The Welfare Effects of Consuming a Cancer Prevention Diet

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by

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ABSTRACT

This study measures the welfare changes in agriculture and to consumers should people eat the recommended levels of fruits and vegetables for a cancer prevention diet. An equilibrium displacement model is used to measure the change in welfare to fruit and vegetable industries, other commodities, and agricultural input markets.

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INTRODUCTION

This study measures the costs and benefits to agricultural industries and consumers should people eat the recommended levels of fruits and vegetables for a cancer prevention diet. Eating the recommended levels would cause the demand for fruits and vegetables to rise significantly, shifting the use of agricultural resources (such as land, labor and other purchased inputs) and benefiting agricultural industries.

Increased consumption of fruits and vegetables has been linked to a decrease in the risk of cancer. In a review of 196 epidemiology studies, scientists determined that the link between fruit and vegetable consumption and a lower incidence of cancer was probable (WCRF and AIC 1997). In addition, convincing evidence exists linking the consumption of specific fruit and vegetable groups to a reduction in certain types of cancers. For example, eating dark vegetables has been associated with a lower incidence of lung and stomach cancers. Therefore, the cancer risk reduction diet provides recommendations for the composition of fruit and vegetable consumption, as well as the total level.

USDA recommendations for a 2,200 calorie diet are 3 fruit servings and 4 vegetable servings a day (McNamara et al 1999). The more specific recommendations for fruit are at least one serving from the citrus/berry/melon group and at least two additional servings of any fruit. Two programs were developed for vegetables. The first recommends at least one serving of dark colored vegetables, one serving of salad, one half serving of a starchy vegetable and one and a half servings of any other vegetable. The second program further disaggregates the vegetable recommendations.

In addition to the recommendations for dark, salad, and starchy vegetables, at least one half serving of cruciferous vegetables, 0.3 servings of tomato, and 0.7 servings of any other vegetable is advised.

Despite the known benefits, many people do not eat recommended levels of fruits and vegetables. In some cases the gap between average and recommended consumption is quite large. McNamara et al. estimate that consumption of dark vegetables would need to increase by over 300 percent in order to meet minimum recommendations (1999).

CURRENT CONSUMPTION OF FRUITS AND VEGETABLES

Current consumption of fruits and vegetables is far below recommended levels. Based on the California Survey of Dietary Practices, average consumption of fruits is 1.85 servings a day and average consumption of vegetables is 1.89 servings (Table 1). Fruit consumption would need to increase by 62 percent and vegetable consumption by 113 percent to achieve the minimum recommendation.

When categories are broken down into subgroups, greater variation in meeting targeted levels is apparent. California consumers come closest to meeting the target level for tomatoes. A 15 percent increase in this vegetable is all that is needed to meet recommendations. At the other end of the spectrum, consumption of dark vegetables would need to increase by over 200 percent.

The consumption levels calculated from the California Survey on Dietary Practices are consistent with the results of estimates from national studies for most food categories (Table 2). National consumption of fruits and vegetables has been estimated from the Continuing Survey of Food Intakes by Individuals (McNamara et al 1999; Tippett and Cleveland 1999) and from food supply data (Kantor 1998).

The main difference between the California data and the US data is in the consumption of starchy vegetables such as potatoes and sweet corn. US consumption is more than one serving per day greater than California consumption.

Table 1. Recommended and Actual Consumption Levels

	Servings per Day		Percent Increase
	Recommended	Actual	Needed
Fruit			
Citrus, Melon, Berry	1	0.763	31
All other fruit	2	1.090	83
Total Fruit	3	1.853	62
Vegetable 1			
Starchy	0.5	0.249	101
Salad	1	0.492	103
Garden	1.5	0.826	82
Dark	1	0.310	223
Total Vegetable		1.877	113
Vegetable 2			
Starchy	0.5	0.249	101
Dark*	1	0.310**	223
Cruciferous*	0.5	0.192**	160
Dark non cruciferous		0.209	
Dark cruciferous		0.102	
Garden cruciferous		0.091	
Tomato	0.3	0.260	15
Salad	1	0.492	103
Garden non cruciferous	0.7	0.475	47
Total Vegetable		1.877	113

*Dark = Dark non cruciferous + Dark cruciferous.
*Cruciferous = Garden cruciferous + Dark cruciferous.
**Not counted in total as the dark cruciferous category would be counted twice.
Source: California Department of Health Services Bi-annual Consumption Surveys.

Part of the difference is attributable to the inclusion of potato chips and french fries in the US data, and their absence in the California estimates. US consumers are eating about 0.7 servings of these potato products a day (Kantor 1998). When adjusted, US consumption of starchy vegetables is 0.58 to 0.7 servings a day. On average, Californians eat more fruit, but fewer vegetables, than US consumers, even when the US data are adjusted by removing potato chips and french fries from the vegetable estimates.

Table 2. Comparison of Results of Food Consumption Studies

	California	CSFII	Food Supply
Citrus, Melon, Berry	0.76	0.74	0.6
Other Fruit	1.09	0.76	0.7
Total Fruit	1.85	1.5	1.3
Dark Vegetable	0.31	0.32	0.3
Starchy Vegetable	0.25	1.28*	1.4*
Other Vegetable	1.32	1.53	1.9
Total Vegetable	1.88	3.13	3.6
Total	3.73	4.63	4.9

*Includes potato chips and french fries

Agricultural industries stand to benefit significantly should consumers achieve the recommended levels of consumption in fruits and vegetables. As the largest producer of fruits and vegetables in the country, California would especially benefit.

The annual value of California production of 25 principal vegetables and melons is $4.4 billion (USDA 1999a). This is 55 percent of the total value of US production of $8 billion. California's share of US fruit production is about the same. California annual fruit production value is $6 billion, just over 55 percent of the US value of $10.7 billion.

Within California, 26 percent of farm receipts are from vegetable production and 29 percent of farm receipts from fruit and nuts (Kuminoff et al., 2000).

California accounts for over 99 percent of national production of artichokes, Brussel sprouts, dates, figs, kiwi, clingstone peaches, persimmons, prunes, and raisins. It accounts for at least 50% of U.S. production of table grapes, wine grapes, lettuce (head, leaf and romaine), strawberries, broccoli, plums, celery, carrots, avocados, fresh market oranges, cauliflower, honeydew, cantaloupes, and processing tomatoes. While it produces less than 50 percent of the US production of spinach and asparagus, California is still the largest producer of these items.

The shift in demand toward more fruits and vegetables would be met through increases in imports from other regions, including the rest of the US, a reduction in California exports to the domestic market, and increased production from within California. The ability of California growers to increase production depends on the resources, such as land, labor and other purchased inputs, at their disposal. O'Brien was the first to address the issue of resource availability (1997). Other researchers have discussed the potential for supply increases from trade, acreage adjustments, and other purchased inputs (Abbott 1999; Young and Kantor 1999).

California has over 27.7 million acres devoted to agricultural production (USDA 1999a). Harvested cropland accounts for 8.5 million acres, with 3.5 million acres used for fruits and vegetables. Labor and other input costs to produce commodities on that acreage account for over half of all farm expenses. Total farm expenses were $16.8 billion in 1997 (USDA 1999a). Hired labor was the single largest category at $3.4 billion.

In total, expenses for hired labor and other purchased inputs such as fertilizers, petroleum products, and pesticides were $5.5 billion, about a third of total farm expenses.

ANALYTICAL MODEL

The benefits to the agricultural sector of greater fruit and vegetable consumption will be measured by estimating the changes in consumer and producer surplus from an equilibrium displacement model. The dual approach used in this analysis lays out basic demand and supply equations from demand and cost functions to show how equilibrium conditions change in response to shocks, such as an increase in the demand for fruits and vegetables. The functions characterize the final market, allow for substitutability between marketing and non-marketing inputs in the marketing sector, includes the farm sector, and changes in input use resulting from changes in crop mix and substitutability in land, labor and other inputs. The model is parameterized with farm, market and consumption data. The increase in fruit and vegetable consumption is modeled as a shift in the demand curve with the shift equal to the percentage increase needed to meet the recommendations of a cancer prevention diet.

An increase in fruit and vegetables as described about will have a major impact on fruit and vegetable industries in the U.S. For states with a large share of production in fruits and vegetables, such as Florida and California, significant shifts in the production of other crops may also occur as inputs are moved into producing fruits and vegetables. Moving inputs from one use to another is not cost free. Therefore, other commodities will also be included in the analysis. The model focuses on increases in demand for fruits and vegetables by California; however, the impact on agricultural industries in other major fruit and vegetable producing states is incorporated into the analysis. The complete mathematical model is in the Appendix. Equilibrium displacement models have been widely used to estimate the benefits of agricultural research (Alston, Norton and Pardey 1995), agricultural policies (Sumner and Lee 1997) and the benefits to the dairy industry of a social marketing program to middle school children (Alston, Chalfant and James 1999).

The advantage of simulating an equilibrium displacement model is that it does not require estimating the underlying demand curves. The supply and demand functions are log-linear approximations to the underlying curves. For small changes in demand they provide estimates of surplus changes that are a close approximation to the actual values (Alston, Norton and Pardey 1995). Another advantage is that it can be estimated with readily available information (Alston, Norton and Pardey 1995).

The main disadvantage is that the larger the shock to the system, the more biased is the estimate of surplus changes. However, this is true for any model where the demand curve is an approximation.

The demand equations take into account the shift in demand to eating more fruits and vegetables and consumer responsiveness to prices. The supply equations take into account all sources of supply, including imports, exports, and domestic production, and grower responsiveness to price changes. The equations also model the changes in resource use for inputs such as land, labor and other purchased inputs.

DATA

Only those fruits and vegetables for which both consumption and production data exist will be included (Table 3). These fruits and vegetables account for about 88 percent of total consumption. Even though consumption of winter squash and summer squash was greater than some of the other vegetables on the list, they are not included because the production data did not match up with the consumption data. Also, some items from the consumption surveys, such as mixed fruit salad, could not be allocated to any specific food items. Therefore, unspecified fruits and vegetables were excluded from the analysis. The remaining excluded commodities account for about five percent of total food consumption.

Significant shifts in the production of other crops may occur in California as inputs are moved into producing fruits and vegetables. Moving inputs from one use to another is not cost free. The production of alfalfa will decrease, potentially causing alfalfa prices to rise. Also, more labor is used to produce fruit and vegetable crops than field crops (Oliveira et al. 1993). If acreage is converted from field crops into fruit and vegetable production, the demand for farm labor will increase. If net farm labor demand increases, wages may increase for all farm laborers, raising the production costs for field, nursery and nut crops. Because other crops are affected by the increase in fruit and vegetable production, commodities such as cotton, hay, rice, and nuts must also be included in the analysis.

Table 3. Fruits and Vegetables that will be included in the analysis

Fruit		Vegetables	
Apple	Nectarines	Artichokes	Cucumbers
Apple Juice	Orange Juice	Asparagus	Eggplant
Apple Sauce	Oranges	Beans, Snap	Lettuce
Apricot	Peaches	Beets	Mushrooms
Avocado	Pears	Bell Peppers	Onions
Banana	Pineapple	Broccoli	Peas
Cantaloupe	Pineapple Juice	Brussel Sprouts	Potatoes
Grape Juice	Plums	Cabbage	Spinach
Grapefruit	Prunes	Carrots	Sweet Corn
Grapefruit Juice	Raisins	Cauliflower	Tomato, Fresh
Grapes	Strawberry	Celery	Tomato, Processing
Honeydew	Watermelon		
Mangos			

In order to estimate the equilibrium displacement model data are needed on the current level of consumption of different food items and on total annual consumption in California, US and California crop production and value, imports, exports, elasticities, and agricultural inputs. The data on current levels of specific food items will allow us to estimate the shift in demand needed to meet targeted levels. The data on annual consumption is needed to calculate the change in consumer surplus.

Data on current consumption of fruits and vegetables

Biennial fruit and vegetable consumption data by Californians were provided by the California Department of Health Services for the years 1989 to 1999. The data were recorded according to how the food was prepared. Therefore, total consumption of a food item is equal to the sum of servings for the prepared item. For example, total consumption of cabbage is equal to consumption of cabbage plus sauerkraut plus coleslaw plus an allocation from the soup and mixed vegetable categories.

In some cases, more than one food was used to prepare the final product. When the prepared item contained two fruits or vegetables, 50 percent of the serving was allocated to each food item. When more than two are included, the allocation is slightly more complicated.

The shift in demand for fruits and vegetables was determined for the fruit and vegetable groups, and for different sub-groups. The fruit sub-groups include the citrus/melon/berry group and all other fruit in another one. The vegetable 1 sub-groups include starchy, salad and dark, plus a garden category for all vegetables not included in the first three categories. For the vegetable 2 sub-groups the garden category is further disaggregated into a tomato and cruciferous sub-group.

The shift in demand for fruits and vegetables needed to reach the minimum recommended servings was determined after current consumption for each food item was calculated. Three different scenarios were developed to determine this shift. The first was to increase all items by the same amount. The second was to increase specific sub-groups to meet targeted amounts, and then increasing all commodities equally. For fruit, the citrus/melon/berry sub-group target needed to be met. For vegetable group 1, the sub-groups of interest are starchy, salad, and dark. These sub-groups are also included in the vegetable group 2, plus the tomato and cruciferous targets are also met before increasing consumption of all vegetables by the same amount. The final method used to calculate the shift needed in consumption is to increase all sub-groups to a targeted amount. Note that, within the sub-groups, each commodity increases by the same amount. For example, consumption of oranges, grapefruit, strawberries and cantaloupe will each increase by 35 percent in order to reach the recommendation of at least one serving from the citrus / melon / berry group.

If consumption of all fruits increases by the same amount, then the minimum recommendation for the citrus / melon / berry group will be met (Table 4). Consumption of citrus / melon / berry increases the most when the targets for that group are met, then consumption is increased by the same amount for all fruits. However, consumption in the citrus / melon / berry category increases the least when the shift is by individual targets. The shift in this category ranges from a low of 35 percent to a high of 91 percent depending up the method used. The reverse happens for other fruits. Consumption increases the most when individual targets are used to determine the demand shift and least when specific sub-group targets are met before increasing consumption of all fruits. Again, a wide range in values is observed in the magnitude of the consumption shift, though not as large as in the citrus / melon / berry category.

Table 4. Consumption Shifts for Fruit Group

		Scenarios for Increases in Consumption					
		All by the same amount		Vitamin C group meets target, then all by same amount		Each group meets individual targets	
	Original Level	New Level	Increase	New Level	Increase	New Level	Increase
Citrus, Melon, Berry	0.763	1.175	61%	1.385	91%	1	35%
All other fruit	1.090	1.825	61%	1.615	41%	2	77%
Total	1.853	3		3		3	

Increasing all vegetable categories by the same amount will not result in achieving the minimum daily recommendation for the dark vegetable category (Table 5). As stated previously the gap between current and actual consumption of dark vegetables is greatest for this sub-group. All other categories reach the recommended levels when the increase is the same for all vegetables.

Table 5. Consumption Shifts for Vegetable Group 1

		Scenarios for Increases in Consumption					
		All by the same amount		Starchy, salad and dark targets met, then all by the same amount		Each group's individual targets met	
	Original Level	New Level	Increase	New Level	Increase	New Level	Increase
Starchy	0.249	0.580	133%	0.611	145%	0.500	101%
Salad	0.492	1.148	133%	1.222	148%	1.000	103%
Garden	0.826	1.595	133%	0.954	22%	1.500	117%
Dark	0.310	0.677	133%	1.214	328%	1.000	250%
Total	1.877	4		4		4	

As in the case of fruits, increasing specific vegetable sub-groups (starchy, salad and dark), and then increasing consumption of all vegetables to achieve the recommended four servings a day increases the percentage shift of the targeted sub-groups and lowers it for the garden vegetable category.

When the vegetable category is further disaggregated to include servings of tomatoes and cruciferous vegetables, calculating the increases in demand become more complicated since items such as broccoli are counted both as a serving of dark and as a serving of cruciferous (Table 6). Because of this a dark cruciferous category was added.

The demand shift within each scenario was then estimated first by assuming that the dark vegetable category, including dark cruciferous, targets were met, then the cruciferous, including dark cruciferous, target met. The second method of calculating the demand shift was done by first looking at the cruciferous targets, and then the dark targets.

Table 6. Consumption Shifts for Vegetable Group 2

		Scenarios for Increases in Consumption									
		All by the same amount		All but garden targets met, then all by same amount- Dark First		All but garden targets met, then all by same amount- Cruciferous First		Each group's individual targets met- Dark First		Each group's individual targets met - Cruciferous First	
	Original Level	New Level	Percent Increase	New Level	Percent Increase	New Level	Percent Increase	New Level	Percent Increase	New Level	Percent Increase
Total Servings Tomato:	0.260	0.606	133%	0.356	37%	0.349	34%	0.300	15%	0.300	15%
Total Servings Salad	0.492	1.148	133%	1.185	141%	1.163	136%	1.000	103%	1.000	103%
Total Servings Cruciferous	0.192	0.406		0.587		0.576		0.500		0.500	
Total Servings Garden Cruciferous	0.091	0.170	133%	0.165	125%	0.232	239%	0.144	90%	0.204	191%
Total Servings Dark Cruciferous	0.102	0.237	133%	0.422	315%	0.344	239%	0.356	250%	0.296	191%
Total Servings Dark	0.310	0.000		1.179		1.157		1.000		1.000	
Total Servings Dark - non Cruciferous	0.209	0.440	133%	0.757	315%	0.813	348%	0.644	250%	0.704	285%
Total Servings Garden - other	0.475	0.820	133%	0.523	19%	0.517	16%	1.056	224%	0.996	201%
Total Servings Starchy	0.249	0.580	133%	0.593	138%	0.581	134%	0.500	101%	0.500	101%
Total	1.877	4.000		4.000		4.000		4.000		4.000	

As was the case with fruit and vegetable group 1 a wide variation exists in the magnitude of the consumption shifts depending upon the method used to estimate the shift. Shifts in the consumption of garden vegetables ranges from 16 percent to 224 percent. Also, the same pattern in consumption shifts is apparent. When specific sub-group targets are met before increasing consumption of all vegetables, the shifts are greater than when each sub-group target is met, except for garden vegetables.

Annual consumption data

No data exists on total annual consumption by Californians. California consumption will be calculated as 12 percent (California's share of the US population) of the US market supply. US market supply is equal to US production plus US imports less US exports.

Supply Data

Data needed to estimate the supply equations include US and California production , trade, prices and elasticities. USDA data for the US and California production and farm value are available from the Fruit and Nut Yearbook and Outlook reports, the Vegetable and Melon Yearbook and Outlook reports, and Agricultural Statistics. The USDA data has California statistics for some, but not all crops. Additional data for California are available from the *Summary of County Agricultural*

Commissioner's Reports by the California Agricultural Statistics Service and county agricultural data available for purchase.

US trade data are available from Foreign Agricultural Trade for the United States (FATUS) and Agricultural Statistics. Both of these sources provide quantity and prices data for only part of the commodities under consideration. The Food and Agriculture Organization (FAO) provides U.S. trade statistics on quantities and values of all the fresh and juice commodities in this study. Data on exports of California commodities are available through the Agricultural Issues Center for the majority of the commodities in this study. For the few commodities not covered, methods used to determine California exports will be used to calculate the figures. For example, Brussel sprouts are not covered in the AIC export statistics; however, California is the only US producer of this crop, so all US exports would be from California.

No data set exists for imports into California that are destined solely for the California market. This figure would need to be calculated. California consumption is equal to production, less exports of California products plus imports into California. Since California specific data exists for consumption, production, and exports, imports can be calculated once the level of California consumption is determined as described earlier.

Wholesale price data may be purchased from the American Marketing Service. These data would cover only fresh fruits and vegetables. The USDA reports retail prices for many of the fresh and processed commodities covered in this study, but not all. For items traded in international markets, import and export prices may also be representative of US market prices. Finally, it may be possible to purchase additional data from the USDA on retail prices for many of the food items in this study. Grocery store scanner data are not available for fruits and vegetables. Data on inputs such as land, labor and purchased inputs are available from the USDA and the California Agricultural Statistic Service.

Demand elasticities have been estimated for apples, oranges, bananas, grapes, orange juice, apple juice, other fruit, lettuce, tomatoes, carrots, potatoes, other vegetables, canned tomatoes, canned peas, and other processed fruit (Huang, 1995).

Supply elasticities are more difficult to obtain. While supply elasticities for some commodities (such as avocados) have been estimated, most commodities included in this analysis have not. For those commodities, the elasticities will need to be extrapolated from other studies. When doing so it is important to distinguish between short-run and long-run effects. Some resources are more easily moved from the production of one commodity and into another. In the short run growers may hesitate to switch land permanently out of rice or cotton production, as it means losing base acreage for farm assistance programs. Tree fruit and nut crops are long-term commitments. Growers cannot move land in and out of production of those crops on an annual basis, as they can with vegetable and melon production. Therefore, tree fruit and nut crops are less responsive in the short run to changes in prices than vegetables and melons. In the long-run, producers are able to move all resources to their best use. The Census of Agriculture for California contains information on input use in California (USDA 1999a).

CONCLUSION

With an increase in fruit and vegetable consumption by Californians, states with large agricultural industries devoted to fruit and vegetable production, such as Florida and California, stand to significantly benefit. These benefits are in addition to those accruing through a reduction in morbidity and mortality rates associated with dietary related cancers and other dietary related illnesses. How best to increase consumption is the challenge. Social marketing programs can be undertaken to change preferences towards increasing consumption of fruits and vegetables. Other strategies can be targeted at incomes or prices, especially for low-income households, which are more susceptible to food security problems arising from an increase in food prices.

References

Abbott, Philip. 1999. "Agricultural commodity production and trade: A trade economist's view on filling US food supply gaps". *Food Policy*. 24:181-196.

Alston, Julian M., James A. Chalfant, and Jennifer S. James. 1999. Doing Well by Doing a Body Good: An Evaluation of the Industry-Funded Nutrition Education Program Conducted by the Dairy Council of California. *Agribusiness.* 15:371-392.

Alston, Julian M., George W. Norton and Phillip G. Pardey. 1995 *Science Under Scarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting.* New York: Cornell University Press.

California Agricultural Statistic Service. 1999. *Summary of County Agricultural Commissioner's Reports.* Sacramento. http://www.nass.usda.gov/ca/bul/agcom/indexcav.htm

Food and Agriculture Organization. 2001. *Agriculture and Food Trade, Crop and Livestock primary and processed.* http://apps.fao.org/page/ collections?subset=agriculture.

Frazão, Elizabeth. 1999. High Cost of Poor Eating Patterns in the United States. Chapter 1, *America's Eating Habits: Changes and Consequences.* Ed. Elizabeth Frazão. United States Department of Agriculture, Agriculture Information Bulletin Number 750.

Huang, Kuo S. (1993) *A Complete System of U.S. Demand for Food.* Technical Bulletin Number 1821, Economic Research Service, United States Department of Agriculture.

Kantor, Linda Scott. 1998. *A Dietary Assessment of the U.S. Food Supply: Comparing Per Capita Food Consumption with Food Guide Pyramid Serving Recommendations.* Economic Research Service. United States Department of Agriculture, Agricultural Economic Report No. 772.

Kinsey, Jean and Bradley Bowland. 1999. "How can the US food system deliver food products consistent with the dietary guidelines?" *Food Policy.* 24:237-253.

Kuminoff, Nickolai V., Daniel A. Sumner and George Goldman. 2000. *The Measure of California Agriculture 2000.* University of California Agricultural Issues Center. Davis, CA.

McNamara, Paul E., Christine K. Ranney, Linda Scott Kantor and Susan M. Krebs-Smith. 1999. *The Gap Between food intakes and the Pyramid Recommendations: Measurement and Food System Ramifications.* Food Policy. 24:117-134.

Nicholson, Walter. Microeconomic Theory, Basic Principles and Extensions. Fourth Edition. The Dryden Press. Chicago. 1989.

O'Brien, Patrick. 1995. *Dietary Shifts and Implications for US Agriculture.* American Journal of Clinical Nutrition. 16(suppl):1390S-1396S.

Oliveira, Victor J., Anne B.W. Effland, Jack L. Runyan and Shannon Hamm. 1993. *Hired Farm Labor Use on Fruit, Vegetable and Horticultural Specialty Farms.* Economic Research Service, United States Department of Agriculture. Agricultural Economic Report Number 616. Washington D.C. 28 pgs.

Sumner, Daniel A. and Hyunok Lee. 1997. "Sanitary and Phytosanitary Trade Barriers and Empirical Trade Modeling." Chapter in Understanding Technical Barriers to Agricultural Trade: Proceedings of a Conference of the International Agricultural Trade Research Consortium. David Orden and Donna Roberts, eds. Department of Applied Economics, University of Minnesota. Pp. 273-285.

Tippett, Katherine S. and Linda E. Cleveland. 1999. "How Current Diets Stack Up." Chapter 3 in America's Eating Habits: Changes and consequences. Elizabeth Frazao, ed. United States Department of Agriculture. Washington D.C.

United States Department of Agriculture. 2000a. *Agricultural Statistics 2000.* National Agricultural Statistics Service. http://www.usda.gov/nass/pubs/agr00/acro00.htm.

United States Department of Agriculture. 2000b. *Fruit and Nut Situation and Outlook Yearbook.* Market and Trade Economics Division, Economic Research Service. FTS-290.

United States Department of Agriculture. 1999a. *1997 Census of Agriculture. California State and County Data.* Volume 1, Geographic Area Series Part 5. National Agricultural Statistics Service. Washington D.C.

United States Department of Agriculture. 1999b. *Vegetables Final Estimates 1992-97.* National Agricultural Statistics Service. Statistical Bulletin Number 964c. Washington D.C.

World Cancer Research Fund and The American Institute for Cancer. *Food, Nutrition and the Prevention of Cancer: A Global Perspective.* Washington D.C. 1997.

Young, C. Edwin and Linda Scott Kantor. 1999. Moving Toward the Food Guide Pyramid: Implications for U.S. Agriculture. Food and Rural Economics

Division, Economic Research Service, U.S. Department of Agriculture. Agricultural Economic Report No. 779. Washington D.C. 26 pgs.

Appendix: Mathematical Model

Demand Equations

The first equation is for market demand D. The demand for commodity j, where j is a fruit, vegetable or other crop, depends upon its own price Pj, the price of other commodities, and an exogenous demand shifter k that represents health preferences. Demand will decline as prices rise.

1.1 $D_j = d_j\left(P_1, ..., P_J, k_j\right)$ for j = 1, . . ., J.

California Production Equations

This equation is based on the cost function to produce commodity Y_j. The price of commodity j is equal to its marginal cost. If the price increases, output increases.

1.2 $P_j = \partial C_j(w_1, ..., w_I, Y_j) / \bullet Y_j$ for j = 1, . . . , J; where C(*) is the cost function for Y_j and w_i is the price of input i where i = 1, . . ., I.

Trade Equations

Two equations represent trade in this model. The first equation is for exports E and the second is for imports M. In both equations trade depends on the price in the home market. If the home market price increases, exports decline and imports increase.

1.3 $E_j = e_j\left(P_j\right)$ Export function for good j for j = 1, . . ., J.

1.4 $M_j = m_j\left(P_j\right)$ Import function for good j for j = 1, . . ., J. Imports are from other states and from other countries.

Input Equations

These equations are for the supply and demand conditions in the agricultural input markets. The first equation describes the demand for input i that is used in the production of commodity j. As the price of input i, w, increases, less will be demanded. Equation 1.6 says that the total demand for input i is equal to its demand by each commodity. Equation 1.7 is the supply function for input i. As the price of input i increases, the supply will also increase.

1.5 $X_i^j = \partial C_j(\bullet) / \bullet w_i$ — derived demand for input i in industry j, for j = 1, . . . , J and i = 1, . . . , I; where X_i^j is the quantity of input i used in the production of good j.

1.6 $X_i = \sum_j X_i^j$ — total demand for input i, i = 1, . . . , I.

1.7 $X_i = g_i(w_i)$ — Supply of input i, i = 1, . . . I.

Equilibrium

This is the market equilibrium condition stating that demand equals supply of good j. Supply is equal to production Y less exports E plus imports M.

1.8 $D_j = Y_j - E_j + M_j$ — Market equilibrium condition for good j for j - 1, . . . , J; where E_j is the quantity of good j that is exported and M_j is the quantity of good j that is imported.

The equations are differentiated and rewritten in elasticity terms for estimation.