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The Cost of Dietary Variety: A Case of Fruit and Vegetables

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Abstract

The 2010 Dietary Guidelines Advisory Committee and MyPyramid recommend eating a variety of vegetables and fruit; for vegetables, this recommendation is coupled with specific weekly serving recommendations. This study used a linear programming model to show the cost of increasing variety in fruit and vegetable consumption when meeting the Dietary Guidelines for Americans fruit and vegetable consumption recommendations with no within-group variety. Efficacy of efforts to promote increased dietary variety may be limited by economic disincentives associated with purchasing a greater variety of fruit and vegetables.

Keywords: Dietary Variety, Linear Programming, Marginal Cost of Variety, Dietary Guidelines for Americans

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Introduction

The 2010 Dietary Guidelines Advisory Committee (DGAC) and MyPyramid recommend including a variety of different foods in the diet. Recommendations are age, gender, and physical activity dependent. Although no specific recommendations for variety are given for fruit, there are for vegetables, with specific amounts of the following categories being recommended: dark green, red/orange, dried beans/peas, starchy, and other. The 2005 Healthy Eating Index (HEI), developed by the US Department of Agriculture (USDA) in conjunction with the Center for Nutrition Policy and Promotion (CNPP), is a scoring system used to determine diet quality, with a higher score indicating a higher quality diet (Guenther et al., 2007). The score is determined by assessing a number of components, which taken together call for dietary variety: total fruit, whole fruit (non-juice), total vegetables, dark green and orange vegetables and legumes, total grains, whole grains, milk, meat and beans, oils, saturated fatty acids, and sodium. The previous HEI was less specific on types of vegetables, fruit, and grains, but an explicitly included component was “variety” (Kennedy et al. 1995), with the highest score for this component received if 16 or more different foods in three days were consumed.

Although dietary variety has been emphasized, little work has been done to estimate the cost associated with dietary variety. This is of particular importance given the higher cost associated with fruit and vegetables relative to many energy-dense, nutrient-poor foods (Drewnowski 2010), and the dramatic increases in food costs when variety is introduced, as shown in our study. We examined the cost of increasing dietary variety while meeting the MyPyramid recommendations. The objectives of the study were to determine: (1) the cost of increasing variety in a diet that meets the MyPyramid recommendations for intake of fruit and vegetables, and (2) how the magnitude of the marginal cost of variety for fruit and vegetable intake changes as the degree of dietary variety is increased.

Fruit and vegetables are naturally low in fat and saturated fatty acids, and have no cholesterol. They are also rich sources of dietary fiber; vitamins, including folate and vitamin C; minerals, such as selenium, magnesium, and potassium; and phytochemicals, including carotenoids and lutein. Consumption of fruit and vegetables is associated with a wide range of health benefits including reduced risk of coronary heart disease, hypertension, stroke, type 2 diabetes, and some types of cancer. A variety of forms, i.e. fresh, frozen, canned, 100% juice or dried, can be consumed to meet the requirements (MyPyramid). Despite extensive, coordinated public health campaigns by government collaboration with industry, most individuals do not meet the recommendations for fruit or vegetables (Blanck et al. 2008; Kimmons et al. 2009). Intake actually declined slightly from 1994-2005 (Blanck et al. 2008). Although there are a number of reasons why people do not consume fruit and vegetables, cost is likely to be a major reason.

Previous Studies

Foot et al. (2004) discussed three types of dietary variety: (1) total variety, which considers the total number of unique foods in the diet; (2) between-group variety, which considers the number of different food groups represented in the diet; and (3) within-group variety, which considers the number of different foods from within the same food group (e.g. carrots and sweet potatoes in the red/orange vegetable group category). However, while the Dietary Guidelines for Americans (DGA) endorses dietary variety and provides some information on variety among groups of

vegetables, specific recommendations are not given. The present study considers the issue of within-group variety and its impact on food cost.

Determining the health benefits of including a variety of foods in the diet has been of interest. McCrory et al. (1999) found that low variety of vegetables and high variety of sweets, carbohydrates, snacks, condiments, and entrees promoted long-term increases in energy intake, and were positively related to body fatness. However, heeding the warning of increased variety in energy-dense foods as noted by McCrory et al. (1999), Foote et al. (2004) emphasized the importance of increasing dietary variety to ensure nutrient adequacy while “maintaining a proper energy balance.” Dietary variety was found to be positively related to nutrient intake, negatively related to sodium and sugar consumption, and positively related to intake of Vitamin C (Drewnowski et al. 1997), which the 2005 DGAC identified as a shortfall nutrient in adults. Kant et al. (1993) counted the number of different food groups included in the diet (varying from 1 to 5) and found that individuals omitting one of the food groups were at a higher risk of early mortality. Steyn et al. (2006) found food variety and dietary diversity to be related to height-for-age and weight-for-age in South African children 1 to 8 years of age. Characterizing what is meant by an appropriate amount of food variety has been of interest (Kant 1996), with studies using various measures, one of the most recent being developed by Drescher et al. (2007). While these previous studies show evidence that dietary variety is important for human health, little work has examined the relationship between variety and food cost.

Socioeconomic status has been linked to consumption of a diet that includes variety (Darmon and Drewnowski 2008). Older people obtain greater dietary variety than younger people (Drewnowski et al. 1997), with McCrory et al. (1999) finding this result specific to vegetables. Estaquio et al. (2008) found that, among French adults, those more likely to meet the 5-a-day fruit and vegetable recommendation were older, more highly educated, moderate alcohol drinkers, nonsmokers, and, in the case of women, engaged in greater physical activity. These studies did not, however, focus on whether the cost of dietary variety impacted consumption among the demographic groups studied.

Economists have also shown interest in determining factors associated with increased dietary variety. Lee and Brown (1989) found food expenditure to be positively related to overall dietary variety. Stewart and Harris (2004) found that vegetable expenditures were positively related to vegetable variety. Thiele and Weiss (2003) and Moon et al. (2002) studied the demand for variety in Germany and Bulgaria, respectively. Both found dietary variety to be positively associated with consumer income.

A number of studies have used linear programming (LP) in the development of individual diets. Increasing the weights of cost constraints (to reduce the overall cost of the diet) on average French diets had detrimental effects on diet (Darmon, Ferguson, and Briend 2002). This finding was consistent with results of Drewnowski and Specter (2004), which noted energy-dense foods cost less than more nutrient-dense, less energy-dense, foods (i.e. fruits and vegetables). The present study utilizes LP models to examine the impact of dietary variety on food costs.

Previous studies in this journal have dealt with consumer acceptance of various foods (Haines 2000; Regmi and Unnevehr 2006) and food accessibility (Godwin and Tegegne 2006), but we are aware of none that have addressed the cost of dietary variety.

Data

Since an LP model was used to examine the impact of increasing fruit and vegetable variety on food cost, prices of a variety of food items were required. Cost per consumable cup (terminology used by Cassady, Jetter, and Culp (2007), discussed in greater detail later) of each of 101 fruit and vegetable items was calculated using their respective average cost per ounce across 60 large full-service grocery stores in the Baton Rouge, LA, metropolitan area. Fruit and vegetable prices were recorded over a 3-week period in 2009: January 5 – January 24. Limiting the period to 3 weeks allowed for examination of prices at one point in time, with minimal variation in prices.

Six individuals were involved in collecting the data: two faculty members, two research associates, and two students in the Department of Agricultural Economics and Agribusiness and the School of Human Ecology at Louisiana State University. The group conducted the first collection of supermarket pricing data together and discussed how to handle situations such as when a product was missing or a designated product size was unavailable. This was done so as to ensure consistency among recorders. The lowest-priced item within the designated size category was recorded, regardless of brand. If a sale item was available for the item / size / form combination and it was the lowest-priced, then it was recorded. It is recognized that optimal combinations of fruit and vegetables chosen by the LP model would change by season, but the impact of variety on cost would likely be similar to that found in the present study. Of the 60 stores, 26 were independents, 11 were considered supercenters (Wal-Mart or Super Target), and 23 were other national or regional chain stores.

Cost per ounce was calculated for each fruit or vegetable item. Fresh produce items may be priced on a piece or per pound basis. For items priced by piece, the USDA National Nutrient Database for Standard Reference-22 (SR-22) was used to determine the average weight of an individual produce item. When there were multiple sizes available from which to choose for weight designation, the medium size was selected. From that size, an average weight was provided by SR-22. From that weight and price collected from the store survey, a cost per ounce was determined. The cost per ounce for each item was then averaged across the 60 stores.

To convert from cost per ounce to cost per consumable cup, the following method was used. The MyPyramid lists daily and weekly dietary recommendations in terms of consumable cups, so price per consumable cup was calculated for each fruit or vegetable, in accordance with SR-22. Similar to Cassady, Jetter, and Culp (2007), price per consumable cup of each fruit or vegetable was calculated accounting for refuse, since a portion of each item is not consumable (e.g., an apple has 10% refuse). Grams per consumable cup and amount of non-refuse associated with each fruit or vegetable item was determined via SR-22.

Methodology

Fruit Linear Programming Model

For a 2000-kcal diet, the MyPyramid recommends consuming 14 cups of fruit per week. This is the recommendation for males ≥ 14 years and women 19-30 years of age (thus, the largest segment of the population). For our study, the goal was to find the cost minimizing combination of

fruit that met the weekly fruit intake recommendations, while introducing variety constraints to determine how increasing within-group variety impacted the total cost of one week's consumption of fruit. As such, the objective function of the LP model was to minimize the cost of meeting the MyPyramid dietary weekly fruit consumption recommendations for this diet:

$$(1) \text{ Minimize } Z = \sum_{f=1}^{24} c_f x_f$$

where c_f is the cost per consumable cup of fruit type f (there were 24 fruit types available in the store survey database) and x_f is consumable cups of fruit type f . Z is minimized subject to a weekly fruit consumption constraint, $\sum_{f=1}^{21} x_f \geq 14$, and fruit variety constraints, $\sum_{f=1}^m x_f \geq \text{RHS}$, where m is the number of fruits introduced into the diet over the one-week period and RHS is the right-hand side value, which is dependent on degree of variety. In addition, $x_f \geq 0$ for $f = 1 \dots 24$.

Table 1 shows selected fruits ranked from lowest to highest in price per consumable cup. By adjusting RHS values for the fruit variety constraints (thereby adjusting the limits of variety), each fruit was introduced sequentially to the LP model to add variety in ascending order from the lowest cost per consumable cup to the highest. With adjustment of the RHS values for variety constraints, products were introduced to evenly distribute the consumed amount of each fruit.

Table 1. Fruit Average Price Per Consumable Cup Ranked from Lowest to Highest Cost.

Fruit Item ($n = 14$)	Average Price Per Consumable Cup of Fruit Ranked Low to High
Fresh orange juice (may be sold as reconstituted from concentrate)	\$0.29
Bananas	\$0.38
Apples	\$0.41
Canned pineapple	\$0.61
Bartlett pears	\$0.63
Nectarines	\$0.71
Peaches	\$0.73
Canned fruit cocktail	\$0.82
Grapes	\$0.82
Plums	\$0.94
Avocados	\$1.04
Watermelon	\$1.22
Cantaloupe	\$1.47
Grapefruit	\$1.48

Additional fruit considered but not included because of higher price or a different form of the same fruit includes applesauce, blueberries, canned peaches, canned pears, frozen concentrate orange juice, mandarin oranges, navel oranges, satsumas, and strawberries.

For example, to ensure at least two fruit types were included in the solution, RHS values of the fruit variety constraints for both the second-least expensive fruit, bananas, and the least expensive fruit, fresh orange juice (this may be from concentrate, but not sold in frozen concentrate form), were seven. These constraints ensured that the individual consumed seven cups of each product for the week. Remaining variety constraints were introduced in a similar manner, with RHS values adjusting for all of the products as each additional fruit item was introduced. Variety constraints extend only to 14 to allow for the smallest portion of each fruit consumed to be one consumable cup. In cases where there were multiple forms of the same fruit, such as frozen concentrated orange juice and fresh orange juice, or fresh and canned peaches, only the less expensive item was introduced for variety. We do not assume that each of the items is “nutritionally equivalent,” whether by type of fruit (e.g., orange or apple) or form (e.g., canned or fresh).

Vegetable Linear Programming Model

For a male aged ≥ 14 years, the MyPyramid recommends 21 cups of vegetables per week, with designated numbers of consumable cups in 5 separate vegetable categories. Table 2 (see Appendix) shows the 5 vegetable groups and MyPyramid recommendations for associated 1-week vegetable intake in consumable cups. Also shown are the vegetables from our store survey list belonging in each group. The survey list included 80 vegetable items, in fresh, frozen and canned forms. The LP model developed to assess the cost of increasing the degree of variety of vegetables in the weekly diet included constraints to ensure the individual would meet the MyPyramid recommendations for minimum consumption of each vegetable group. Thus, the model assessed the cost of adding greater variety by introducing constraints that increase variety within each vegetable group, for within-group variety.

The objective function was to minimize the cost of meeting the MyPyramid weekly vegetable consumption recommendations for a male aged ≥ 14 years:

$$(2) \quad \text{Minimize } Z = \sum_{t=1}^5 \sum_{n=1}^{80} c_{t,n} x_{t,n}$$

where $c_{t,n}$ is the cost per consumable cup of vegetable t , product n and $x_{t,n}$ is the consumable cups of vegetable t , product n . Similar to the procedure with fruit, price per consumable cup of vegetables for each vegetable category was ranked from lowest to highest to determine which products yielded the lowest cost of meeting the weekly dietary vegetable requirement of 21 consumable cups. Since MyPyramid has additional recommendations on numbers of consumable cups within each vegetable group, for each group, a constraint was introduced to ensure consumption of at least the required number of consumable cups. Thus, Z is minimized subject to: $\sum_{n=1}^{80} x_{t,n} \geq 21$, the weekly vegetable consumption constraint; $\sum_{n=1}^{12} x_{1,n} \geq 3$, the dark green vegetable consumption constraint; $\sum_{n=13}^{21} x_{2,n} \geq 2$, the orange vegetable consumption constraint; $\sum_{n=22}^{38} x_{3,n} \geq 3$, the dry beans and peas consumption constraint; $\sum_{n=39}^{48} x_{4,n} \geq 6$, the starchy vegetable consumption constraint; $\sum_{n=49}^{80} x_{5,n} \geq 7$, the other vegetable consumption constraint; and $\sum_{f=1}^n x_{t,n} \geq \text{RHS}$, the vegetable variety constraints, where n is the number of vegetables introduced into the diet. Variety constraints were applied within each vegetable group and varied in both the number of vegetables n and the RHS, depending on the vegetable group composition and consumption recommendations for each group. In addition, $x_{t,n} \geq 0$ for $t = 1 \dots 5$ and $n = 1 \dots 80$.

Variety constraints became binding as additional variety was forced into solution, similar to the fruit model. However, since vegetables had multiple categories, for subsequent variety constraints, an additional vegetable was added to each of the vegetable categories. As with fruit, the smallest serving for each vegetable was set as one consumable cup. Once the within-group variety of vegetables reached an evenly distributed number and servings of one cup of each vegetable group were in solution, no further variety constraints were added for that group. In cases where there were multiple forms of the same vegetable, such as canned whole potatoes and fresh baking potatoes, only the lowest priced was included. In the case of starchy vegetables, there were only four different starchy vegetables in the database, so only four variety constraints could be added.

Results

Fruit Analysis

Fruit LP model results are included in Table 3 and Figure 1. The minimum cost of 14 consumable cups of fruit per week was estimated to be \$4.05, which would be obtained if an individual consumed only fresh orange juice to meet the recommended weekly fruit requirement. It is noted, however, that the DGA recommends no more than one-third of fruit servings come from 100% fruit juice. Consuming a different fruit for each consumable cup per week cost \$11.49, which can be considered the total cost (TC). The marginal costs associated with introducing each additional degree of variety (we term this the marginal cost of variety, MCV) are also shown.

Table 3. Total Cost and Marginal Cost of Variety for Increased Variety, Meeting the MyPyramid Fruit Intake Recommendations; Fruit Costs Averaged for 60 Large Grocery Stores.

Degree of Variety	Total Cost for Weekly Fruit Servings of 14 Consumable Cups	Marginal Cost of Variety
1	\$4.05	...
2	\$4.68	\$0.63
3	\$5.02	\$0.34
4	\$5.88	\$0.86
5	\$6.46	\$0.59
6	\$7.03	\$0.57
7	\$7.49	\$0.46
8	\$7.90	\$0.41
9	\$8.29	\$0.39
10	\$8.79	\$0.50
11	\$9.30	\$0.51
12	\$9.93	\$0.63
13	\$10.81	\$0.88
14	\$11.49	\$0.68

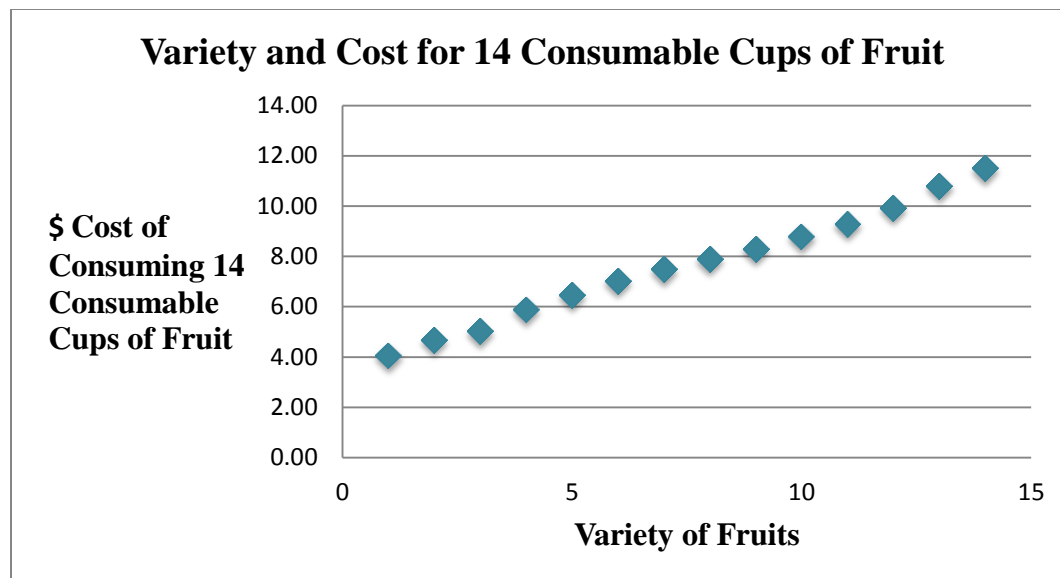


Figure 1. Plot of Points for the Cost of Consuming 14 Consumable Cups of Fruit for an Increasing Degree of Variety.

Results show that the TC increases as numbers of fruit included in the weekly fruit diet increase. The MCV remains positive as variety increases, fluctuating somewhat depending upon the prices of each additional fruit entering the weekly fruit consumption, so the MCV would not necessarily be a “smooth” graph. What is particularly striking is that full variety (14 different fruit types) costs nearly three times as much as the no-variety scenario. If greater refuse is associated with greater variety (and this is reasonable to expect since some fruit are not expected to be available in 1-cup servings), then the magnitude of differences would be greater, with higher MCVs.

Vegetable Analysis

Vegetable LP results are shown in Table 4 and Figure 2. The minimum cost for an individual to consume the recommended 21 consumable cups of vegetables per week, while also eating the recommended level of vegetables in each vegetable category, is estimated to be \$5.13. Note that this minimum cost assumes a degree of between-group variety, as one vegetable from each of the five vegetable categories is consumed. However, since only one vegetable in each category is consumed, there is no within-group variety. Similar to the LP results for fruit and as expected, the MCV remains positive as variety is increased – or an additional vegetable is introduced in each category. The MCV generally increases at a decreasing rate, partly because the maximum number of one-cup servings is reached at two cups for orange vegetables, three cups for dark green vegetables and dry beans, and four cups for starchy vegetables, so less and less additional variety is introduced as more variety is introduced in the “other vegetables” group. As with the fruit model, changes in the MCV were not uniform in magnitude, fluctuating as variety was introduced. Because there is significant between-group variety even with the least variety in the vegetable group, and within-group variety does not increase to the degree it does with fruit (for example, only two vegetables in the orange vegetable category versus 14 in the fruit group constitute full variety), the increase in cost is not as extensive as it is with fruit. For vegetables, the increase is from \$5.13 with no within-group variety to \$6.90 with full variety.

Table 4. Total and Marginal Costs of Meeting the MyPyramid Vegetable Intake Recommendations; Vegetable Costs Averaged for 60 Large Grocery Stores.

Degree of Variety	Cost for Weekly Vegetable Servings of 21 Consumable Cups	Marginal Cost of Variety
1	\$5.13	...
2	\$5.76	\$0.63
3	\$6.04	\$0.28
4	\$6.46	\$0.42
5	\$6.66	\$0.20
6	\$6.79	\$0.13
7	\$6.90	\$0.11

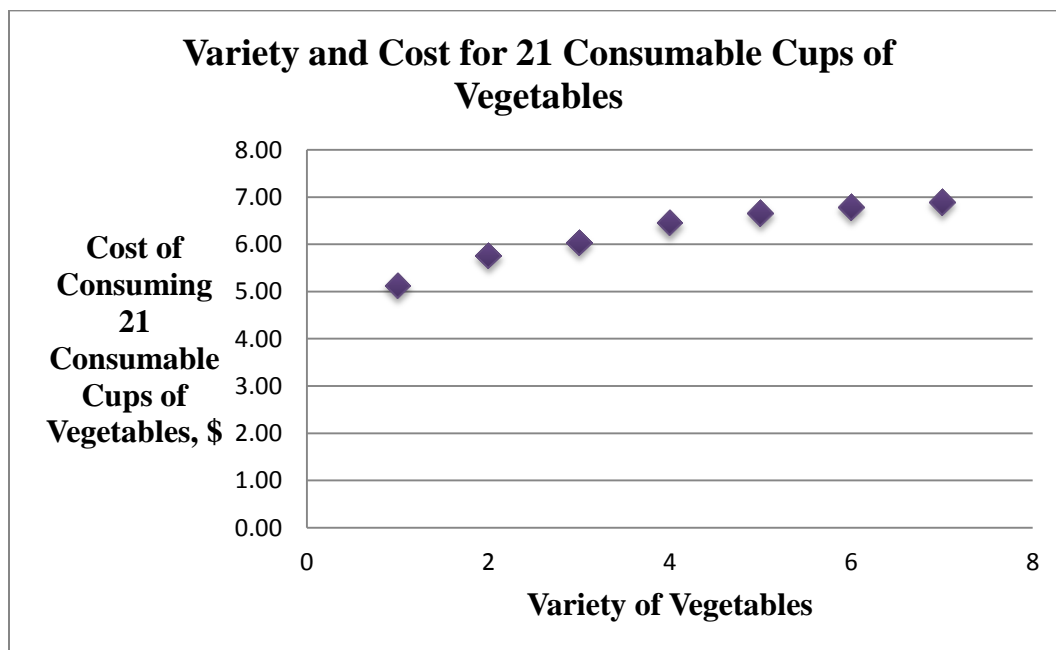


Figure 2. Plot of Points for the Cost of Consuming 21 Consumable Cups of Vegetables for an Increasing Degree of Variety.

Conclusions

Results of this study showed that increasing the degree of within-group variety for both fruit and vegetables increased the cost of meeting the MyPyramid recommendations. The analysis showed, based on average costs of fruit and vegetables at large grocery stores in the Baton Rouge, LA, metropolitan area, that as variety increases within both the fruit and vegetable categories, the cost of meeting the weekly MyPyramid recommendations for each food group also increases. The MCV for fruit remained positive as degree of variety was increased, and the magnitude was striking. In the case of vegetables, induced binding of the last few variety constraints caused the MCV to increase throughout, but meeting between-group variety constraints throughout led to less dramatic increases in TC from “no within-group variety” to full within-group variety.

The Centers for Disease Control and Prevention has replaced the “5 A Day” program with the “Fruits and Veggies-More Matters” campaign to promote the consumption of a greater variety of fruit and vegetables to promote better health. Our study showed that, for the vegetables and fruit we priced, assuming one-cup servings, maximizing the variety included in a diet of fruit and vegetables that meets the MyPyramid recommendations costs more than double the amount associated with no dietary variety. The totals are \$9.18/week (\$4.05 fruit + \$5.13 vegetables) for no variety and \$18.39 (\$11.49 fruit + \$6.90 vegetables) when adequate variety is accounted for. Thus, for a male aged ≥ 14 years, moving from no fruit variety to complete variety (defined in this study as 14 different items over the course of the week) while meeting the DGA would increase the cost of fruit by almost \$30/month. The results for vegetables are less dramatic, assuming between-group variety is maintained throughout, but within-group variety increases. These results assume all purchased fruit and vegetables were consumed (no refuse), an assumption that is limiting since some fruit and vegetable products are not available as one piece, but as bunches, cans with >1 cup, etc. Our MCV estimates would thus be “on the low side” if refuse increases with variety. In all, this suggests that consumers have rather strong economic incentives to limit the variety of foods consumed. The efficacy of advocacy efforts for increased dietary variety such as the “Fruits and Veggies-More Matters” campaign may be constrained by the correlation of rising costs with increased fruit and vegetable variety for patrons of large grocery stores, especially among low-income consumers.

The USDA Food and Nutrition Service has advocated the use of Supplemental Nutrition Assistance Program (SNAP) benefits at farmers’ markets and other venues that sell assortments of fruit and vegetable items. Such efforts may be an important component in improving the economic incentives of consumers to purchase and consume fruit and vegetables in order to meet the MyPyramid fruit and vegetable recommendations. However, greater variety without specific program provisions to encourage it is unlikely if SNAP benefits are not high enough to cover the costs associated with variety.

A limitation to this study is that we surveyed stores once, during January, 2008, in one metropolitan area. Due to seasonality, the specific food economic environment of 2008, and location, prices of specific items are not expected to be entirely representative of those to be found during a different season, year, or location. As such, the magnitudes of MCV and TC will differ somewhat depending upon those factors. However, the concept of an increasing TC and associated positive MCV will hold, and in general, the cost of variety is likely to be substantial.

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Appendix

Table 2. List of the 5 Vegetable Groups with Consumption Recommendations

Vegetable Groups	MyPyramid Weekly Recommendation Male ≥ 14 Years Old	Products Introduced with Successive Increases in Variety Constraints, Low to High Costs	Price Per Consumable Cup	Other Vegetables Not Chosen by LP Model Due to Higher Price
Dark Green	3	1) Fh romaine lettuce 2) C turnip greens 3) C spinach	1) \$0.36 2) \$0.48 3) \$0.48	Fh broccoli, fh spinach, fh collard greens, fh kale greens, fh mustard greens, fh turnip greens, fz broccoli, fz spinach, fz mustard greens
Red/Orange	2	1) Fh whole carrots 2) C yams	1) \$0.30 2) \$0.39	Fh sweet potatoes, fh butternut squash, fh acorn squash, c carrots, c sweet potatoes, c pumpkin, fz carrots
Dry Beans and Peas	3	1) C black beans 2) C black-eyed peas 3) C kidney beans	1) \$0.36 2) \$0.44 3) \$0.44	D black beans, d black-eyed peas, d kidney beans, d lentils, d lima beans, d pinto beans, d great northern beans, c baked beans, c lima beans, c garbanzo beans, c great northern beans, c pinto beans, fz lima beans
Starchy	6	1) Fh red potatoes 2) C green peas 3) Fh baking potatoes 4) C whole kernel corn	1) \$0.28 2) \$0.31 3) \$0.31 4) \$0.45	Fh corn on the cob, c creamed corn, c white potatoes, fz green peas, fz corn
Other	7	1) Fh green cabbage 2) Fh cucumbers 3) Fh red cabbage 4) C cut green beans 5) Fh eggplant 6) Fh yellow onions 7) Fh iceberg lettuce	1) \$0.11 2) \$0.14 3) \$0.18 4) \$0.25 5) \$0.31 6) \$0.31 7) \$0.32	Fh brussels sprouts, fh cauliflower, fh celery, fh green pepper, fh okra, fh green onions, fh radishes, fh yellow squash, fh zucchini squash, fh green beans, fh red beets, fh turnips, c artichokes, c asparagus, c beets, c mixed vegetables, c mushrooms, c okra, c okra and tomatoes, c diced tomatoes, fz cauliflower, fz green beans, fz mixed vegetables, fz cut okra

C=canned, D=dried, Fh=fresh, Fz=frozen