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Effects of nutrient profiling and price changes based on NuVal® scores on food purchasing in an online experimental supermarket

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Abstract
Objective: The goal of the present study was to apply experimental economic methods in an online supermarket to examine the effects of nutrient profiling, and differential pricing based on the nutrient profile, on the overall diet quality, energy and macronutrients of the foods purchased, and diet cost.
Design: Participants were provided nutrient profiling scores or price adjustments based on nutrient profile scores while completing a hypothetical grocery shopping task. Prices of foods in the top 20 % of nutrient profiling scores were reduced (subsidized) by 25 % while those in the bottom 20 % of scores were increased (taxed) by 25 %. We evaluated the independent and interactive effects of nutrient profiling or price adjustments on overall diet quality of foods purchased as assessed by the NuVal® score, energy and macronutrients purchased and diet cost in a 2 × 2 factorial design.
Setting: A large (>10 000 food items) online experimental supermarket in the USA.
Subjects: Seven hundred and eighty-one women.
Results: Providing nutrient profiling scores improved overall diet quality of foods purchased. Price changes were associated with an increase in protein purchased, an increase in energy cost, and reduced carbohydrate and protein costs. Price changes and nutrient profiling combined were associated with no unique benefits beyond price changes or nutrient profiling alone.
Conclusions: Providing nutrient profile score increased overall NuVal® score without a reduction in energy purchased. Combining nutrient profiling and price changes did not show an overall benefit to diet quality and may be less useful than nutrient profiling alone to consumers who want to increase overall diet quality of foods purchased.

Keywords
Nutrient profiling
Price changes
Purchasing
Experimental economics

Nutrient profiling (i.e. classifying foods based on their nutrient composition) and pricing are two methods for improving diet quality of foods purchased[1–3]. There are a variety of nutrient profiling systems available, including systems that categorically rate foods[4,5] and ones that develop a food score based on a ratio of healthier to less healthy ingredients[6–10]. There are three potential uses of nutrient profiling to improve diet quality of foods purchased. First, nutrient profiling information could help shoppers identify healthier foods[2,3] and allow them to select healthier alternatives within the same food category (e.g. low-fat milk *v.* whole milk). In this case, shoppers may 'trade up' to a healthier version of a specific food. In addition, a shopper may find that the full range of foods within a commonly consumed food group has a low nutrient profiling score, and so may decide to shift to a different, healthier, food group, rather than shift within a food group (e.g. from candy to fruit).

Second, nutrient profiling may be the basis for innovative methods of adjusting food prices. Current practices and the majority of research studies have focused on taxes or subsidies on specific food groups to raise or lower the costs of products, respectively, such as taxing sugar-sweetened beverages or candy, or subsidizing fruits and vegetables[11]. Research has shown that increasing the price of unhealthy foods decreases purchasing of those foods and reducing the price of healthier foods increases their purchasing[12–15]. Yet, because of substitution effects, the simple tax/subsidy options considered to date that focus on particular classes of foods (e.g. sugar-sweetened beverages) have limited effects on net energy intake or diet quality, which is important for chronic health

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conditions such as obesity, CVD and cancer[14,16]. An alternative tax/subsidy approach to modifying food prices is to differentially tax/subsidize foods based on their nutritional content so that low-nutrient-density foods would be taxed and high-nutrient-density foods would be subsidized. In this way, if the price of soda increased, consumers would not be able to shift purchasing to sweetened fruit juices, energy drinks or even beer[17].

Third, nutrient profiling may act as an incentive for reformulation by the food industry. If manufacturing companies display the products' nutritional scores on packages, the food industry may be motivated to reformulate its products to raise the scores to make the products more appealing to consumers[18]. Consequently, food products that are reformulated to improve their nutrient profile may lead to healthier purchases[19].

High-energy-density, low-nutrient-density foods are generally less expensive than low-energy-density, high-nutrient-density foods, making low-energy-density foods less accessible for individuals on a limited budget[20,21]. This increases the energy cost of foods purchased[22,23] for individuals who plan to eat healthier. This may lead to purchases of less healthy foods because they provide greater energy per dollar spent[24,25]. Price increases and reductions based on low and high nutrient density scores, respectively, may mitigate this effect and result in overall higher diet quality of purchases.

NuVal® is a nutrient profiling system that has been shown to be a valid measure of the overall diet quality of foods purchased[9,10] and higher NuVal® scores are associated with a reduction in the risk of chronic disease[1]. NuVal® is used in supermarkets throughout the USA, is user-friendly and easy for participants to understand[9,26], and was used as the nutrient profiling system for the present study.

The goal of the present study was to apply experimental economic methods in an online supermarket to examine the effects of nutrient profiling, and differential pricing based on the nutrient profile score, on the overall diet quality, energy and macronutrients of the foods purchased and diet cost. We predict that both NuVal® and price changes will influence food purchasing, but that nutrient profiling will be associated with largest improvements in nutrient quality of foods purchased.

Method

Participants

Participants were 781 women who were recruited from an existing family database, flyers, brochures and postcards distributed around local campuses and the community; web-based recruitment (e.g. ads on Craig's list, Facebook, Twitter and the department's website); and targeted direct mailings. We chose to limit the sample to female shoppers to maximize generalizability to family nutrition, rather than single people who are only shopping for themselves. Females were chosen because they constitute the largest percentage of household grocery shoppers[27]. Participants were screened by telephone to ensure they met the following criteria: (i) 19 years of age or older and the primary grocery shopper for a household containing at least one child between the ages of 2 and 18 years; (ii) purchased the majority of their groceries once weekly or could realistically shop for one week's worth of groceries in our online supermarket; (iii) no dietary restrictions that could interfere with the experiment, including food allergies or religious or ethnic practices that severely limit food choice; (iv) not currently pregnant; and (v) no medical conditions, psychopathologies or developmental disabilities that would limit participation. Participant flow is shown in Fig. 1. Participants were compensated $US 50 for completion of the study and were given a one-in-ten chance of winning the groceries they selected during their shopping session. Participants did not have the option to actually purchase the products they selected. Participant characteristics are shown in Table 1.

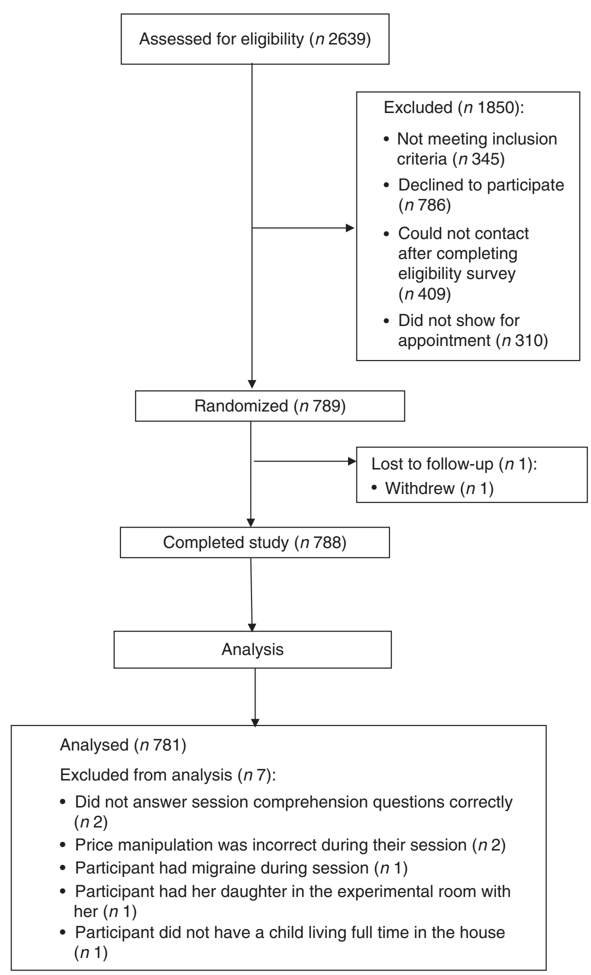

Fig. 1 Participant flow diagram

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Procedures

Prior to the session, participants completed a basic demographics form that included information on family income, adult education level, race/ethnic background of the participant, household size (e.g. number of adults and children) and information on the level of food assistance. Participants were asked to refrain from consuming food or drinking beverages, other than water, for 2 h prior to the appointment to limit variability in hunger[28] that can affect product selections during the shopping task[28,29]. Upon arrival at the laboratory, participants read and signed consent forms. Next, a same-day multi-pass food recall and hunger scale were completed, followed by a hypothetical shopping session in the online supermarket. In addition, participants completed comprehension questions based on the condition they were assigned to, to ensure that they understood the manipulation prior to the start of the shopping task. After completion of the shopping task, participants' height and weight were measured. Height was measured with a digital stadiometer (Measurement Concepts & Quick Medical, North Bend, WA, USA) and weight was assessed using a Tanita digital scale (Arlington Heights, IL, USA). BMI (kg/m^2) was calculated using the formula BMI = weight/height^2. Finally, participants were debriefed and compensated.

Prior to the start of the study, participants collected approximately two weeks' worth of household food receipts which were used to estimate a budget to be spent on food during the shopping trial. Participants were randomly assigned to one of four possible shopping conditions in a 2 × 2 factorial design: (i) nutrient profiling using NuVal®[9,10]; (ii) taxes/subsidies based on nutrient profiling; (iii) nutrient profiling and taxes/subsidies combined; and (iv) no manipulation.

Online virtual shopping experience

The virtual supermarket was designed as an analogue to an online supermarket shopping experience. The virtual supermarket simulated other experimental online shopping tasks[28,30,31] and a local supermarket website. Participants were able to browse or search for approximately 12 000 food items. The online supermarket organized these products into eight food categories, such as protein, produce and beverages, which were each divided into smaller sub-categories, such as beef, fresh vegetables or carbonated beverages. A food's picture, package size, price, nutritional information, ingredients and warnings were visible on the product page, which could be accessed through the sub-category pages or by requesting the item using a search box. Nutrition facts for each product were based on nutritional information provided by NuVal® LLC or the US Department of Agriculture's National Nutrient Database (http://ndb.nal.usda.gov/). Participants were able to add items to their online grocery cart and a running total of their cart was displayed on the right-hand side of the screen. The virtual supermarket contained a wide range of national and local brand products as well as various sizes and flavours of products. To ensure participants' selections were reflective of their usual shopping, they were asked to find suitable substitutes for any products that they would normally purchase but were not available in the online store.

Taxes (price increases) were indicated by a red circle, while subsidies (price decreases) were indicated by a green circle next to the picture of the food, as well as the new price displayed in red or green text next to the original price. Participants were informed that price changes were made on the basis of the nutritional quality of the food. In the nutrient profiling condition, NuVal® scores were displayed for every product in the store (exceptions included coffee, water and tea, which do not receive scores). In the combination condition, NuVal® scores and price changes were displayed simultaneously. The control condition experienced typical grocery shopping without any modifications to the appearance of the store.

Foods with the highest 20 % of NuVal® scores, from 33 to 100, were subsidized, spanning a wide range of products, including most fruits and vegetables and various products within sub-categories of the store such as yoghurts, eggs and egg substitutes, beans, crackers, cold cereals and pasta. Foods in the lowest 20 % of NuVal® scores, from 1 to 3, were taxed, including some carbonated beverages, baked goods, candy, butter and shortening. In the present study we chose taxes and subsidies that increased or decreased by 25 %. The increase in price is within the range of price increases that consumers normally experience. For example, price increases for tomatoes have been up to 52 % in one year[32]. Similarly, price reductions of up to 20 % have been observed within a year for such foods as strawberries[32].

Prior to the shopping session, participants in all groups were given an informational and interactive orientation to using the online grocery store that showed participants how to navigate the store, add items to their shopping cart and determine the total cost of their shopping cart. Aspects of the orientations that differed by condition were the logic and specifics of the price changes or NuVal® information.

After reviewing instructions, the experimenter left the room. Participants were asked to select groceries their family would need for a typical week, assuming that this would be the only opportunity that week to purchase food. Prior to checking out from the store, the experimenter reviewed the shopping cart with the participant to ensure it accurately reflected her purchasing decisions.

Measures

Nutrient profiling system and nutritional measures

NuVal® is a nutrient profiling system that scores foods on a 1–100 scale based on an algorithm that takes into account both positive (fibre, vitamins, minerals, etc.) and negative (*trans*-fat, salt, sugar, etc.) nutrient aspects of the food. Low scores are applied to foods with a lower nutritional quality. Higher NuVal® scores are related to healthier diets and decreased risk of chronic disease[1,10].

Based on the food items selected by each shopper, dependent variables included calories (kcal), grams, macro- and micronutrients, adjusted for family size, and average NuVal® score of items selected. The NuVal® score for each shopping cart was calculated using the average of all NuVal® scores of products selected, weighted by the total servings selected of each product.

Food prices were based on local food prices from a large, regional supermarket chain that displayed NuVal® scores, updated every 3–4 months. Based on these prices, measures of energy and diet cost, defined as the kilocalories purchased per dollar spent and the kilocalories of macronutrients purchased per dollar spent, respectively, were calculated adjusting for family size.

Same-day dietary recalls

Participants recalled all foods and drinks consumed before coming to the laboratory that day using a same-day multi-pass recall to verify adherence to the study protocol that they had not consumed food or drink (except water) for 2 h prior to the appointment.

Hunger

Subjective ratings of hunger were collected using a 7-point Likert scale anchored by 'not at all hungry' (1) to 'extremely hungry' (7).

Data analysis

One-way ANOVA compared differences across groups in the amount spent in the online store *v.* receipts, and correlations were used to establish the relationship between usual spending and spending in the store. Independent effects of price and nutrient profiling and their interaction were assessed using 2 × 2 factorial ANOVA models, with NuVal® (no NuVal®, NuVal®) and price (price change, no price change) as between-group variables; dependent variables included energy, macronutrients, micronutrients, and energy and macronutrients purchased per dollar spent. *Post hoc* linear contrasts were used to compare effects between groups for significant interaction effects. Analyses were completed using the statistical software package Systat 11·0 (SYSTAT Software, Inc., Richmond, CA, USA). With the exception of the average NuVal® score for a family, other nutritional variables (e.g. energy, macronutrients) are adjusted for family size, by dividing by the variable by the number of people in the household to get the per person value.

Hypothetical revenue gained from the 25 % tax on low-nutrient-density foods was calculated as (total dollars spent per shopper on taxed foods)/125 × 25. An analogous approach was used to quantify the costs of the subsidy ((total dollars spent on subsidized foods)/75 × 25). The difference between the tax and subsidy represents the net cost of the tax/subsidy condition.

Sample size was based on previous research[31] showing an effect size of 0·10 for price changes on energy purchased. Using α of 0·05 and power of 0·80, this effect can be detected with 198 participants per group or 792 participants in total.

Results

Characteristics of the participants are shown in Table 1. Thirty-one per cent of the participants were minority and 29 % received food assistance, which is representative of the families in the local county[33]. On average, participants had completed some college education and had an average family size of approximately four people. The majority of participants (approximately 94 %) reported never having shopped for groceries online.

There were no significant differences ($P = 0·11$) in the amount of money spent on food between the four groups, but the average amount spent in the online store was significantly greater than the amount calculated from their usual receipts ($US 139·19 (SD 61·33) *v.* $US 115·46 (SD 64·79); $P < 0·001$). The amount individuals spent in the online store was correlated with the receipts provided by participants ($r = 0·65$, $P < 0·0001$).

Table 2 presents the main effects and interactions for NuVal® score, energy, macronutrients, and energy and macronutrient costs. Results for additional nutrients (saturated fat, *trans*-fat, cholesterol, sodium, vitamin A, vitamin C, fibre, iron and calcium) did not show any significant main or interactive effects between groups.

Nutrient profiling

Being presented with NuVal® nutrient profiling information, collapsed across the price change conditions, was associated with improvements, collapsed across the price change conditions, in the overall NuVal® score, with overall NuVal® score improving from 38·6 (SD 14·1) to 41·1 (SD 14·6), $P = 0·019$. There was also a reduction in the fat calorie cost with NuVal® information, as fat calories/dollar decreased from 29·5 (SD 18·4) to 26·0 (SD 13·6), $P = 0·003$. No other significant effects of nutrient profiling were observed.

Price changes

Price changes, collapsed across nutrient profiling conditions, were associated with an increase in protein purchased ($P = 0·048$), as well as an increase in energy ($P = 0·005$), carbohydrate ($P = 0·002$) and protein ($P < 0·001$) costs per dollar. No other significant effects of price changes were observed.

Price and NuVal® effects

No interactions of price by NuVal® nutrient profiling were observed for any of the variables studied.

Revenue gained from the 25 % tax on taxed foods was $US 2·26 per shopper and the net cost from subsidizing products purchased was $US 18·98 per shopper, for a

Table 1 Characteristics of the female participants (*n* 781) in the online experimental supermarket (USA) by experimental group

	Control		Pricing		NP		Pricing + NP	
	n, Mean or %	SD	*n*, Mean or %	SD	*n*, Mean or %	SD	*n*, Mean or %	SD
*n**	193	–	196	–	197	–	195	–
Age (years)	43·1	8·6	42·4	8·2	42·4	8·8	41·6	7·8
BMI (kg/m^2)	31·1	7·9	30·9	8·2	30·8	8·0	31·3	8·6
Years of education	16·1	3·3	16·0	3·4	16·2	3·5	16·1	3·5
Family income ($US)	67 448	49 281	64 197	45 186	67 664	50 209	64 213	44 182
Minority (%)†	30·9	–	30·4	–	32·5	–	29·9	–
Assistance (%)‡	31·6	–	25·5	–	30·0	–	28·4	–
Family size	3·8	1·2	3·8	1·1	4·0	1·4	3·9	1·2
Hunger	3·8	1·6	3·8	1·7	3·7	1·7	4·0	1·6

NP, nutrient profiling.
*Not all participants reported income, minority or assistance. *n* for these three variables are as follows: Control (174, 191, 193); Pricing (180, 194, 196); NP (182, 197, 197); Pricing + NP (178, 194, 194).
†Minority refers to non-Caucasian.
‡Assistance refers to families receiving benefits from the Supplemental Nutrition Assistance Program (SNAP), the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) or the Home Energy Assistance Program (HEAP).

Table 2 Overall diet quality, energy and macronutrients, and diet cost (energy and macronutrients per dollar), of foods purchased, by group, in the online experimental supermarket (USA) and between-group differences

	Control		Pricing		NP		Pricing + NP		*P* value		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	NP	Pricing	Pricing + NP
NuVal® score	37·6	14·8	39·7	13·3	41·1	15·1	41·0	14·2	0·019	0·35	0·29
Energy and macronutrients											
Energy (kcal)	10 930·8	5574·0	11 067·3	5059·7	10 278·8	4429·3	11 056·6	5345·8	0·37	0·21	0·38
Fat (kcal)	3833·9	2622·9	3706·7	2194·4	3360·0	1834·7	3576·1	2301·7	0·06	0·78	0·29
Carbohydrate (kcal)	5466·5	2960·9	5690·1	2745·9	5353·4	2447·1	5766·8	2802·1	0·93	0·11	0·63
Protein (kcal)	1760·3	802·6	1807·7	732·1	1694·8	684·8	1860·3	786·1	0·90	0·048	0·27
Sugar (kcal)	2357·1	1302·2	2301·2	1350·6	2161·1	1137·5	2395·3	1319·5	0·58	0·33	0·11
Money spent per person											
Total $US	38·7	16·1	36·1	15·2	37·0	15·5	37·0	17·3	0·70	0·25	0·25
Diet cost											
Energy (kcal/$US)	82·0	37·3	90·3	35·1	78·6	35·4	84·3	29·4	0·057	0·005	0·60
Fat (kcal/$US)	28·8	20·3	30·2	16·3	25·4	14·1	26·6	13·0	0·003	0·25	0·93
Carbohydrate (kcal/$US)	40·8	19·4	46·0	18·6	41·1	19·7	44·2	17·6	0·60	0·002	0·45
Protein (kcal/$US)	13·4	6·2	15·2	6·7	13·0	5·7	14·6	5·3	0·22	< 0·001	0·77
Sugar (kcal/$US)	17·7	9·3	18·5	9·6	16·8	10·2	18·5	9·2	0·50	0·07	0·49

NP, nutrient profiling.

net cost of $US 16·72 per shopper in the tax/subsidy condition. Shoppers purchased $US 9·04 worth of foods that were taxed, with a tax of $US 2·26 on those foods, and shoppers spent $US 56·95 on foods that were subsidized that were worth $US 75·93.

Discussion

Results show that NuVal®, a type of nutrient profiling system that assigns a number value to foods based on consideration of over thirty nutrients, is associated with a significant, although small overall improvement (NuVal® scores increased from 38 to 41) in nutrient quality of foods purchased with or without a pricing manipulation. Changing prices of foods based on nutritional quality was not associated with an additional improvement in overall food quality.

It is interesting that in no case was the combination of price changes and nutrient profiling superior to either manipulation alone in improving purchasing. This may be due to people naturally focusing on one type of information when they are simultaneously presented, or that presenting both types of information results in information overload that reduces people's ability to improve decision making, rather than enhancing it. It is well known that presenting a wide variety of information can strain working memory capacity and result in more impulsive decision making, rather than improved decision making[34]. If this effect is observed in an experimental online supermarket, it is likely to be even more of a factor when people are shopping in a traditional supermarket and are bombarded with a wide variety of sensory inputs beyond that of food price or nutrient profile. It is also possible that the two approaches may have competing effects. For example, nutrient profiling may lead to better

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nutritional choices but subsidies may lead to purchasing more foods and the cheaper prices for healthier foods may lead to purchasing less healthy, 'indulgence' foods. This combination of seemingly complementary strategies could result in a null effect on purchasing.

The use of nutrient profiling and pricing approaches relies on the assumption that all shoppers will benefit from the same approach[35,36]. However, this may be too simplistic, as different approaches may be needed for shoppers with various health conditions such as obesity, diabetes, hypertension or hyperlipidaemia. On the other hand, there are common dietary improvements that could influence health across these conditions, such as reducing energy purchased, choosing low-glycaemic-index foods, reducing dietary sodium, and reducing total fat and saturated fat purchases[37]. Perhaps the biggest impact on health would be to help people maintain a healthy body weight[37], but none of the approaches tested here resulted in an overall reduction in energy purchased. This may be due in part to the fact that the NuVal® nutrient profiling system does not include energy or energy density as a major component of the NuVal® score. It is likely that improved nutrition would be beneficial to most shoppers, but the effect would be greater if there was improved nutrition in the context of a reduced-energy diet.

An important limitation of the current study is that participants shopped in the experimental supermarket on only one occasion and did not actually purchase the food chosen. Participants had only one occasion to experience shopping in the online supermarket, with 94 % of the sample never having shopped online for groceries. It may take multiple shopping experiences before people fully adapt to the changes in their shopping context and their purchasing habits stabilize. The use of one shopping experience limits the knowledge on whether the influence of the manipulations in the usual shopping context can be accurately estimated.

In addition, it is a limitation that participants did not purchase products they selected in the online supermarket. This may have caused them to put less emphasis on prices than they do in brick-and-mortar supermarkets. Further, the lure of winning the products they selected may have influenced them to select products they desired but do not normally purchase; the increased amount spent in the store *v.* usual shopping suggests this may be the case. Another limitation is that results may not be reflective of real-life price changes because participants' attention was drawn to the increases and decreases in price. Sales promotions have been shown to lead to an increase in sales of the promoted product[38], suggesting that in the pricing condition participants may have been influenced by the decreases in price which may have affected their shopping so that they 'stocked up' on products that were on sale. While it is common for supermarkets to advertise price reductions, price increases are normally not advertised. This was done in the present study because participants were informed of the NuVal® nutrient profiling system, which made it necessary to inform participants of price changes so that this was common to both independent variables and did not bias results towards the NuVal® manipulations. It is also possible that purchasing was influenced by social desirability bias. For example, participants in the NuVal® conditions may have purchased products with a higher NuVal® score either because they wanted to 'trade up' or because they thought we wanted them to 'trade up'. Social desirability is hard to eliminate, but future research should assess the degree of social desirability bias[39].

Experimenters were not blinded to participants' condition, but we attempted to reduce experimenter bias through training and using scripts to implement the protocol to ensure equivalent experiences across groups. Although participants were not told which condition they were randomized into, they could work it out based on the modifications in the online supermarket.

An important public policy implication of the study is the cost of implementing this policy, which was $US 16·72 for each shopping experience. The cost of implementing subsidies for foods with higher nutrient profile scores was much greater than the revenue gained from taxing foods with low nutrient profile scores. Of course, these values depended on the tax and subsidy amounts, and the specific foods that were taxed and subsidized. It might be expected that, over time, as the system is more effective at increasing (and subsidizing) purchases of high-nutrient-density foods and reducing (and losing money on taxes) low-nutrient-density foods, the imbalance will grow even greater. There is no research we are aware of that compares separate *v.* simultaneous taxes or subsidies, but policies that are closer to balancing the cost of the subsidy to the amount of revenue gained might consider increasing the number of items taxed, while reducing the number of items subsidized. For a pricing system to be revenue neutral, it may be necessary to tax more foods to generate sufficient resources to pay for the subsidies. One conceptual challenge for a taxing scheme is that the better it works to shift people from buying less healthy foods, the less money that is generated. Thus, it may only be possible to be revenue neutral if staples of the diet are also taxed. In our study we had the same proportion of foods that were taxed or subsidized, but this may not be the best formula for an effective public policy. Further research should focus on revenue-neutral policies that look at the best formulation for taxing and subsidizing products.

Experimental economics provides a platform for evaluation of public health approaches to food purchasing that can help policy makers make more informed decisions about policies to improve health. Premature use of ineffective approaches may reduce public confidence in the utility of these approaches to improve health and compromise their overall effectiveness. The combination of simultaneous pricing strategies to increase the cost of low-nutrient-density products and decrease the cost of high-nutrient-density products plus nutrient profile information did not improve quality of foods purchased. However, nutrient profiling was associated with a small but significant improvement in the overall quality of foods selected. There may be other ways to combine nutrient and cost systems that might produce additive or synergistic effects on purchasing. Research on more sophisticated public policies for improving diet quality of foods purchased are warranted and will require more research to recommend the best approach.

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