

How Economic Factors Influence the Nutrient Content of Diets

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Problem

For the past several decades, Federal nutrition education efforts in the United States have issued several *Dietary Guidelines for Americans* to help them make healthful food choices. While health concerns are important in affecting food choice decisions, economic factors such as food prices and consumer income are also important determinants of food choices, with potential consequences for nutrient availability. For example, beef prices were high in the early 1990s, so cattle's producers expanded their herds to increase profits. Since it can take up to three years for a calf to go from grazing to ground beef, now we are seeing the results of that expansion--the price of beef is cheaper. Per capita consumption of beef jumped by about 3 pounds recently from a bottom low of 65 pounds in 1993. That is a great increase of about 700 million pounds of beef as a nation. The increase of beef consumption seems more a matter of price than health concerns.

The objective of this research is to improve our understanding about how economic factors affect food choices with a consequence to the nutrient content of diets. The results in this article are compiled from Huang (1997), which is an extension of Huang's earlier study (1996) in the following two ways. First, this study provides more detailed measurement of nutrient responses than the earlier study by increasing the number of nutrients studied from 15 to 28. Second, the information on nutrient values for the edible portion of food as purchased is compiled from U.S. Department of Agriculture (1996), *The Online Version of Agriculture Handbook No. 8*. In addition to updated nutritional information, the nutrient values used in this study correspond more closely to the disappearance food quantity data underlying the

estimated demand system. The earlier study used nutrient data from Gebhardt and Matthews (1991) on the nutrient content for the edible portion of food as consumed.

Methodology

Since the change of a food price or income will affect all foods consumed and cause a wide variety of nutrients to change simultaneously, the information from a complete food demand system is needed to translate changes in food prices and consumer income into changes in the levels of nutrients available. Let a demand system of n commodities be expressed in differential form as $dq_i/q_i = \sum_j e_{ij} (dp_j/p_j) + \eta_i (dm/m)$, and the quantity of k th nutrient available, say ϕ_k , be expressed as $\phi_k = \sum_i a_{ki} q_i$, where q_i , p_i , and m are quantities demanded, price, and per capita income, e_{ij} and η_i are price and income elasticities, and a_{ki} is the quantity of the k th nutrient in a total of ℓ nutrients obtained from a unit of the i th food. Accordingly, the relative change in nutrient availability can be expressed as a function of the relative changes in food prices and per capita income as follows:

$$\begin{aligned} d\phi_k / \phi_k &= \sum_j (\sum_i e_{ij} a_{ki} q_i / \phi_k) (dp_j / p_j) + (\sum_i \eta_i a_{ki} q_i / \phi_k) (dm / m) \\ &= \sum_j \pi_{kj} (dp_j / p_j) + \rho_k (dm / m) \end{aligned}$$

Where $\pi_{kj} = \sum_i e_{ij} a_{ki} q_i / \phi_k$ is a price elasticity measure relating the effect of a change in the j th food price on the availability of the k th nutrient, and $\rho_k = \sum_i \eta_i a_{ki} q_i / \phi_k$ is an income elasticity measure relating the effect of a change in income on the availability of that nutrient.

The unique feature of this model is that it incorporates the information of a food demand system including own- and cross-price elasticities and income elasticities into the measurement of aggregate nutrient responses.

Results

Data Sources

According to the procedure for estimating nutrient demand elasticities, two sets of input information are required: one is the matrix of food demand elasticities and the other is the matrix of nutrient shares of each food category. The information on food demand elasticities is obtained from a complete food demand system in Huang (1993). The demand system consists of 1,680 price and expenditure (income) elasticities for 39 food categories and 1 nonfood sector. This demand system was estimated by using the constrained maximum likelihood method, while the parametric constraints of homogeneity, symmetry, and Engel aggregation are imposed at sample means. The simulation performance based on the calculated relative root-mean-square errors to sample means indicates that the errors of simulated quantities demanded are less than 5 percent in most cases. The close correspondence between simulated values and sample observations indicates that this demand system is reliable for use in estimating nutrient elasticities.

To calculate the nutrient shares of each food category, per capita food consumption data and information on nutrient value of food per pound are needed. The definition of food categories and the sources of food consumption data are the same as those in Huang's food demand system. Some "other" food and nonfood categories in the demand system, however, are excluded from nutritional analysis because of either difficulty or irrelevance in defining nutrient values for these categories. Therefore, the demand elasticities compiled for this study contain 1,260 estimates of own- and cross-price elasticities and income elasticities for 35 food categories. Per capita food consumption data are obtained from the food disappearance series

for the average consumption over 1989-93 (Putnam and Allshouse, 1994). The disappearance data represent the quantities of food supplies moving through the U.S. marketing channel available for domestic consumption. The foods are reported mostly in their raw commodity form, such as wheat flour or meats in retail weight equivalent.

Information on nutrient values is compiled from the updated version of *USDA's Agricultural Handbook No. 8* available online in the Internet containing data on the nutrient content of 5,635 food items. (U.S. Department of Agriculture, 1996) Food energy is measured in kilocalories (kcal, commonly referred to simply as calories); protein, fat, carbohydrate, and dietary fiber are measured in grams; vitamin A is measured in retinol equivalents (RE), vitamin E is in alpha-tocopherol equivalents (ATE), vitamin B₁₂ and folate in micrograms, and all other nutrients in milligrams. These nutrient unit values and quantities of per capita food consumption over 1989-93 comprise the basic information for computing the share of nutrients for each food category.

Estimates of Nutrient Demand Elasticities

Given the nutrient shares of individual food categories (S) and food demand elasticities (D) including a complete set of own- and cross-price and income elasticities, the matrix of nutrient demand elasticities (N) is then calculated as $N = S * D$.

The empirical estimates of nutrient demand elasticities are compiled in table 1. These elasticities show how the availability of 28 nutrients would change in response to changes in 35 food prices and per capita income. For example, the net effects of a 10-percent decrease in the price of beef (holding other prices and income the same) would increase protein by 1 percent, saturated fat by 0.66 percent, cholesterol by 0.38 percent, calcium by 0.8 percent,

iron by 1.34 percent, vitamin C by 1.2 percent, and vitamin B₁₂ by 2.24 percent. Even though no vitamin C is in beef, its price change would affect the availability of that nutrient because a change of beef price would affect not only the consumption of beef but all other foods as well through the cross-commodity effects. In addition, although beef contributes little to total dietary fiber, a 10-percent decrease in the price of beef has a much larger effect (0.67 percent) on the overall availability of dietary fiber than does a 10-percent decrease in the price of wheat flour (0.18 percent), whereas wheat flour contributes about half of the total dietary fiber available. These examples highlight the importance of interdependent demand relationships among the different food categories through cross-price effects.

In terms of potential public concern about health effects, some significant estimates in table 1 show that the largest increases in daily per capita food energy (0.32 and 0.38 percent) would occur with a 10-percent decrease in the price of beef or cheese. Price decreases for beef and cheese would also substantially increase the daily availability of saturated fatty acids by 0.66 and 0.75 percent. A 10-percent decrease in the price of beef or eggs would increase daily availability of cholesterol by 0.38 and 0.28 percent, respectively. The same price decrease for fluid milk or evaporated and dry milk would increase the daily availability of calcium by 0.59 and 1.25 percent, respectively. A 10-percent decline in prices of beef and wheat flour would increase the daily availability of iron by 1.34 and 0.45 percent, respectively. A 10-percent price drop in oranges or fruit juices would increase vitamin C daily availability by 1.72 and 1.69 percent, respectively. The same price decrease in carrots would increase daily availability of vitamin A by 1.45 percent.

Likewise, the net effects of changes in food consumption caused by a 1-percent increase in

income are listed in the last column of table 1. According to the estimates, the change in income would increase energy by 0.26 percent, protein by 0.267 percent, saturated fats by 0.385 percent, cholesterol by 0.314 percent, calcium by 0.316 percent, iron by 0.212 percent, vitamin A by 0.354 percent, and vitamin C by 0.351 percent. Because income changes affect all nutrients in the same direction, those insufficient intakes of nutrients (calcium, iron, and various vitamins) could be improved with increased incomes. Those already excessive intakes of nutrients (energy, saturated fats, and cholesterol), however, the situation would be worsened with increased incomes. Therefore, the net nutritional effect of increasing consumer income is mixed.

Conclusion

This study develops a new research model to measure how economic factors influence aggregate nutrient availability. The unique feature of this model is that it incorporates the information of a food demand system including own- and cross-price elasticities, and income elasticities into the measurement of aggregate nutrient responses. The empirical results show that changes in the availability of all nutrients vary depending on how food price and income changes manifest themselves through the interdependent food demand relationships.

The nutrient elasticity estimates provide useful information for studying possible food program effects on the overall availability of nutrients. One way to accomplish this task would be to simulate alternative food policy scenarios and explore the effects of food prices and income changes on the amounts of foods and nutrients available for consumption. In addition, the estimates of nutrient income effects can be a starting point in evaluating possible

effects of income changes on dietary quality when the benefits of U.S. food stamp recipients are cut or increased. It should be noted, however, that the estimates in this study represent an average person's nutrient change, and adjustments might be needed to reflect differences in behavior across different population groups. Adjustments would also be needed when studying food stamp benefits to take into account the case that food spending from food stamps may be different than food spending out of money income.

In addition, it should be emphasized that these nutrient responses were estimated at the aggregate level, based on foods in their commodity forms, and may not be accurate reflections of the nutrient changes that would occur at the consumer level. The food disappearance data commonly used by demand analysts are unable to take into account food preparation methods, which can heavily influence the final nutrient content of foods. For example, whether the chicken is fried or roasted and whether the skin is eaten considerably affects the final nutritional characteristics of the chicken consumed. Similarly, although grain products are naturally low in fat, preparation methods that incorporate added fats result in a high-fat content for many grain food products, such as baked goods. Also, the food disappearance data are slow in measuring and reflecting changes in the nutrient composition of the commodities themselves, such as for lean meat and increasing availability of lower-fat cheeses, and, therefore, may not accurately reflect the current nutrient contribution of each food group to each nutrient's total. Therefore, to develop a consumer-based comprehensive food demand and nutrition study, further collaborative research between economists and nutritionists is needed to improve the availability of data on prices, quantities, and nutritional profiles for final food products.

Table 1--Percentage changes in nutrients in response to a 10-percent decrease in food price or a 1-percent increase in income

Percentage change																	
Nutrient			Beef	Pork	Chicken	Turkey	Fish	C. fish	Egg	Cheese	Milk	E. milk	Flour	Rice	Potato	Butter	
Margar.	Oils	Apple	Orange														
Energy			0.316	0.073	0.040	-0.046	0.156	-0.025	0.083	0.379	-0.087	0.029	0.253	-0.031	0.103	0.085	0.040
0.215	0.087	0.137															
Protein			1.000	0.214	0.342	0.109	0.141	0.027	-0.009	0.348	0.126	0.409	0.343	-0.091	0.021	0.066	0.118
-0.220	-0.014	0.145															
Total fat			0.333	0.140	0.067	-0.111	0.148	-0.115	0.014	0.531	-0.333	-0.135	0.215	0.024	0.136	0.178	-0.021
0.549	0.160	0.196															
Saturated fat			0.660	0.330	-0.015	-0.178	0.216	-0.069	-0.015	0.745	-0.166	-0.018	0.298	-0.033	0.103	0.320	-0.065
0.450	0.142	0.227															
M-unsat. fat			0.480	0.399	0.115	-0.055	0.107	-0.096	-0.019	0.438	-0.397	-0.022	0.224	-0.002	0.130	0.087	-0.009
0.432	0.106	0.141															
P-unsat. fat			-0.470	-0.550	0.096	-0.124	0.127	-0.216	0.099	0.409	-0.495	-0.468	0.072	0.157	0.203	0.140	0.010
0.923	0.275	0.249															
Cholesterol			0.378	0.286	0.128	0.142	0.093	0.138	0.276	0.334	-0.083	-0.033	0.431	-0.032	-0.022	0.163	-0.017
0.025	0.068	0.118															
Carbohydrate			0.082	-0.047	-0.095	-0.020	0.178	0.061	0.178	0.229	0.112	0.104	0.248	-0.064	0.093	-0.017	0.086
-0.013	0.034	0.079															
Dietary fiber			0.672	0.239	-0.407	0.044	0.495	0.227	0.229	0.239	-0.307	0.305	0.180	-0.049	0.151	-0.081	0.236
-0.021	0.055	0.198															
Calcium			0.801	0.246	-0.297	-0.111	0.404	0.101	-0.239	0.893	0.592	1.254	0.188	-0.108	0.053	0.126	0.192
-0.340	-0.066	0.377															
Iron			1.339	0.047	-0.096	0.033	0.298	0.098	0.273	0.310	-0.293	0.140	0.448	-0.122	0.075	0.002	0.191
-0.213	0.076	-0.027															
Magnesium			0.735	0.219	-0.134	0.094	0.341	0.149	0.005	0.288	0.225	0.614	-0.044	0.060	0.081	-0.120	0.246
-0.379	-0.023	0.268															
Phosphorus			0.823	0.255	0.042	0.016	0.221	0.056	-0.071	0.530	0.319	0.696	0.313	-0.107	0.047	0.110	0.132
-0.228	-0.026	0.221															
Potassium			0.755	0.551	-0.396	0.196	0.365	0.193	-0.024	0.269	0.106	0.696	-0.181	0.136	0.146	-0.227	0.382
-0.481	-0.019	0.408															
Sodium			1.440	0.455	-0.245	-0.073	0.515	0.279	-0.044	0.792	-0.308	1.510	0.102	-0.200	-0.017	0.340	0.490

-0.600	-0.037	0.398															
Zinc	1.636	0.166	0.139	0.131	0.161	-0.020	-0.091	0.370	0.095	0.476	0.311	-0.161	0.030	0.034	0.140		
-0.230	-0.026	0.156															
Copper	0.693	0.343	-0.361	0.176	0.344	0.222	0.170	0.058	-0.270	0.474	-0.115	0.061	0.195	-0.069	0.426		
-0.398	0.081	0.261															
Manganese	0.295	-0.185	-0.098	0.022	0.385	0.033	0.157	0.180	-0.083	0.218	0.346	-0.151	0.147	0.046	0.227		
-0.101	0.028	-0.014															
Vitamin A	-0.771	-0.035	-0.960	0.549	1.300	0.079	0.063	0.810	-1.373	-1.134	1.549	-0.448	-0.192	-0.203	0.352		
0.152	-0.347	-0.228															
Vitamin C	1.201	1.473	-1.173	0.324	0.230	0.211	0.576	0.400	-0.688	0.680	-0.958	0.369	0.450	-0.300	0.659		
-0.747	0.142	1.716															
Thiamin	0.791	0.892	-0.177	-0.079	0.246	0.051	0.258	0.389	-0.097	0.114	0.446	-0.116	0.105	-0.019	0.130		
-0.203	0.082	0.037															
RIboflavin	0.804	0.219	-0.175	0.018	0.296	0.110	0.089	0.477	0.241	0.440	0.288	-0.041	0.058	-0.070	0.135		
-0.250	0.003	0.109															
Niacin	0.914	0.266	0.453	0.091	0.207	0.095	0.106	0.204	-0.108	0.057	0.284	-0.012	0.044	-0.065	0.170		
-0.265	0.046	0.044															
Pantothenic	0.232	0.247	0.089	0.224	0.255	0.108	-0.006	0.231	0.278	0.439	-0.085	0.091	0.066	-0.124	0.197		
-0.325	-0.027	0.244															
Vitamin B-6	0.751	0.434	0.325	0.249	0.239	0.076	-0.068	0.059	0.140	0.456	-0.085	0.125	0.041	-0.265	0.248		
-0.259	-0.096	0.318															
Vitamin B-12	2.243	-0.278	-0.033	0.163	0.052	0.090	-0.048	0.208	0.369	0.676	0.430	-0.155	-0.020	0.144	0.108		
-0.315	-0.099	0.188															
Folate	0.817	0.428	-0.477	0.154	0.159	0.057	0.366	0.314	-0.306	0.277	0.070	0.001	0.151	-0.070	0.212		
-0.377	0.047	0.353															
Vitamin E	-0.334	-0.783	-0.131	-0.116	0.195	-0.171	0.143	0.402	-0.635	-0.313	0.067	0.152	0.222	0.143	0.051		
0.922	0.260	0.257															

Continued-

Table 1--Percentage changes in nutrients in response to a 10-percent decrease in food price or a 1-percent increase in income -- Continued

Nutrient	Banana	Grape	Grapef.	Lettuce	Tomato	Celery	Onion	Carrot	Juice	C. tomato	C. peas	Cocktl.	Peanut	Sugar	Sweet.	Coffee
Frzn. D Income																
Percentage change																
Energy	0.051	0.126	0.090	-0.069	0.087	0.059	0.009	0.024	0.022	-0.018	-0.016	-0.014	-0.078	0.051	0.209	
-0.008 -0.159	0.260															
Protein	0.086	0.116	0.058	-0.075	-0.055	0.074	0.018	-0.028	-0.023	0.019	0.033	-0.015	0.001	-0.006	0.264	
-0.053 -0.191	0.267															
Total fat	0.016	0.093	0.131	-0.118	0.246	0.078	0.017	0.019	-0.054	-0.040	-0.038	-0.017	-0.134	-0.056	0.353	
-0.019 -0.028	0.374															
Saturated fat	-0.046	0.104	0.112	-0.114	0.245	0.069	0.005	-0.009	-0.021	-0.043	-0.053	-0.019	-0.048	-0.118	0.422	
-0.071 -0.008	0.385															
M-unsat. fat	0.014	0.075	0.093	-0.100	0.161	0.064	0.018	0.017	-0.029	-0.014	-0.033	-0.049	-0.142	-0.051	0.284	
-0.017 -0.048	0.363															
P-unsat. fat	0.097	0.111	0.217	-0.160	0.394	0.116	0.034	0.065	-0.146	-0.079	-0.031	0.033	-0.249	0.021	0.395	
0.050 -0.009	0.380															
Cholesterol	-0.013	-0.016	0.053	-0.080	0.010	0.012	-0.023	-0.032	0.082	-0.005	0.006	-0.051	0.020	-0.033	0.037	
-0.085 -0.015	0.314															
Carbohydrate	0.090	0.169	0.055	-0.016	-0.034	0.036	0.001	0.043	0.118	-0.001	-0.008	-0.010	-0.042	0.187	0.040	
0.020 -0.293	0.137															
Dietary fiber	0.415	0.274	0.049	-0.036	0.204	0.085	0.041	0.063	0.086	0.138	-0.057	0.023	-0.186	0.156	0.027	
0.018 -0.619	0.206															
Calcium	0.197	0.242	0.080	-0.201	-0.048	0.162	0.042	-0.193	0.011	0.069	0.087	0.019	0.043	-0.101	0.705	
-0.136 -0.141	0.316															
Iron	0.045	0.198	0.037	0.054	0.037	0.038	0.005	0.056	-0.013	0.023	-0.018	0.017	-0.099	0.077	0.163	
0.004 -0.398	0.212															
Magnesium	0.310	0.162	0.080	-0.078	0.014	0.131	0.044	-0.071	0.077	0.100	0.015	-0.008	-0.020	0.040	0.220	
-0.014 -0.298	0.268															
Phosphorus	0.121	0.153	0.071	-0.116	-0.041	0.105	0.021	-0.077	0.014	0.033	0.054	-0.005	0.026	-0.038	0.391	
-0.077 -0.161	0.287															
Potassium	0.376	0.191	0.106	-0.089	0.131	0.174	0.053	-0.110	0.203	0.157	0.035	0.001	-0.085	0.006	0.161	
0.000 -0.343	0.310															
Sodium	0.346	0.355	0.020	-0.074	0.396	0.194	0.050	-0.176	-0.108	0.257	-0.039	0.113	-0.143	-0.163	0.895	

-0.214 -0.111 0.422																
Zinc	0.079	0.134	0.067	-0.085	0.013	0.085	0.012	-0.067	0.026	0.030	0.050	-0.003	0.011	-0.085	0.249	
-0.061 -0.114 0.301																
Copper	0.253	0.228	0.084	0.021	0.320	0.131	0.047	-0.082	0.120	0.175	-0.037	0.043	-0.122	0.049	0.018	
0.010 -0.287 0.260																
Manganese	0.180	0.409	0.084	-0.002	0.065	0.071	-0.006	0.019	-0.018	0.079	-0.019	0.048	-0.088	0.108	0.106	
-0.012 -0.301 0.205																
Vitamin A	0.871	0.325	-0.518	-0.197	-0.811	-0.177	-0.431	1.453	0.511	0.009	-0.304	0.041	-0.483	-0.025	0.646	
0.008 -0.624 0.354																
Vitamin C	0.464	0.244	0.308	-0.106	0.729	0.225	0.100	-0.077	1.685	0.280	-0.114	0.012	-0.529	0.161	-0.282	
0.083 -0.518 0.351																
Thiamin	0.019	0.196	0.061	0.040	-0.054	0.035	-0.001	0.075	0.081	-0.011	-0.015	-0.002	-0.099	0.116	0.137	
0.024 -0.433 0.237																
Riboflavin	0.093	0.164	0.063	-0.070	-0.122	0.082	0.015	-0.043	0.002	0.008	0.064	-0.020	-0.014	0.048	0.262	
-0.020 -0.315 0.240																
Niacin	0.089	0.128	0.026	-0.005	-0.088	0.034	0.022	0.024	-0.080	0.020	-0.018	-0.007	-0.069	0.079	0.161	
-0.002 -0.362 0.224																
Pantothenic	0.190	0.108	0.080	-0.127	-0.047	0.113	0.018	-0.109	0.044	0.062	0.056	-0.029	-0.008	0.056	0.122	
-0.013 -0.225 0.255																
Vitamin B-6	0.537	0.153	0.100	-0.076	-0.000	0.148	0.088	0.010	0.044	0.130	-0.021	-0.040	-0.104	0.036	0.099	
-0.020 -0.348 0.279																
Vitamin B-12	0.112	0.042	0.103	-0.087	0.057	0.124	-0.012	-0.036	-0.063	0.064	0.092	-0.049	0.158	-0.144	0.209	
-0.040 -0.005 0.325																
Folate	0.192	0.080	0.085	0.035	0.120	0.086	0.002	0.029	0.692	0.042	-0.020	-0.009	-0.088	0.148	-0.024	
0.014 -0.391 0.263																
Vitamin E	0.150	0.151	0.213	-0.149	0.466	0.131	0.036	0.073	-0.118	-0.033	-0.041	0.032	-0.274	0.019	0.407	
0.047 -0.009 0.378																

Note: The notations are M-unsat. fat (monounsaturated fat), P-unsat. fat (polyunsaturated fat), Pantothenic acid, C. fish (canned fish), E. milk (evaporated and dry milk), Margar. (margarine), Grapef. (grapefruits), C. tomato (canned tomatoes), C. peas (canned peas), Cocktl. (fruit cocktail), Sweet. (sweeteners), and Frzn. D (ice cream and other frozen dairy products).

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