There was a significant relation between own-price arc elasticity for healthy ($\beta = 0.46$, $P < 0.001$) and less healthy ($\beta = 0.12$, $P = 0.036$) foods, because mothers and children responded in a similar fashion to price changes.

Epstein et al (14, 25) used an analog supermarket in which mothers shopped for their families from 68 common foods and beverages, which were equally distributed among high-calorie-for-nutrient and low-calorie-for-nutrient (52) foods. The first study (25) used a mixed design with price change (±25% of reference value) as a between factor and study income and price manipulation as within factors. Price increases influenced purchases of less healthy foods (own-price arc elasticity = −1.6) more than price decreases influenced purchases of healthier foods (own-price arc elasticity = −0.6). Once again, shoppers were more likely to substitute healthy foods when the price of less healthy foods increased (cross-price arc elasticity = 0.6), but they did not change purchases of less healthy foods when the price of healthy foods changed (cross-price arc elasticity = −0.06). In this study, mothers were provided with 2 levels of budgets for shopping, but neither level moderated the effects of the price changes. BMI did moderate the effects, because nonobese women were more sensitive to changes in prices of healthier foods and were also more likely to substitute healthy foods when the price of less healthy foods increased.

In a subsequent shopping study that used a within-subject design in which prices changed from ±25% of reference value, the focus was not only on purchases of specific foods but on overall energy and macronutrients purchased (14). In this study, price changes influenced the purchase of less healthy foods (own-price arc elasticity = −1.4) and healthier foods (own-price arc elasticity = −1.0). In addition, shoppers substituted healthy

TABLE 1
Characteristics of the experiments reviewed[1]

Authors	Setting	Primary dependent measure	Participants	Design	Results
Laboratory/analog experiments					
Epstein et al (34)	Analog convenience store	Purchases of food	Mother-child pairs (n = 10) Mothers Age: 39.9 ± 6.9 y[2] BMI (in kg/m^2): 28.9 ± 7.7 Children Age: 11.3 ± 0.8 y BMI: 20.0 ± 1.7 20% minority	Within-subject design: Price increased from \$0.50 to \$2.50 in \$0.50 increments; 5 trials in which prices of LED foods increased, whereas HED foods held constant; and 5 trials where prices of HED foods increased and LED foods held constant	Prices influenced purchases of mother and child for healthy and less healthy foods. Mother and child sensitivity to price changes were correlated for healthy and unhealthy foods.
Epstein et al (35)	Analog convenience store	Purchases of food	1: 10–12 y olds (n = 32) 47% females	Within-subject design: 1: Price increased from \$0.50 to \$2.50 in \$0.50 increments; 5 trials where price of LED food increased, whereas HED food held constant; and 5 trials where price of HED food increased and LED food held constant	1: Price influenced purchases of healthy and less healthy foods.
			2: 10–14 y olds (n = 20) 50% females 25% minority	2: Prices ranged from 50% to 150% of the reference value in 25% intervals; 5 trials where prices of LED foods increased from −50% to +50% of reference value, whereas HED foods held at reference value; and 5 trials where prices of HED foods increased from −50% to +50% of the reference value and LED foods held constant at the reference value; this was repeated for each of the 3 budget levels (\$1, \$3, \$5) for a total of 30 trials	2: Price influenced purchases of healthy and less healthy foods. Children substituted healthy for less healthy foods when price of less healthy foods increased and reduced purchase of less healthy foods when price of healthy foods was reduced. Income interacted with prices of less healthy foods to influence purchase of healthy foods, and income interacted with price of healthy and unhealthy foods to influence purchase of unhealthy foods.
Epstein et al (25)	Analog supermarket	Purchases of food	Mothers (n = 47) Age: 39.9 ± 5.5 y BMI: 28.1 ± 7.1 27.7% minority	Mixed design: between-subject factor was whether prices of HED or LED foods were changed; within-subject factors were price changes varying from the reference price to ±25% of	Price influenced purchases of healthy and less healthy foods, and mothers substituted healthy for less healthy foods when price of healthy foods increased.

(Continued)

TABLE 1 (*Continued*)

Authors	Setting	Primary dependent measure	Participants	Design	Results
				the reference price and 2 income conditions ($15/person, $30/person); order of income level was counterbalanced, and price manipulation was randomized; 3 trials at each income level where prices of either LED or HED foods increased, whereas prices of the other food (LED or HED) held constant for a total of 6 shopping trials	BMI interacted with price to influence demand for healthier foods: nonobese individuals were more likely to substitute healthier foods for less healthy foods when prices of less healthy foods increased and were more responsive to price changes of less healthy foods.
Epstein et al (14)	Analog supermarket	Change in number of calories purchased and in macronutrient composition of foods bought per family member	Mothers (n = 42) Age: 43.5 ± 6.7 y BMI: 31.3 ± 7.7 23.8% minority	Within-subject design: 12.5% and 25% subsidy on LCFN foods, 12.5% and 25% tax on HCFN foods, and reference value; 5 trials, one shop in each price condition, with the order of conditions counterbalanced	Subsidy conditions increased calories, fat, carbohydrates, and protein purchased and purchases of HCFN and LCFN foods. Tax conditions were associated with decline in calories, fat, and carbohydrates purchased and the decreased proportion of calories from fat and increased calories from protein purchased. Taxes increased LCFN purchases and decreased HCFN purchases.
Giesen et al (32)	Analog cafeteria	Calories purchased	College students (n = 178) 47% females	Mixed design: between-subject factors were budget ($10 or $20) and calorie information with random assignment to groups	Taxes reduced calories purchased, as did calorie information.
				Within-subject factor was 0%, 25%, or 50% tax on high-calorie menu items; 3 trials where subjects asked to purchase lunch in each menu price condition	Taxes interacted with calorie information to influence calorie purchases; taxes influenced purchases only in the no-calorie information condition. Restraint interacted with taxes and calorie information; taxes reduced calories purchased for all low-restraint individuals, whereas taxes reduced calories purchased for high-restraint individuals only when no calorie information was provided.

(Continued)

TABLE 1 (*Continued*)

Authors	Setting	Primary dependent measure	Participants	Design	Results
Giesen et al (15)	Analog online supermarket	Calories purchased; purchases of high-, moderate-, and low-energy-dense products	College students (n = 70) 76% females	Mixed design: between-subject factors were 50% tax or 50% subsidy and low and high impulsivity as assessed by the stop signal task; within-subject factor was purchasing at the usual price or at a modified price. Foods were taxed or subsidized on the basis of nutrient density; 33% of foods were taxed, 36% were subsidized	Taxes reduced calories purchased, subsidies increased calories purchased. More-impulsive individuals purchased fewer calories in tax condition, mainly from HED foods, and purchased more calories in subsidy condition, mainly from HED foods. More-impulsive persons reduced purchase of HED products more during the tax condition and increased purchase more during the subsidy condition. Less-impulsive persons were more likely to reduce purchases of LED foods when they were taxed and to increase purchases of LED foods when they were subsidized.
Harnack and French (36)	Analog fast-food restaurant	Energy of meals ordered	Adolescents and adults (n = 594) 40.6% male; 42.6% nonoverweight or obese	2 × 2 factorial design comparing value pricing (receiving more calories for less money as portion sizes increase) with similar pricing/ounce for portion size with or without calorie information; subjects ordered and received dinner from a fast-food menu	There were no significant effects of value pricing or calorie information.
Nederkoorn et al (31)	Analog online supermarket	Calories from HED and LED foods; calories from carbohydrates, protein, and fat	Internet users (n = 306) Age: 41.2 y BMI: 25.9 ± 5.6 76% females	Between-subject design: Random assignment to 50% tax on HED foods or reference prices; one trial shopping session	Taxes reduced purchases of calories, HED calories, and carbohydrates.
Yang and Chiou (29)	Analog cafeteria	Purchases of healthy or unhealthy beverages	Students (n = 108) Age: 19.6 ± 1.36 y 23% overweight 52% females	Mixed design Between-subject factor: random assignment to health claims or no health claims groups Within-subject factor: price change in preferred healthy or unhealthy	Price changes influenced purchases of healthy and less healthy beverages. Persons substituted healthy beverages when the price of less healthy beverages increased and substituted less healthy

(Continued)

TABLE 1 (*Continued*)

Authors	Setting	Primary dependent measure	Participants	Design	Results
				beverage from $1 to $3 in $0.50 increments; 5 trials where healthy beverage prices increased, whereas unhealthy beverage prices held constant; 5 trials where unhealthy beverage prices increased, whereas healthy beverage prices held constant	beverages when prices of healthy beverages were increased. Health claims interacted with price changes for healthy beverages: purchase of less healthy beverages was reduced when the price of healthy beverages was lowered more than without health claims; health claims interacted with price changes of less healthy beverages, increasing purchase of healthy beverages when the price of less healthy beverages was increased more than without health claims.
Cafeteria/restaurant experiments					
Block et al (37)	Cafeteria	Purchases of regular soft drinks, diet soft drinks, and zero-calorie water; other beverages	Hospital cafeteria (n = 154 respondents)	Within-subject design: 5 intervention phases: *1*) baseline, *2*) 35% tax on regular soft drinks, *3*) washout, *4*) educational campaign, and *5*) combination tax and education	Regular soft drink sales decreased by 26%; with education + tax, −36%. Diet drink sales increased by 20%; with education + tax, diet drink sales increased by 14%. 82% of individuals noticed the educational intervention, but only 18% noticed price changes; the largest effect was seen for regular soda drinkers.
Cinciripini (38)	Cafeteria	Food purchases	Students (n = 5542 individual observations)	Within-subject design: 7-phase intervention: *1*) baseline, *2*) caloric feedback, *3*) baseline, *4*) labeling highly nutritious food, *5*) baseline, *6*) token rebate ($0.10) for highly nutritious food, and *7*) baseline	Caloric feedback was associated with decreased carbohydrate and red meat intake. Labeling was associated with increased vegetable, soup, fruit, and low-fat dairy intake among obese individuals. Token system produced the most uniform behavior change; associated with sales of salad, vegetable, low-fat dairy, fruit, soups, chicken, fish, turkey; sales of high-fat desserts and sauces decreased with price reduction.
French et al (39)	Cafeteria	Fruit, carrot, salad purchases	Two high-school cafeterias n = 1431 (43% nonwhite) n = 1935 (7% nonwhite)	Within-subject design: 3-phase intervention: *1*) baseline; *2*) 50% subsidy on targeted	Fruit sales increased by 439.6%; carrot sales increased by 218.0%; there was a nonsignificant increase in salad sales of 9.6%.

(Continued)

TABLE 1 (*Continued*)

Authors	Setting	Primary dependent measure	Participants	Design	Results
				healthy foods, promotional signage; and *3*) baseline	There were no changes in customers or total dollar sales for á la carte purchases during price changes.
Horgen and Brownell (30)	Restaurant	Purchase of targeted items	Restaurant customers (n = 250 customer evaluations)	Within-subject design: 6-phase intervention: *1*) baseline, *2*) 20–30% subsidy on healthier foods, *3*) baseline, *4*) health messages, *5*) combination health message and subsidy, and *6*) baseline	Price decreases were related to higher sales for all targeted foods and were more effective at increasing purchases of healthier foods than health messages alone. There were no significant differences in daily sales by phase.
Jeffery et al (40)	Cafeteria	Purchases of salad and fruit per day	University cafeteria (n = 321 respondents) Age = 38.7 y 62% females	Within-subject design: 3-phase intervention: *1*) baseline; *2*) 50% subsidy on targeted healthy foods, healthy foods, selection increased; and *3*) baseline	Fruit and salad purchases increased ~3-fold during the intervention. Fruit purchases at follow-up were not significantly greater than those at baseline, but salad purchases remained significantly greater.
Lowe et al (2010) (33)	Cafeteria	Food purchases, energy purchased, energy from macronutrients, 24-h recalls, BMI, percentage of body fat, lipids, blood pressure	Two hospital cafeterias (n = 96) Age = 44.2 y; 46% minority; 81% females BMI: 29.7 ± 6	Between-subject design: random assignment to environmental change (healthier foods + food labels) or environmental change plus (healthier foods + food labels + education + 15–25% subsidy on LED foods)	Both groups decreased overall energy intake. In general, there was no differential effect of interventions on observed intake or on other measures.
Michels et al (41)	Cafeteria	Purchase of healthy and unhealthy foods	College cafeteria (no. unknown)	Within-subject design: 3-phase intervention: *1*) baseline; *2*) 20% subsidy on healthy foods, education on tables, blood pressure readings; and *3*) baseline	There was a 6% increase in consumption of healthy foods and a 2% decrease in consumption of unhealthy foods. Consumption of healthy foods increased by 17% at follow-up with maintenance of the 2% decrease in unhealthy food consumption. There was no significant change in total calories or number of servings purchased.
Vending machine experiments					
French et al (42)	Vending machine	Purchase of low-fat and regular snacks	9 vending machines at a university	Within-subject design—3-phase intervention: *1*)	Price reductions increased purchases of healthier options.

(Continued)

TABLE 1 (*Continued*)

Authors	Setting	Primary dependent measure	Participants	Design	Results
				baseline; *2*) 50% reduction in price for healthier foods, promotional signage; *3*) baseline	The percentage of low-fat snacks went from 25.7% to 45.8% of the snacks purchased, with an increase in low-fat snacks of 126.8%. Total snacks purchased did not change with the intervention.
French et al (28)	Vending machine	Purchase of low-fat snacks, net profit, total product volume	Workers and high-school students (n = 12 worksites, n = 12 schools)	Between-subject design: sites randomized by location (workplace, school) × price (0%, 10%, 25%, 50% subsidy for low-fat snacks) × signage (no sign, low-fat label, low-fat label + promotional sign)	Price reductions of 50%, 25%, and 10% led to 93%, 39%, and 9% increases, respectively, in purchases of low-fat snacks. Low-fat snack promotion was associated with increased sales. Subsidies were associated with greater sales volume; profits were not negatively affected by promotions.
French et al (43)	Vending machine	Proportion of healthy compared with less healthy entrée, snacks, beverage purchases	Employees at 4 bus garages Age = 47 y, BMI = 32.3, 63% nonminority 21% women	Between-garage design: usual vending machines compared with increased selection of healthy foods + 10% subsidy for healthier food items (50% of foods)	Compared with control garages, there was a relative increase in healthy snack purchases (48% of total vs 6% of total), healthy cold-beverage sales (54% vs 40%), and healthy frozen foods (24% vs 14%).
Supermarket/farmers' market experiments					
Anderson et al (44)	Farmers' market	Attitudes about buying, preparing, and eating fruit and vegetables; redemption of coupons; and number of fruit and vegetables consumed	WIC participants (n = 564 completed pretest, n = 455 completed posttest) Age = 29.5 y, 49.4% nonminority	Between-subject design: $20 discount coupons for fruit and vegetables, education about storage and nutrition, education + $20 coupons, control	There was a significant effect of education on attitudes and beliefs about fruit and vegetables. There was a significant effect of discount coupons on measures of fruit and vegetable consumption.
Kristal et al (45)	Supermarket	Purchases and consumption of fruit and vegetables	Eight supermarkets (n = 120 respondents) 84% female	Between-supermarket design: 4 stores randomized to informational signage + flyers + 50-cent coupons for fruit and vegetables + food demonstrations, 4 stores as control	There was no significant finding of intervention effects on purchases or consumption of fruit and vegetables.

(Continued)

TABLE 1 (*Continued*)

Authors	Setting	Primary dependent measure	Participants	Design	Results
Herman et al (46)	Supermarket and farmers' market	Consumption of fruit and vegetables	602 mothers enrolled in WIC Age: 27.5 ± 5.8 y BMI: 28.1 ± 5.0 89.1% Hispanic 5.9% African American	Nonequivalent control group design with mothers assigned to $10/wk vouchers for fruit or vegetables at a supermarket or farmers' market or to a control group given vouchers for diapers	Vouchers increased fruit and vegetable consumption compared with controls at both supermarkets and farmers' markets. Intervention effects were primarily due to increases in vegetable purchases. Intervention effects were maintained at follow-up.
Ni Mhurchu et al (16) Blakely et al (47)	Supermarket	PESF in supermarket purchases; total fat, protein, carbohydrates, energy density, sodium, sugars; and total quantity of healthier foods purchased	Primary household shoppers (n = 1104) Age = 44 y 86% female	Between-subject design: between factors were random assignment to usual shopping, 12.5% subsidy (discount) on healthier foods, tailored nutrition education, discount + nutrition education	There was no significant difference in PESF between groups; neither price discount nor tailored nutrition education had a reliable significant effect on PESF or on major nutrients; the increase from baseline in amount of healthier foods purchased was significantly greater for those receiving 12.5% discounts than for those not receiving discounts. There was little evidence of variation in intervention effects by ethnicity or socioeconomic status except by ethnicity for the price decrease for healthier food purchasing and PESF at 6 mo.

[1] HCFN, high calories for nutrients; HED, high-energy-density; LCFN, low calories for nutrients; LED, low-energy-density; PESF, percentage of energy from saturated fat; WIC, Supplemental Nutrition Program for Women, Infants, and Children.

[2] Mean ± SD (all such values).

foods for less healthy foods when the price of less healthy foods was increased (cross-price arc elasticity = 0.22) and increased purchases of less healthy foods when the price of healthier foods was reduced (cross-price arc elasticity = −0.68). Foods were categorized as healthy or less healthy on the basis of their calorie-for-nutrient score, which uses nutrient profiling to set price policy (52). In general, when healthier foods, as defined by calories per nutrient, were reduced in price, a significant increase in calories was observed, whereas when prices of less healthy foods increased, a significant decrease in calories was observed. Taxing less healthy foods resulted in a reduction in purchases of dietary fat and an increase in protein. These results suggest that when mothers saw lower prices for healthier options they increased their purchases of these foods, but they also used the savings to buy more unhealthy items. As a result, whereas price increases for less healthy foods result in reductions in calories, subsidizing healthy foods may result in a net increase in calories. BMI did not moderate the effects of price changes. One limitation of the study design was that subjects were encouraged to spend all or almost all of the money available to them, which may have caused shoppers to purchase unhealthy foods in the condition in which healthier foods were subsidized. It is possible that without that stipulation shoppers would have spent less and saved money when healthier foods were subsidized.

Two experimental studies were conducted in an analog of a cafeteria: Giesen et al (32) studied lunch purchases, and Yang and Chiou (29) studied beverage purchases. Giesen et al randomly assigned participants to 4 groups with budget (high/low) and calorie information (information/none) as between factors and price manipulation (0%, +25%, +50%) as a within factor. Results showed that price changes were more effective than calorie information in reducing calories purchased but that price changes had almost no effect on calories purchased when caloric information was available. In analyses of moderators, dietary restraint interacted with taxes and calorie information. For low-restraint participants, taxes lowered calories purchased; but for high-restraint participants, taxes lowered calories purchased only when no calorie information was provided.

Yang and Chiou (29) used a mixed design to study the effects of price changes and health claims on purchases of healthy and less healthy beverages. The within-subject factor was price change, whereas the between-subject factor was health claims. An example of a healthy beverage was unsweetened green tea, whereas an example of a less healthy beverage was sweetened iced tea. They showed price influence purchases of both healthier and less healthy beverages (own-price elasticities = −0.93 and −0.91, respectively). In addition, moderate levels of substitution were observed when prices of less healthy beverages (cross-price arc elasticity = 0.69) or healthier beverages (cross-price arc elasticity = 0.53) increased. An interaction of health claims and price was observed, but unlike Giesen et al (32) they found the effect of price changes was greatest when health claims were present.

Nederkoorn et al (31) asked people to purchase foods in an analog to an online grocery store, which contained 708 foods and beverages, when prices were neutral or when high-energy-dense foods were increased by 50% in a between-subject design. Price increases were applied to approximately one-third of the foods in the grocery store. Results showed that a 50% price increase resulted in a reduction in calories of 16%. The price increase also reduced purchases of carbohydrates. Neither BMI nor income moderated the effect of taxes on calories or macronutrients purchased.

Giesen et al (15) studied the moderating effect of impulsivity on online supermarket purchases of calories and low-, medium-, and high-energy-dense foods when foods were purchased at usual prices or with a 50% tax or 50% subsidy on the basis of energy density. Impulsivity has been shown to interact with hunger to predict caloric purchases in an online supermarket (53), but the moderating effects of impulsivity on price sensitivity were not known. Results showed that people reduced purchases of calories when foods were taxed and increased purchases of calories when foods were subsidized, which is consistent with previous research (14). In addition, more-impulsive people were more sensitive to both taxes and subsidies in terms of total calories purchased and high-energy-dense foods purchased. Less-impulsive people did not show overall changes in calories or high-energy-dense foods purchased when foods were taxed or subsidized. On the other hand, less-impulsive people increased purchases of low-energy-dense foods when they were subsidized and reduced their purchase of these foods when they were taxed. The authors suggested that taxes would result in optimal food purchasing for more-impulsive people, whereas less-impulsive people would benefit more from subsidies of lower-energy-dense foods.

Harnack and French (17) studied the effects of value pricing and calorie information in a 2 × 2 factorial design on energy purchased in an analog of a McDonald's. Although the experiment was conducted in an analog of a fast-food restaurant, participants were led to believe that they were actually purchasing the food, increasing the external validity of the study. The importance of testing value size pricing, in which the customer can buy a larger portion for relatively less money, is that customers may buy and consume larger portions because they appear to be saving money, even though the larger portions may contribute to overeating and obesity. Results showed no effects of value size pricing or calorie information on energy purchased.

Summary of experimental laboratory and analog studies

The experimental studies have addressed each of the primary aims of the review. Several of the studies examined patterns of substitution when prices were changed. Research did show the substitution of healthier foods when prices of less healthy foods were increased and a reduction in purchases of less healthy foods when prices of healthier foods were reduced. These results are very relevant to informing policy decisions, but the pricing manipulations did not selectively tax or subsidize specific foods. Rather, pricing manipulations were implemented on the basis of the characteristics of foods, such as energy density (31) or calories per nutrient (25). Under these experimental conditions, it is impossible to substitute another unhealthy food for one that is taxed, because these substitute foods would also be taxed. This is very different from taxing a specific type of food, such as soda, which may be associated with the substitution of other unhealthy drinks or sources of sugar. Whereas these data may not provide information relevant to current ideas about taxing policy, these studies provide an alternative approach to taxing that warrants future consideration in field studies.

Several studies have measured changes in nutritional characteristics of foods purchased in addition to the more typical changes in purchases. In each case, price changes resulted in improvements in nutritional characteristics of foods purchased (14, 31, 32). Perhaps the most notable finding in regard to taxing nutritional characteristics of food is that taxes resulted in a reduction in energy purchased, whereas subsidies increased energy purchased (even for healthy foods, such as fruit and vegetables), which would favor taxes as a strategy to reduce obesity (14, 15). There are several characteristics of the studies that warrant consideration. One of the studies (14) required subjects to spend all or most of their money, which may have resulted in subjects purchasing more high-energy-dense foods than they normally would have even if healthier foods were discounted; the other study had college students shopping for one day for groceries (15). Both studies used nutrient-profiling methods to change prices, rather than tax individual foods, so more research comparing taxes and subsidies on total calories purchased is needed.

Three studies examined the interaction of additional interventions with price changes, and the effects were mixed. Yang and Chiou (29) found that health claims had the largest effects when combined with price changes. The effects increased purchase substitution, with greater increases in healthier beverage purchases when prices of less healthy beverages increased, and greater increases in purchases of less healthy beverages when prices of healthier beverages increased. Giesen et al (32) showed that both price changes and calorie information independently reduced energy purchases overall, but calorie information did not add to the effect of price increases to further reduce energy purchased. Harnack et al (36) did not find an independent effect of calorie information on food purchases, and calorie information did not interact with value pricing to influence purchasing.

Finally, several studies measured moderators of sensitivity to price. In one study in children, the amount of money available was related to substitution of healthier for less healthy foods when the price of less healthy foods was increased (35). That finding was not replicated in a second study in which money available to participants for food purchases was manipulated between groups (25) and did not occur when natural variations in income were used as moderators of price sensitivity. BMI moderated sensitivity to price and cross-price elasticity in one study (25), but that effect was not replicated in 2 other studies (14, 31). One study showed that dietary restraint interacted with taxes and calorie information to influence purchasing (32), with restraint limiting the effects of taxes when calorie information was presented. Impulsivity has been shown to interact with hunger to predict total calories purchases (53), and impulsivity moderates the effect of both taxes and subsidies on food purchases (15). Research suggests that more-impulsive people would benefit more from taxes, and less-impulsive people would benefit more from subsidies (15).

The laboratory research focused more on internal than on external validity, and many of the studies used relatively small sample sizes. However, 3 of the studies had relatively large sample sizes: there were 178 subjects in a study in an analog cafeteria (32), 306 subjects in an analog of an online grocery store (31), and 594 subjects in an analog of a McDonald's (36). The randomized studies ensured that groups were equivalent at baseline, and several studies sought to study samples that were representative of usual shoppers (31, 36).

Cafeteria and restaurant experiments

Cafeteria and restaurant studies have the advantage of external validity in that they are implemented in working cafeterias and restaurants. Thus, there is less concern about whether the interventions will work in the "real world" than is the case for laboratory experiments. However, these studies typically do not have individualized information about the shoppers, and as such, cannot study individual-level moderators of food purchasing.

Cinciripini (38) studied people in a university cafeteria across calorie information, labeling, and monetary rebate phases in a within-subject design for purchasing healthier foods ($0.10/ for each purchase of healthy food). Each of the 3 experimental phases was separated by a return to baseline. Results showed that the token rebate system increased purchases of healthier foods (salad, vegetables, fruit, low-fat dairy, soups, chicken, fish, and turkey), whereas purchases of less healthy foods (high-fat foods, desserts, and sauces) decreased. Whereas calorie information was associated with the greatest reductions in red meat and carbohydrate purchasing, the token rebate had the greatest effect on purchases and was effective across all participants; the labeling intervention was effective only for subgroups of participants.

Jeffery et al (40) and French et al (39) implemented pricing studies in university (40) and high-school (39) cafeterias. Jeffery et al (40) studied sales of fruit and salads as a function of a 50% subsidy on these purchases in a university cafeteria by using a baseline, subsidy, baseline design. Sales of these products increased 3-fold, with a return to baseline levels of purchasing after removal of the subsidy. French et al (39) studied fruit, carrot, and salad purchases across 2 high-school cafeterias in which these foods were highlighted as healthy and were subsidized by 50% by using a baseline, subsidy, and return to baseline design. Results showed increases in purchases of fruit by 439.6%, increases in carrot sales by 218%, and salad increases by 9.6%. When the subsidy was removed, purchasing returned to baseline levels, increasing confidence that the changes were due to the subsidy.

Block et al (37) studied the effects in a hospital cafeteria of a 35% increase on the price of regular soft drinks along with an educational campaign that indicated weight loss that could occur by reducing sugar-sweetened soda intake, suggesting diet soda or water as substitutes, on sales of sugared soft drinks, diet soft drinks, and zero-calorie water and sales of other beverages. Phases were baseline, price increase on soft drinks, baseline, educational campaign, and education plus price change. Regular soft drink sales decreased by 26% with the price increases and decreased by 36% in combination with the educational campaign. Substitution effects were observed, because diet drink purchasing increased by 20% for price change alone and by 14% for price change plus education. Sugary water sales (eg, SoBe Lifewater) and juice sales decreased and coffee sales increased during the combination phase. Soda purchases did not return to baseline after the first price manipulation, but this may be a function of the short time duration of the phases (2 wk), because soda purchasing increased from baseline during the education phase.

Horgen and Brownell (30) studied the influence of a 20–30% subsidy of healthier foods along with health messages in a restaurant. Conditions included baseline, price decrease, baseline, health message, health message plus price decrease, and return to baseline. Price decreases generated higher sales for subsidized foods and were more effective than health promotions alone. For example, sales of chicken sandwiches, chicken salad, cups of soup, and bowls of soup increased by 612.7%, 130.3%, 127.1%, and 157.1%, respectively, during the price-decrease phase. Sales increased more for foods that had their prices changed during the price-reduction phase than during the health message phase. In addition, there was no benefit to the combination of health message plus price reduction compared with price reduction alone, and the authors suggested that health messages may reduce the effects of price reductions.

There were 2 additional studies identified in cafeterias that included price changes as part of multicomponent interventions. Lowe et al (33) studied the introduction of healthier food products, education, and food labels plus a 15–25% subsidy for low-energy-dense foods on food purchases in hospital cafeterias. Subjects were studied during a 3-mo baseline and a 3-mo comparison of interventions and underwent follow-up measurements at 12 and 18 mo. Subjects were randomly assigned to one of two conditions. The Environmental Change (EC) group was exposed to new, lower-energy-dense foods and nutrition labels on all foods. In addition to what the EC group experienced, the EC+ group also received nutrition education and financial discounts on the basis of energy density, with 15% discounts for low-energy-dense foods (0.6–1.5 kcal/g) and a 25% discount for very-low-energy-dense foods (<0.6 kcal/g). Subjects had to eat in the hospital cafeterias at least twice per week, and 96 subjects began the experiment. Unfortunately, attrition was relatively high, with a dropout rate of 19.8% at the end of the intervention and 42.7% at the final follow-up. This study was unique in that individuals were recruited to participate, so that food purchased in the cafeteria as well as usual intake, weight, lipid, and blood pressure changes were all monitored. Results showed no differential effects of their interventions, because subjects in both groups reduced energy intake and percentage of energy from fat, whereas percentage of energy from carbohydrates increased. Thus, no effects of education about energy density or price reductions for low-energy-dense foods were observed, with the implication that providing food labels corresponding to energy density was the main influence on energy intake.

Michels et al (41) studied changes in food purchases of healthier (salad bar, stir-fried dishes, Saluté entrée, whole-grain pizza, yogurt, and fruit) and less healthy (regular entrée, regular pizza, hamburger, hot dog, French fries, cookies, cakes, and desserts) food options in a college cafeteria as a function of a 20% subsidy on healthy foods, educational materials on the tables, and blood pressure readings. Phases included baseline, combined intervention, and return to baseline. Results showed a 6% increase in consumption of healthy foods and a 2% reduction in consumption of unhealthy foods during the intervention. However, after return to baseline, the purchase of healthy foods increased further to 17%, with no change in the purchase of less healthy foods. The further increase in purchasing after removal of the combined intervention suggests that the nutrition education learned during the combined intervention facilitated maintenance, because if the active component of the intervention was the price change, purchases would have returned to baseline levels.

Summary of experimental cafeteria studies

Only one of the cafeteria studies examined substitution effects (37), and that study showed the substitution of healthier beverages when soda was taxed. There was no suggestion that subjects substituted other sugared beverages such as sugared water when the price of soda increased. Only one of the cafeteria studies assessed nutritional characteristics of foods, and this study did not show any benefits for pricing, although it was not possible to isolate pricing effects due to the combined interventions (33). The study by Lowe et al (33) is notable for collecting health data in addition to purchasing and nutritional data.

Several studies combined price changes with other interventions, and in 2 of the studies there were price-alone phases as well as price changes plus complementary interventions, which provide the opportunity to compare additive effects of adding complementary interventions. Horgen and Brownell (30) did not show that adding health messages improved purchasing more than did price changes alone, and these investigators suggested that health messages may have compromised effects of pricing alone, which is similar to the effect of calorie information in the experimental research by Giesen et al (32). Block et al (37) showed enhanced effects of the combination of calorie/health messages plus price changes compared with price changes alone. There was only one study that collected individual difference information, and that study did not report any moderation of experimental conditions, although the design did not permit the assessment of individual differences as a moderator of sensitivity to price (33).

The cafeteria studies are very strong in regard to external validity, because they were implemented in working cafeterias. The investigators used innovative within-subject designs to assess the effects of price changes, and in all studies except for one conditions returned to baseline, which provides confidence that the observed changes were due to the experimental interventions. The study by Lowe et al (33) was not designed to isolate the effects of pricing manipulations, but it did show improvements in purchasing and a reduction in energy intake as function of the manipulations; however, these improvements did not result in weight changes over time, suggesting some compensation in energy intake at other meals. This is an important implication that may reduce the impact of manipulations in cafeterias. The challenge for cafeteria studies is to collect more individual data to assess the impact of changes in the cafeteria on health outcomes.

Vending machine experiments

Another innovative place to study price changes is in vending machines. French et al have studied manipulating prices in vending machines in a university setting (42), in high schools and worksites (28), and in a bus garage for transportation workers (43). In the university setting, prices for low-fat snacks were lowered by 50%, and signs for low-fat products were posted. Phases included baseline, price reduction, and return to baseline in a within-subject design. Results showed that the percentage of low-fat snacks went from 25.7% to 45.8% of the snacks purchased, with the percentage decreasing to 22.8% when the

intervention was removed. The purchase of low-fat snacks increased by 126.8%, and there was a 33.3% reduction in purchase of regular snacks during the manipulation (42), suggesting that low-fat snacks were substituted for regular snacks. The study in 24 high schools and worksites used a between-subject design; the high schools/worksites were randomized to conditions that had subsidies (10%, 25%, or 50%) for low-fat snacks and labels (none, low-fat labels, low-fat labels plus signs promoting low-fat snacks), respectively. Vending machine sales were recorded over a 12-mo period. Results showed a graded linear response between price changes and purchasing behavior change: price reductions of 50%, 25%, and 10% led to increases in purchases of low-fat snacks of 93%, 39%, and 9%, respectively. A small, but significant difference in the purchase of low-fat snacks was observed for the label-plus-sign condition (−15.4%) compared with low-fat snack sales for the no-label (−14.3%) and label-alone (−14.5%) conditions. Although energy intake was not directly measured, the authors suggested that with price decreases there was a large increase in total sales, which may indicate an increase in total energy intake, an unwanted side effect of price reduction but consistent with previous increases in energy purchased with price reductions in a laboratory study (14). Importantly, profits of the vending machine company were not negatively affected by the promotions given the additional purchases at the lowered price (28). No interaction between prices changes and labels were reported.

Finally, with the use of a between-subject design, a 10% subsidy was implemented for the 50% healthiest foods in vending machines at 4 bus garages, 2 of which were randomly assigned to price changes with the other 2 as control garages (43). In addition to price changes, the intervention included an increase in the percentage of healthier foods offered, with the goal of 50% of the foods meeting healthy criteria. Sales were monitored over an 18-mo period. Foods included snacks (eg, fresh fruit), entrées (eg, lean turkey pocket), and beverages (eg, diet soft drinks). In comparison to control garages, healthy snack purchases were 48% of snack purchases after the subsidy compared with 6% for the controls, healthy entrees were 24% of entrée purchases after the subsidy compared with 14% for the controls, and healthy beverages were 54% of beverage purchases compared with 40% for the controls, which suggested that in the context of bus garage vending machines, small price reductions can affect food purchases. A reduction in the purchase of foods from vending machines in the garages decreased over time, according to self-report surveys.

Summary of experimental vending machine studies

The vending machine experiments represent an innovative test of pricing manipulations to influence purchasing, and these experiments represent the first field experiments to use between-subject methods to compare effects of price manipulations with complementary interventions (28). A reduction in the purchase of regular snacks was observed when prices of low-fat snacks were lowered, which is indicative of substitution of low-fat snacks for regular snacks (42). None of the vending machine experiments assessed nutritional aspects of the diet. The study implemented in schools and worksites (28) provided the opportunity to test whether there was an interaction between pricing and labels or promotional activities, and there were independent effects of the 2 types of interventions, the effects of pricing were much greater than labels or promotions, and there were no reported interactions. An important limitation of these studies is that individual purchases were not measured, so it is not known whether the intervention changed the customer pool. Similarly, because the characteristics of individual subjects were not measured, individual differences cannot be linked to food purchases, and the study of moderator variables was not possible.

The vending machine studies were also very strong in regard to external validity, and they incorporated strong designs that include both within- and between-subject experiments. A design challenge for the between-group experiments is the very small number of vending machine sites assigned to each condition, with only 2 sites per condition. An additional concern about vending machines is their potential impact on public health; the study on vending machine purchases in bus drivers showed only about one-third of the transportation workers used the snack food or cold drink vending machines $\geq$3 times/wk, and only 8% used the cold food vending machine $\geq$3 times/wk. The low use of the vending machines to purchase snacks, drinks, or meals in this setting may limit the effects of vending machine manipulations on health. Vending machines may be more widely used in schools, and thus could have a bigger impact on purchasing and nutritional quality of the diet in school settings.

Supermarket and farmers' market experiments

Although the strengths of the cafeteria and vending machine studies are their external validity, one of the limits of these studies is that they sample only a limited part of a person's food consumption. A broader assessment of how pricing may influence food purchasing is by modifying prices in supermarkets. Although there have been a number of analog studies using online supermarkets (31, 53), there are also studies that manipulated prices in a supermarket or farmers' market with the aim of quantifying changes in consumer demand (16, 44, 45). Kristal et al (45) implemented an 8-mo, point-of-purchase intervention in which 4 supermarkets were randomized to fruit and vegetable promotional signage, including recipes, food tastings, and nutrition-related information, and 50-cent coupons for fruit and vegetables, and 4 supermarkets received no promotion or coupons. Data were collected from a random sample of 120 shoppers from each store at baseline and after 1 y. No significant differences in demographic characteristics of shoppers were observed between the control and intervention stores. Results showed no significant effect on fruit and vegetable purchases or recall of signage among shoppers. Due to problems in data collection, it was not possible to quantify purchases at the cash register, which is one reason for the focus on self-report of purchases. In addition, the investigators suggested that the intervention may not have been intensive enough, because less than half of the shoppers in the intervention group (43%) recalled flyers promoting the intervention, although most of those who recalled seeing the flyers did use the discount coupons at least once.

Herman et al (46) assigned 602 mothers enrolled for postpartum services in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) from 3 sites to groups receiving a $10/wk voucher for fruit and vegetables at either a supermarket or a farmers' market or to a control group receiving vouchers for diapers. Four hundred fifty-one mothers completed

the intervention, with dropout rates of 30% for the supermarket group, 16% for the farmers' market, and 29% for the control group. Sites were matched for access to supermarkets or farmers' markets, and no differences in subject characteristics were observed by group. Dietary recalls were collected by interview at baseline, at 2 mo into the intervention, at the end of the 6-mo intervention, and at a 6-mo follow-up. Results showed significant increases in fruit and vegetable consumption from baseline to intervention for the supermarket and farmers' market groups in comparison to the control group, and increases were primarily in purchases of vegetables. Increased vegetable intake was sustained for the supermarket group compared with the control group, but effects of the farmers' market on vegetable intake were not sustained. In comparison to the Kristal et al (45) experience, subjects in this study redeemed >90% of the coupons provided.

Anderson et al (44) compared effects of 4 interventions on questionnaire-derived fruit and vegetable consumption in a large sample of WIC or Community Action Agency Commodity Supplement Food Program participants over a 5-mo period. Six hundred sixty-nine women were recruited, with 455 completing the posttest. On the basis of when women attended WIC recertification appointments, subjects were assigned to the following groups: control, education about the nutritional value of fruit and vegetables and proper storage, a $20 discount coupon on fruit and vegetables, or the combination of education plus coupons. Subjects in the control group and education-only group received cash incentives at baseline. Results showed significant effects of discount coupons on fruit and vegetable consumption, whereas education improved attitudes and beliefs about fruit and vegetables. No interactions between education and coupon discounts were observed. Coupon use was quite high, with 87% using some coupons, and 58% redeeming all coupons.

More recently, a well-designed study followed 1104 shoppers (a representative sample that included an equal distribution of Maori, Pacific, and non-Maori/non-Pacific individuals) who were randomly assigned in a 2×2 factorial design to a 12.5% discount on healthier foods, tailored nutrition education program interventions, combination discounts and education, or a control. The participants were studied in 8 supermarkets over an 18-mo period, which included 6-mo baseline, intervention, and follow-up intervals (16). Only 7% were lost to follow-up. Thirty-five percent of foods met the healthy criteria for discounts on the basis of the Heart Foundation's Tick nutrient profiling system. The primary outcome was percentage of purchased energy from saturated fat, but a wide variety of measures of nutritional quality of the diet were collected, including percentage of energy from fat, carbohydrates, and protein; energy density; sodium; sugars; and change in quantities of foods purchased, including cereals, fats and oils, fruit and vegetables, meat and meat alternatives, and milk and milk products. Results showed an 11% increase in purchases of discounted healthy foods during the intervention, and significant, although smaller increases were maintained at follow-up; purchases of nondiscounted foods did not significantly change. The largest effect of discounts was on fruit and vegetables. No consistent differences in overall food expenditure were observed, and there were no significant changes in energy from saturated fat or in other nutrients studied. Tailored nutrition education had no effect on purchases. The investigators suggested that the small increase in purchases of healthier foods of only 11% may be the reason for the lack of effects. They followed this study with an analysis of moderators, including ethnic group, education, and income. Moderator analysis showed greater increases in healthier food purchasing in European and Pacific groups rather than in Maori (47). Approximately 40% of those randomly assigned to the discount group never or seldom took advantage of the discounts.

Summary of experimental supermarket and farmers' market studies

The 4 supermarket studies all were based on providing discounts for fruit and vegetables or, more broadly, healthy foods; and these studies provided data on the 4 areas studied. The only study (16) that assessed purchases of other types of foods did not show any significant changes in purchases of nondiscounted, less healthy foods; and the investigators did not attempt to provide detailed data on substitution effects due to increases in healthy food purchases. However, the lack of overall effects suggests that there may have been some compensation in terms of purchasing. The Ni Mhurchu et al study (16) also provided a detailed list of nutritional characteristics of foods purchased, and whereas there was an increase in healthy foods purchased, this did not result in improvements in overall nutritional characteristics of the foods purchased. Several of the studies provided alternative or complementary interventions, with 3 of the studies providing educational interventions. In all cases, price changes were more effective than was education on food purchases. Finally, 3 of the 4 studies included individual-level data because subjects were assigned to groups. Only one of the studies provided data on moderators of change, and results suggested ethnic differences in intervention-related increases in purchases of healthy foods. Interestingly, neither income nor education moderated effects of discounts.

The supermarket and farmers' market studies have excellent external validity, and they used strong factorial designs to evaluate independent and interactive effects of interventions (16, 44). These studies are also notable in randomizing or assigning subjects to interventions, providing the opportunity to study moderators of price change. It is interesting that there was wide variability in the performance evaluation of the discount interventions. In 2 of the studies in which the discounts were implemented at the supermarket level, the intervention was not as widely used as anticipated (16, 45), which may have affected the results. On the other hand, the 2 studies that provided discount coupons for low-income families who received supplements for food purchases showed higher use of the discounts (44, 46). This may have been in part due to the lower income of these families, but also in part because these interventions were implemented as part of a food supplement program. Obviously, it is not sufficient to provide discounts alone unless they are widely perceived and used. However, it is worth reporting that only one study directly measured food purchases (16), and 2 of the studies that showed significant effects used self-report of consumption, which can be subject to error (54, 55).

DISCUSSION

As expected, price changes influence food-purchasing patterns. Increasing prices of less healthy foods reduced their purchase, and reducing prices of healthier options increased their

purchase. The review was designed to go beyond the law of demand to provide insight into 4 questions: *1*) whether substitution is observed when foods are taxed or subsidized, *2*) do price changes modify overall nutrition or health indexes, *3*) do alternative or complementary interventions improve the effects of price changes, and *4*) are their moderators of sensitivity to price?

Effect of price changes on substitution effects

Several of the laboratory studies provided clear evidence of substitution of healthier foods when prices of less healthy foods were taxed or reductions in less healthy foods when prices of healthy foods were reduced (25, 35). However, many of the laboratory studies have used taxes based on nutrient profiling, such as taxes based on energy density (15, 31) or calories per nutrient (14), and, as such, it has not been possible in these studies to examine the possible substitution of types of foods within a broad category of foods, such as substitution of energy drinks if soda is taxed. The cafeteria study by Block et al (37) showed an increase in purchases of nonsugary beverages when sweetened soda was taxed. Interestingly, sugary water sales that were not taxed also decreased, and coffee sales increased. Unfortunately, detailed data on other types of foods were not available, so it is not possible to know if purchases of other sources of sugar changed.

Substitution effects are not limited to taxes, because people may reduce purchases of less healthy foods when provided with price reductions for healthier purchases. Of course, providing subsidies may not have as much of an effect as expected if people still want to buy less healthy foods in their budget. There are 2 ways this can happen. First, these individuals may buy the same amount of healthy foods they always buy, but because these are now cheaper, they have more money for less healthy foods. Second, they can buy cheaper-quality or smaller sizes of healthier foods that are discounted, again providing more money to purchase less healthy foods. It is relevant that even though shoppers bought 11% more discounted healthy foods when they were discounted by 12.5%, no overall changes in nutrition were observed, which may have been due to some compensation in purchasing (16).

Current discussion of taxes focuses on targeting specific types of foods, such as taxing soda. The efficacy of tax or subsidy policies may depend on the types of foods that are targeted for price changes. Research has estimated effects of changing prices on specific types of foods, such as sugar-sweetened beverages (29, 37) or salads (39). On the other hand, price changes can target broader categories of food and use energy-density (32) or nutrient-density profiling systems (14) to set prices. The broader the categorization system used to set prices, the less of a concern that participants will be able to substitute with similar less healthy products. This is particularly relevant as the science of nutrient profiling is being developed (56–61), which may provide a better basis for pricing foods than price changes on narrow categories of food, such as sugar-sweetened beverages. Research comparing selective targeting of price changes of specific foods compared with broader, nutrient-profiling–based approaches is warranted in future research.

Assessment of nutritional quality or health indexes

Another important issue is the choice of the best dependent variable to inform public policy. Studies have used number of purchases of food or nutritional characteristics of the foods as dependent variables. These studies show that the conclusions on pricing effects may differ if the amount of purchases is the dependent variable rather than nutritional characteristics of the foods (14, 16). The importance of changing pricing for public health should be changes in energy for obesity prevention and changes in quality of the diet for preventing disease or improving general health (61, 62); although knowledge of the number of purchases is important to understand the influence of pricing changes, when possible, studies should include measures of the nutritional changes that result from changes in pricing. Some laboratory studies have shown improvements in nutritional indexes with price changes based on nutrient profiling (14, 25, 31), but field studies have not shown overall improvement in nutrition when price has been changed in cafeteria (33) or supermarket (16) settings. In addition, in the only study that reported body-composition or health indexes, cafeteria pricing changes had limited effects on health (33). Modifying purchases of specific types of foods is an important outcome, but in field studies that measure individual subjects it is also important to assess overall nutritional and health indexes. Studies are needed that take promising pricing approaches to modifying purchasing and implement them over sufficient duration to observe whether they in fact do make a difference in terms of modifying purchasing in the short term and health outcomes in the long term.

Effects of pricing plus alternative or complementary interventions

Several studies have included nonpricing approaches to modifying purchases. In nearly all cases, pricing effects are larger than the effects of information alone (16, 28, 30, 32, 37, 44). There is mixed support for the combination of pricing with adjunctive interventions. Whereas calorie information by itself has limited effects on purchasing (17, 36), investigators have studied whether effects are enhanced when combined with pricing. For example, Block et al (37) showed greater changes in sugar-sweetened beverage consumption when price increases were combined with an educational intervention, but Giesen et al (32) suggested that providing calorie information for foods compromises the effect of taxes on purchasing. Vending machine (28, 42) and supermarket (16, 44, 45) studies showed minimal effects of additional interventions on purchasing, and no one has shown interactive effects of price change with another intervention in factorial studies designed to show interactions between interventions.

Many of the proposals for taxes recommend relatively small taxes, which may be politically acceptable but project to very small effects on food purchasing (4, 18), with the rationale that they would raise money for informational or educational programs. Thus, research is needed to develop programs that influence purchasing and health. It is possible that the effectiveness of pricing manipulations would be enhanced by some adjunct interventions and not by others, but research is needed to identify the ideal combination of interventions to maximize the effect on diet quality. There are a wide variety of adjunctive interventions, ranging from point-of-purchase nutrient profiling and nutritional

and educational signage, to more intensive educational interventions. To our knowledge, there are no studies that have developed or tested behavioral interventions designed to improve shopping behaviors in shoppers with health problems who could benefit from improved food purchases. Given that calorie and nutritional information may have limited effects on food purchases (63, 64), and are less powerful than price changes in experimental studies (30, 32, 38), there may be ways to improve point-of-purchase information to boost effects of pricing, but more powerful and individualized behavioral interventions may need to be paired with price changes to maximize effects of manipulating prices.

Moderators of price sensitivity

Whereas pricing has powerful effects on purchasing, research suggests that some individual difference characteristics may moderate the effects of pricing. For example, studies show that BMI (25), income (35), impulsivity (15), dietary restraint (32), ethnicity (47), and regular purchase of the commodity (37) can moderate the effects of price changes. However, research has not shown any of these moderators to replicate over multiple studies, so the influence of these moderators on purchasing should be considered tentative at this point. This type of research is needed to know whether all segments of the population will benefit equally from the intervention or that no moderators were reliably found to moderate price effects. Price changes would be considerably less useful if families less in need of the intervention (less obese, more affluent) were the ones who responded best to the intervention (25, 66).

Because food purchases represent a series of choices, it may be worthwhile to test variables derived from behavioral choice or behavioral economics theory as moderators. Choice can be conceptualized in terms of immediate choice among concurrent alternatives such as a healthy or less healthy option or temporal choice, in which someone makes an impulsive choice by choosing a smaller reward now instead of a larger one later (eg, a dish of ice cream now instead of weight loss later). Concurrent choices among reinforcers or impulsivity represent 2 variables that are prospectively and cross-sectionally related to obesity, and may interact to influence choice of foods. For example, people who find food more reinforcing or value the food more may be willing to pay more money for that food, and not shift purchases when prices are increased (3). Similarly, impulsive people may not make the rational choice to purchase healthy foods when they are discounted, but rather make the impulsive choice to purchase and eat a less healthy food. Research does suggest that impulsivity is related to purchases of greater energy value (53) in an online supermarket, and impulsivity can moderate the effect of price changes on total calories purchased, as well as purchase of low- and high-energy-dense products (15).

Implementing pricing interventions

An important issue across the studies is how widely used were the interventions. In some of the field studies on taxes (37) and subsidies (45), there was evidence of unawareness of the manipulations, which could have minimized the influence of the intervention. In the usual shopping situation, shoppers receive flyers or advertisements in newspapers of what foods are on sale, and discounts for selected foods are broadly displayed; shoppers often know in advance or can identify what foods are "on sale" as they shop. Thus, experimental studies can provide shoppers with the information needed to identify which products are discounted as they shop. However, providing the label that a product is on sale may have an effect independent of the price change, and studies are needed to assess the independent effects of price change alone, without the label of a product being on sale. It may be necessary to do more than display price reductions for discounts to have maximal effects.

Although shoppers may be notified of products on sale, taxes or increases in price are usually not displayed during the shopping experience, and shoppers may not be provided with information on which products are now more expensive. If taxes are implemented as excise taxes, the tax would raise the price of the product (18), which is the model for all of the experimental studies. Sales taxes are collected at the register, and many shoppers may not know how much more they are paying for particular products. This may minimize the effects of price increases on purchasing. Even when the prices are raised, surveys to understand the impact of a taxing intervention have shown that only 18% of cafeteria shoppers realized that there was a tax on sugar-sweetened soda (37). Regular consumers of sugar-sweetened soda were more likely to notice, and regular consumption did moderate the effects of the price increase, but the large majority of shoppers did not even know a tax was being implemented. Without the knowledge that a tax was implemented, the tax could not influence behavior. Thus, one implication of this study is that research is needed to understand the best way to inform people of taxes to maximize their effect on purchasing. Similarly, Harnack and French (17) found that many participants did not notice posted calorie information and fewer noticed the changes in price from value pricing to pricing based on ounces. Without keeping track of price changes over time, and a very good memory, some shoppers may have a difficult time noticing price changes without environmental prompts. Because lower-income shoppers must spend a greater proportion of their income on food, they may be more observant and sensitive to price changes than more affluent shoppers, but the experimental research has yet to consistently show (35) that income levels moderate the effects of price change on purchasing.

Feasibility of pricing interventions

One important issue is the economic feasibility of implementing price changes in real-world settings. Research clearly shows that changing prices modifies purchasing, with greater effects for larger price changes, but large price changes may be needed to have significant effects on purchasing and biological outcomes. Research is needed to quantify how much price change is needed to produce health benefits. Although there are economic analyses based on observational data outcomes (3, 11–13, 20, 26, 67), experiments are needed that address what size of change is necessary. Experimental studies have varied prices by as much as 50% from usual prices (28), which is probably too large of a price change to sustain. Experimental studies are particularly important in this regard, because observational studies seldom capture data on large taxes or subsidies to estimate effects on purchasing or health. The amount of taxes may have different effects on behavior compared with generating revenue.

If the taxes are large enough to reduce purchasing, then there may be an overall reduction in revenue generated. Whereas taxes increase revenue, subsidies run the risk of losing revenue.

When implemented in a variety of settings, price discounts did not appear to negatively affect total revenue (30, 42, 68) due to increased sales of targeted items, but research has not assessed whether profits differ as a function of price changes. Profit-neutral schemes can be developed based on considerations of implementing a subsidy in which sales of less healthy taxed items help to cover the cost of lowered prices on healthier foods. By using price elasticities of demand, the range of possible net gains and losses can be estimated when implementing pricing strategies. One study in a high-school cafeteria found that increasing prices of 3 high-fat foods by 10% and lowering prices of 4 low-fat foods by 25%, revenues could be expected to be within 5% of the normal range (69); however, the study did not report whether there were any changes in profits. Without significant fluctuation in profits, taxes and subsidies could plausibly become a feature of cafeterias, markets, or restaurants where people generally purchase most food items without posing a financial threat to owners and operators.

Policy issues and price changes

Although the emphasis of research on price changes is usually related to the health benefits of eating better, there may be benefits to price changes even if no changes in purchasing were observed. In fact, several simulations based on observational data suggest that small price changes in the range that may be politically acceptable may not project enough changes in food purchasing to lead to health benefits (22, 23). Even if this were the case, generating increased tax revenue could have the benefit of providing funding for special educational programs, subsidizing healthier foods, or treating disorders associated with unhealthy eating (4, 19).

Sales taxes for food or specific types of foods sold in grocery stores or vending machines have been implemented in 40 US states since 2007 (70); internationally, Denmark is now taxing foods that contain >2.3% saturated fat (71). It is interesting that a European country has chosen to tax foods on the basis of their nutrient characteristics, consistent with several laboratory studies (14, 15), rather than tax individual foods. Taxing broad categories of foods on the basis of their nutrient characteristics should be associated with less substitution of other less healthy foods in comparison to taxing individual types of foods, such as soda. There are also substantial subsidies provided for food in the form of Special Nutrition Assistance Program (SNAP) and WIC programs, with WIC serving 9 million women, infants, and children at a cost of >6 billion dollars in 2009, and SNAP serving >28 million participants at a cost of >34 billion dollars (72). Given the inverse relation between socioeconomic status and obesity (73), and observations that SNAP may inadvertently increase the risk of obesity (74, 75), creative thinking about better ways to use food subsidies to improve health is warranted. For example, would restrictions on what food can be purchased with subsidies improve health, or could subsidies only be provided for healthier foods, similar to discounts on fruit and vegetables implemented in several supermarket or farmers' market studies (16). Studies in WIC participants that successfully show that vouchers for fruit and vegetables can increase consumption are encouraging for generalizing findings to low-income families (44, 46). Money spent on improving diets of lower income families may be well worth the cost in reducing incidence of disease. Research is needed on these issues to better inform public policy (74).

Across all studies, elasticity estimates for food purchases ranged from −0.5 (34) to – 3.8 (40), which, in general, is larger (more elastic) than the elasticity of demand for cigarettes (76), which is estimated to be approximately −0.3 to −0.5 in the short term and −0.5 to −0.6 in the long term (77). In several studies, the observed elasticities were similar to those generated from observational studies. For example, in a cafeteria setting, Block et al (37) observed own-price elasticity of −0.75 for soda when the price of regular soda was 35% compared with the best estimate of elasticity of soda on the basis of 14 observational studies of −0.79 (10), supporting the external validity of the study. In other experimental studies, the demand elasticities observed after price changes were much higher than those from observational data. For example, after a 50% reduction in price in high-school cafeterias, sales of fruit and carrots increased by 439.6% and by 218.0%, respectively, which is much higher than the expected demand elasticities for fruit and vegetables of −0.70 and −0.58, respectively (10). There are several possible reasons for these differences. First, many of the experimental studies required participants to spend their entire budget. This may attenuate demand responses compared with the real world in which consumers can react to higher prices by purchasing products elsewhere. In addition, the real world has nearly infinite potential substitute products, whereas experimental studies are often limited to a few choice sets. In general, own- and cross-price effects will be larger the more substitutes are available. For example, fewer substitutes are what allow movie theaters to charge much higher prices without reducing profits. This is not possible when higher prices can lead consumers to switch to other venues. To this point, experimental studies that include a broad range of substitute and complementary products, and that do not require customers to spend their entire budget, would be expected to generate results closer to those observed in observational, real-world studies. There may also be differences in shopping experiences in relatively closed economies, such as cafeterias or vending machines, in which there may be limited availability of other foods to purchase, in comparison to open economies in which people are free to shop at multiple supermarkets. The experimental studies generally assess elasticities over very large price ranges, which is why we used the term *arc elasticity* throughout, whereas most observational studies quantify point (or near point) elasticities on the basis of smaller fluctuations in prices. This limits the comparability of elasticity coefficients, because for nearly all demand curves, elasticities are nonconstant and will differ depending on the magnitude of the price changes tested.

In summary, experimental research on price changes and how they influence different aspects of public health is in its infancy. The research agenda is vast, with much to be done in a number of areas. The amount of price change needed to influence purchasing and to produce meaningful changes in measures related to public health needs to be a first research priority. Research is needed to determine whether targeting specific foods or types of foods, such as fruit and vegetables or sugar-sweetened beverages, would be more efficacious or whether price changes should be

based on nutrient profiles of foods. Research is needed to assess health benefits of pricing manipulations on specific subgroups who need intervention most, which could include low-income shoppers as well as people with particular health problems who would benefit from improved food choices.

Experimental economic research provides a methodology to inform public policy. In biomedicine there is an emphasis on a series of randomized trials to inform clinical work, and the analogy to food pricing is straightforward. As shown by the ingenuity of investigators in multiple settings, randomized trials on pricing can be implemented in laboratory and real-world settings. Ideally, research should be implemented at multiple levels of analysis, with laboratory and field studies providing complementary arenas to test the efficacy and effectiveness of new ways to implement pricing interventions. Experimental research on pricing is clearly in its infancy, but the potential to use scientific findings to improve purchasing and eating behaviors at the population level makes experimental economic research on pricing a valuable approach to public health.

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